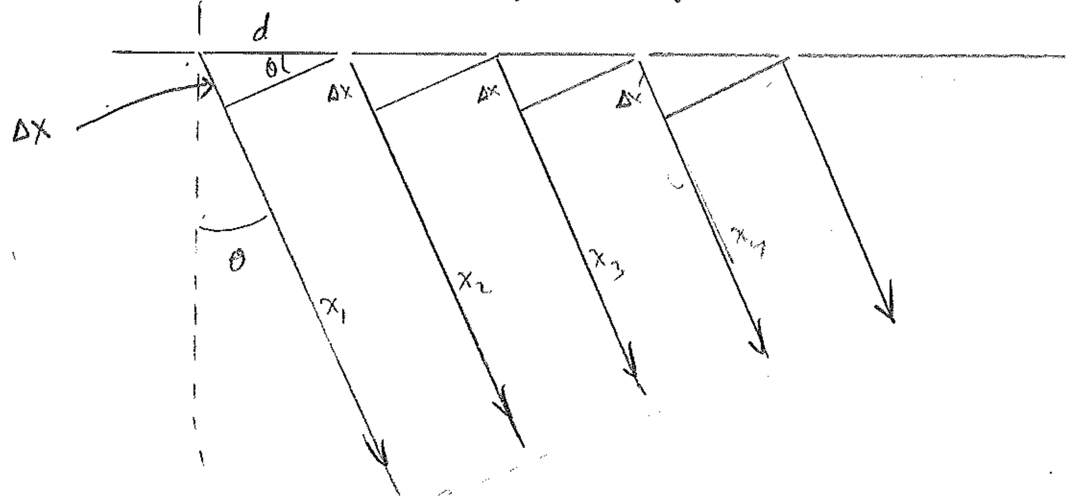
Diffraction grating: glass plate scored w/ very closely spaced parallel lines each of which scatters incident light

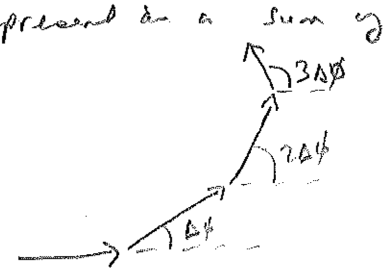
[can think of it as an opaque screen w/ many parallel slits]



$\Delta x = d \sin\theta$, $\Delta\phi = k\,\Delta x$

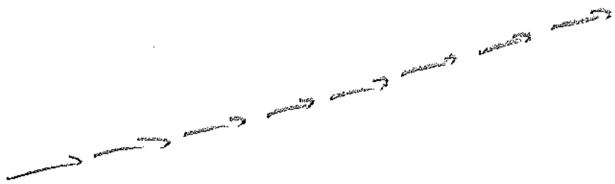
$$E_{tot} = A\sin(\omega t - kx_1) + A\sin(\omega t - kx_1 + \Delta\phi) + A\sin(\omega t - kx_1 + 2\Delta\phi) + \ldots$$

Represent as a sum of phasors



This almost always leads to largely destructive interference because phasors roughly cancel out

The exception is when $\Delta\phi = 2\pi m$ because then all phasors are parallel



$A_{tot} = NA$

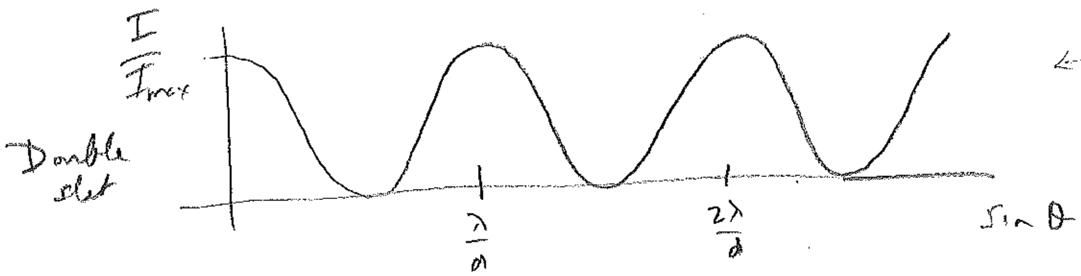
$N = $ # of slits

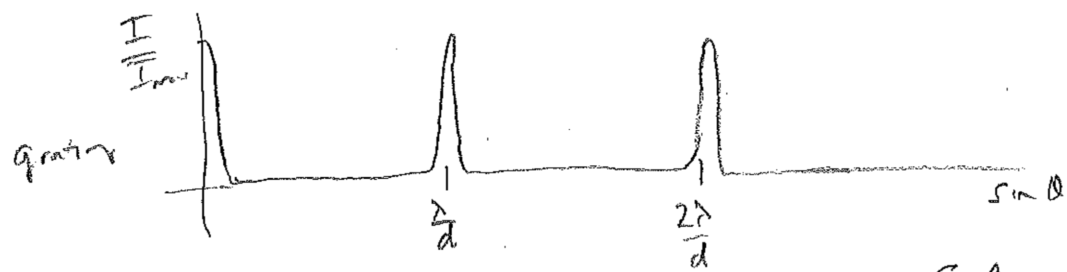
Constructive interference

$$\Delta\phi = k d \sin\theta = 2\pi m \Rightarrow \boxed{d \sin\theta = m\lambda}$$

m = order of diffraction

Peaks of the intensity pattern are much narrower than for 2-slit





(also see overhead) →

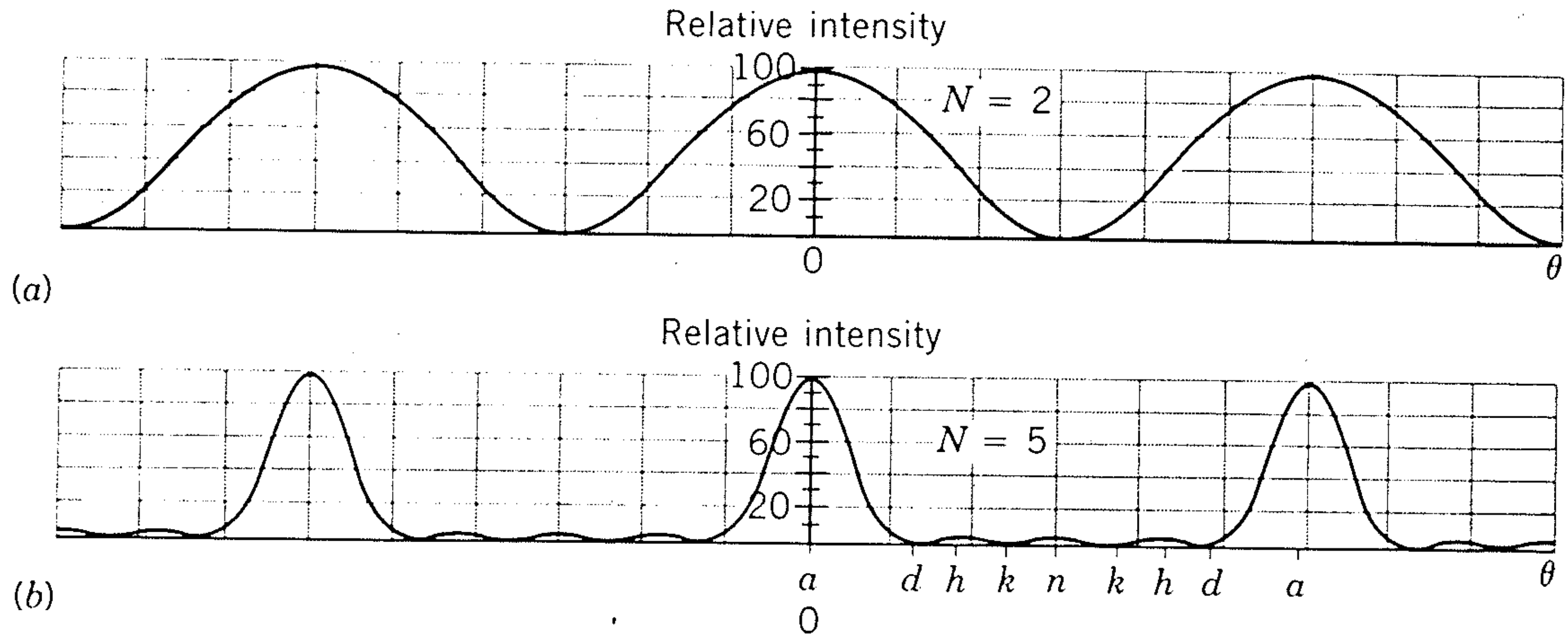


Figure 3 Calculated intensity patterns for (*a*) a two-slit and (*b*) a five-slit grating, having the same values of d and λ. Note the sharpening of the principal maxima and the appearance of faint secondary maxima in (*b*); compare with Fig. 2. The letters in (*b*) refer to Fig. 6. This calculation does not include diffraction effects due to the slit width; that is, we assume we are near the central region of Fig. 2 where the principal maxima have essentially equal intensities.

<u>Demo:</u> Laser pointer through diffraction grating onto screen

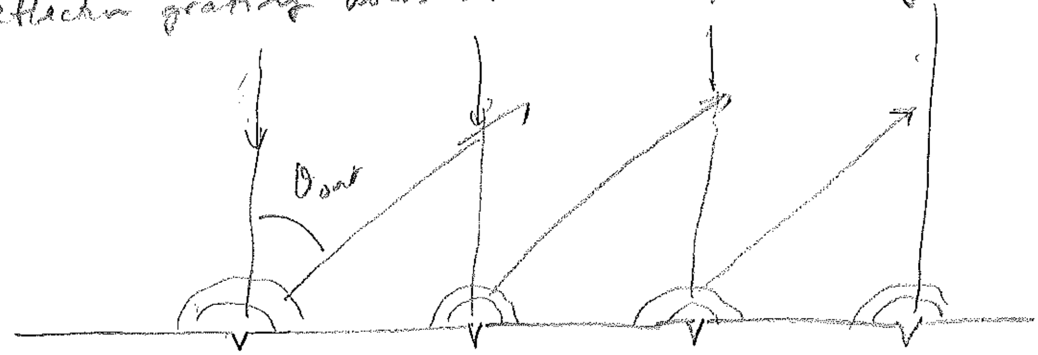
- Put big white laser on front corner of lectern facing perpendicular to the screen
- Put big grating in holder on a cart fairly close to screen
- Can see 2 orders of diffraction
  measure distance to calculate $\theta = 29° = 0.50$ rad
  and ∴ obtain d using $\lambda = 633$ nm; $d = 1.3$ μm

- Q: what if use green laser? $\lambda = 532$ nm?
  Take green laser on w/ cellophane + place on top of big white

- 2 sheets of paper on OH projector ⇒ spectrum
  Note: opposite order of colors from prism
  (this is how monochrometer works)

- reflection gratings; CD ...

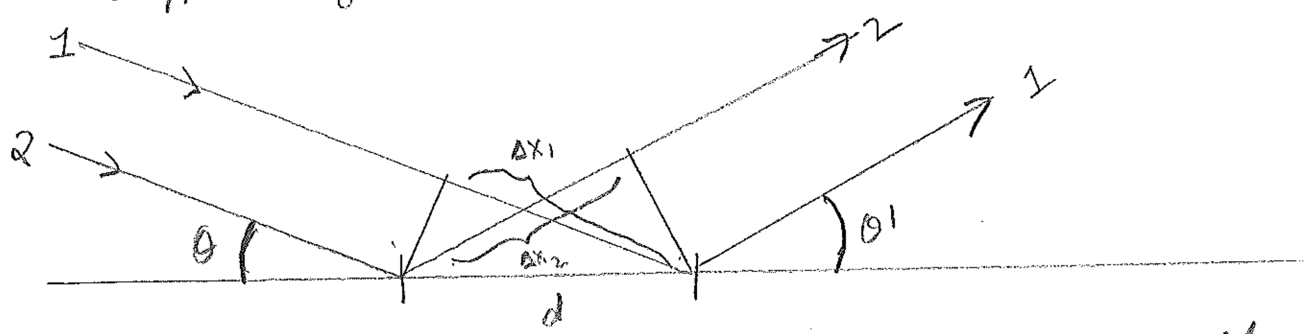
Reflection grating works similar to diffraction grating



grooves scatter light

[HW: find θout for which constructive interf. occurs]

Suppose light is not incident along the normal



Note θ here measured up from the surface rather than from normal (glancing angle)

$\Delta x_1 = d \cos\theta$

$\Delta x_2 = d \cos\theta'$

If $\Delta x_1 = \Delta x_2$ then path lengths of rays 1 + 2 are equal

$\Longrightarrow \Delta\phi = 0 \Rightarrow$ constructive interference

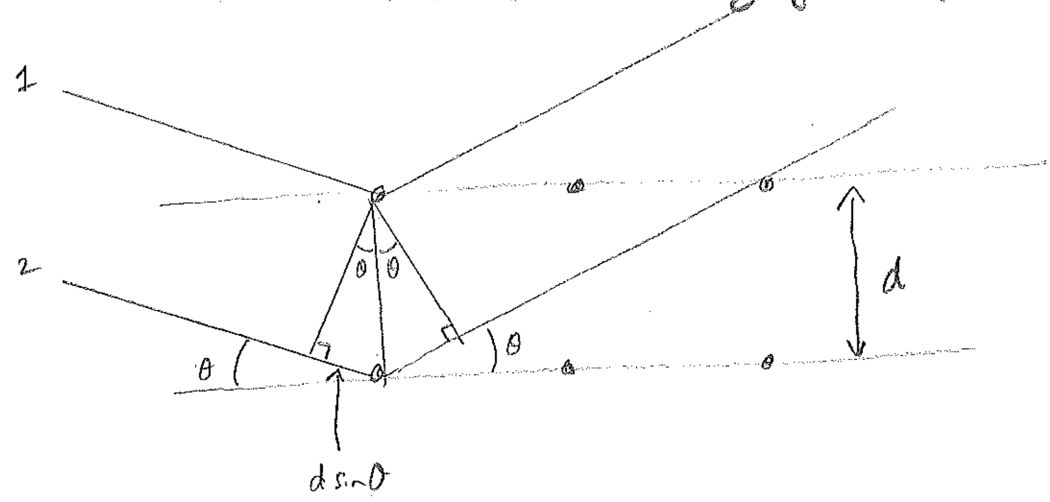
If $\theta' = \theta$, then constructive interference always occurs for any d or λ.

Law of reflection is a result of constructive interference of all the atoms on a surface.

[cooperative scattering]

Bragg scattering (X-rays from crystals)

Consider a 3 dimensional array of scatterers



Constructive interference will occur for **all** scattered waves provided paths 1 + 2 differ by a multiple of λ.

$$\Delta l = 2d\sin\theta = m\lambda \quad \Rightarrow \quad \boxed{d\sin\theta = \frac{m\lambda}{2}}$$

Condition for Bragg scattering
(ie from a 3d structure)

Note: λ must be less than $2d$ (otherwise $\sin\theta > 1$) impossible

If $d \approx 0.1$ nm (atomic dimensions)
then wave must be X-rays.

Use Bragg diffraction { to use d to find λ
to use λ to find d
↳ eg. DNA structure