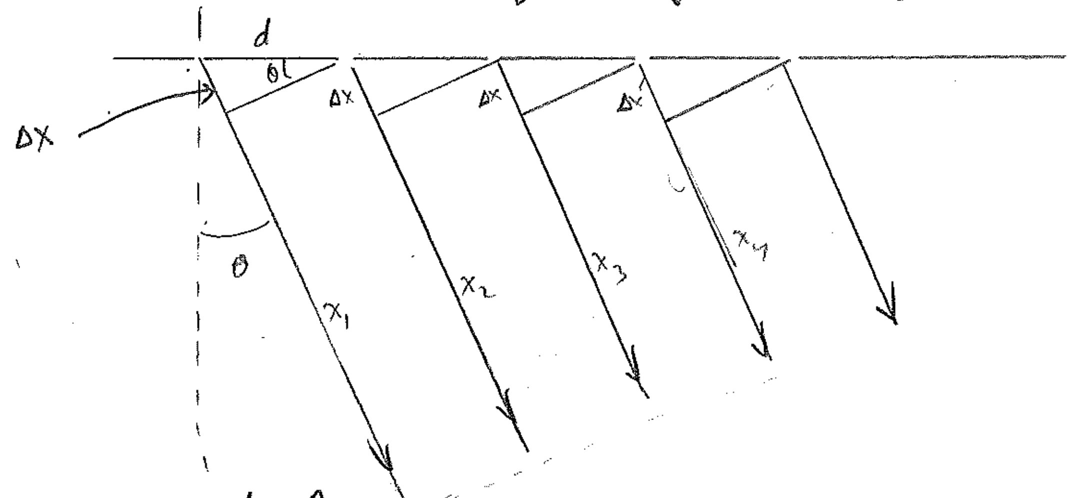
$\boxed{\text{Diffraction grating}}$ = glass plate scored w/
very closely spaced parallel lines
each of which scatters incident light
[can think of it as an opaque screen w/ many parallel slits]



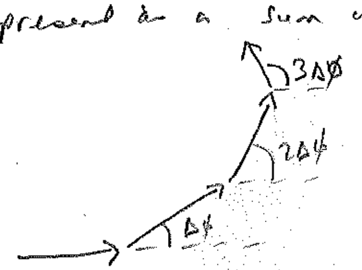
$\Delta x = d \sin\theta$

$$E_{tot} = A\sin(\omega t - kx_1) + A\sin(\omega t - kx_2) + A\sin(\omega t - kx_3) + \dots$$

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

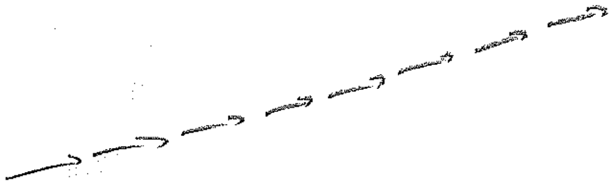
where $\Delta\phi = k\,\Delta x$

Represent as a sum of phasors



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

The exception is when $\Delta\phi = 2\pi m$ for $m = \text{integer}$
so that all phasors are parallel



$E_{tot} = NA \sin(\omega t - kx_1)$

$A_{tot} = NA$

$N = \#$ of slits

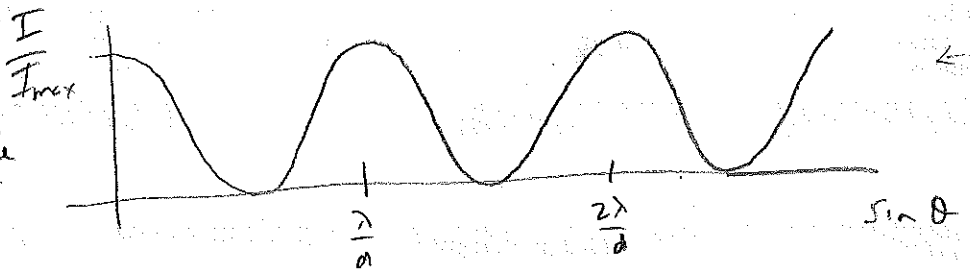
Constructive interference

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

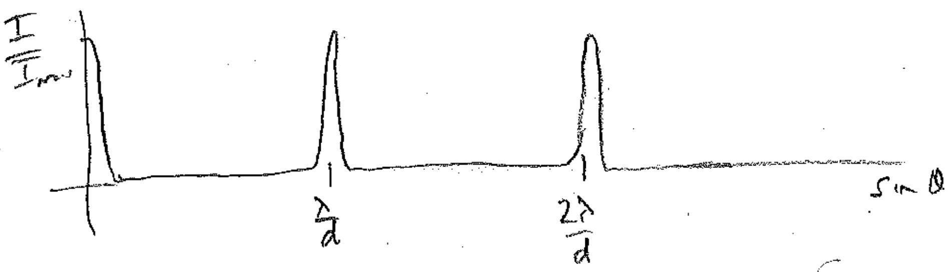
m = order of diffraction

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

Double slit



grating



see OH, QC3

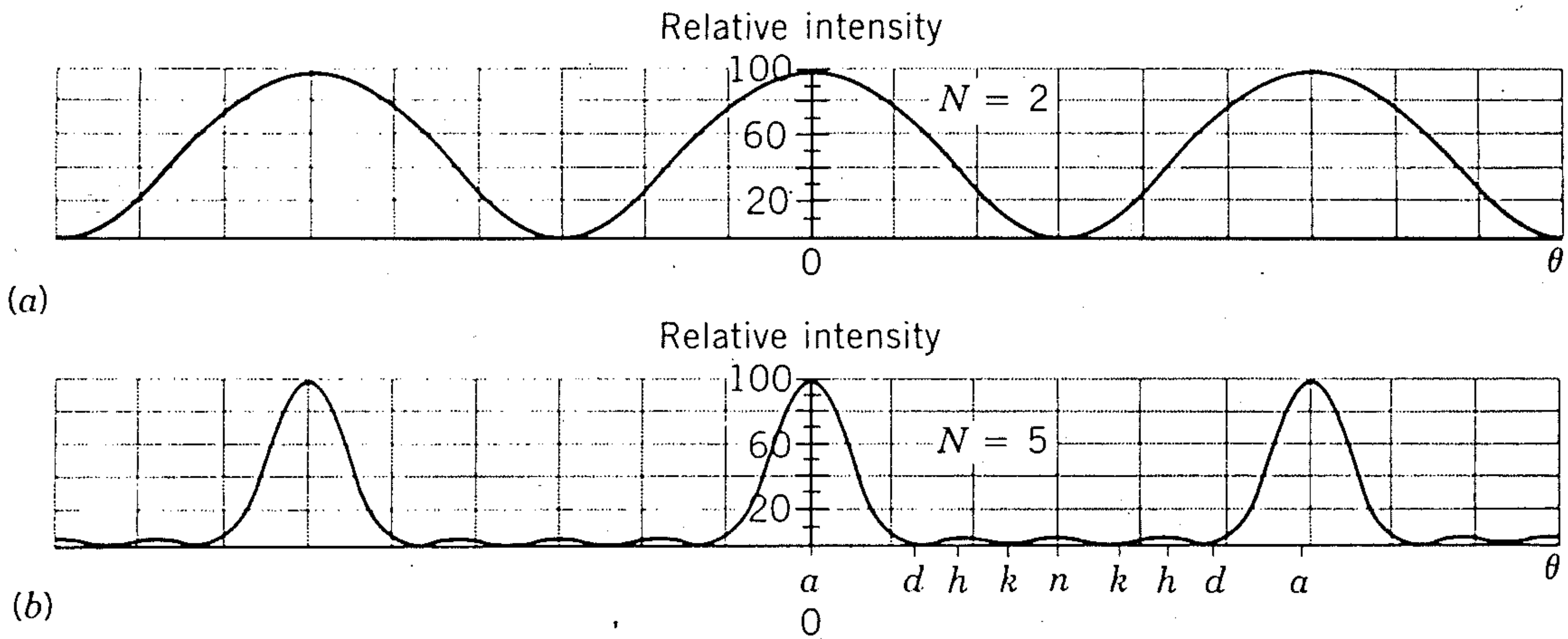


Figure 3 Calculated intensity patterns for (*a*) a two-slit and (*b*) a five-slit grating, having the same values of d and λ. Note the sharpening of the principal maxima and the appearance of faint secondary maxima in (*b*); compare with Fig. 2. The letters in (*b*) refer to Fig. 6. This calculation 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.

QC3

Demo: Laser pointer through diffraction grating onto screen

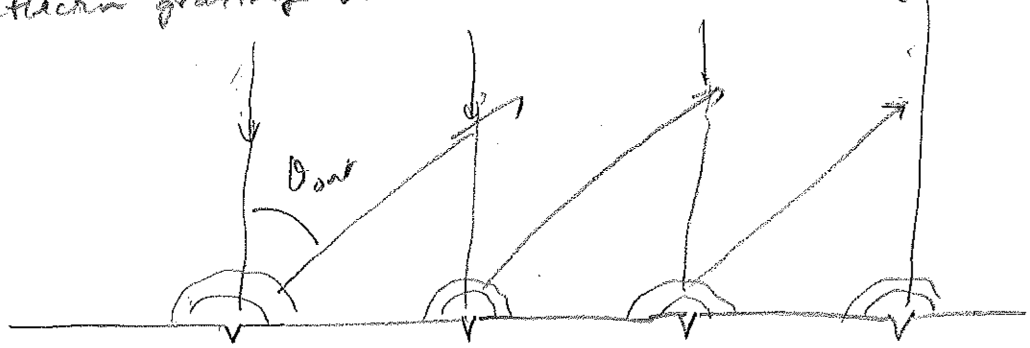
- Put big white laser on front corner of lectern facing perpendicular to the screen
- Put big grating in holder on a cart fairly close to screen
- Can see 2 orders of diffraction
  measure distances to calculate $\theta = 29° = 0.50$ rad
  and $\therefore$ obtain d using $\lambda = 633$ nm; $d = 1.3\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

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

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

- reflection gratings; CD ...

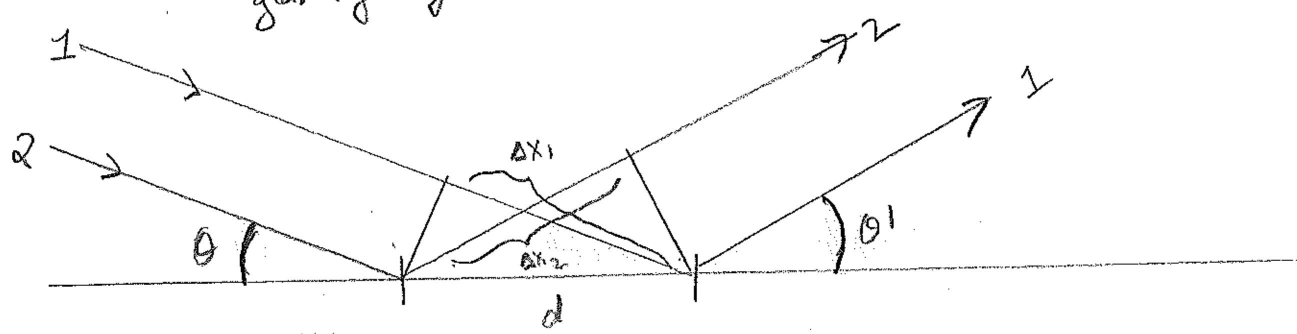
Reflection grating works similar to diffraction grating



grooves scatter light

[HW: find θ_{out} for which constructive interf. occurs]

Suppose light strikes grating at an angle
(Note: here measure light up from surface, not down 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

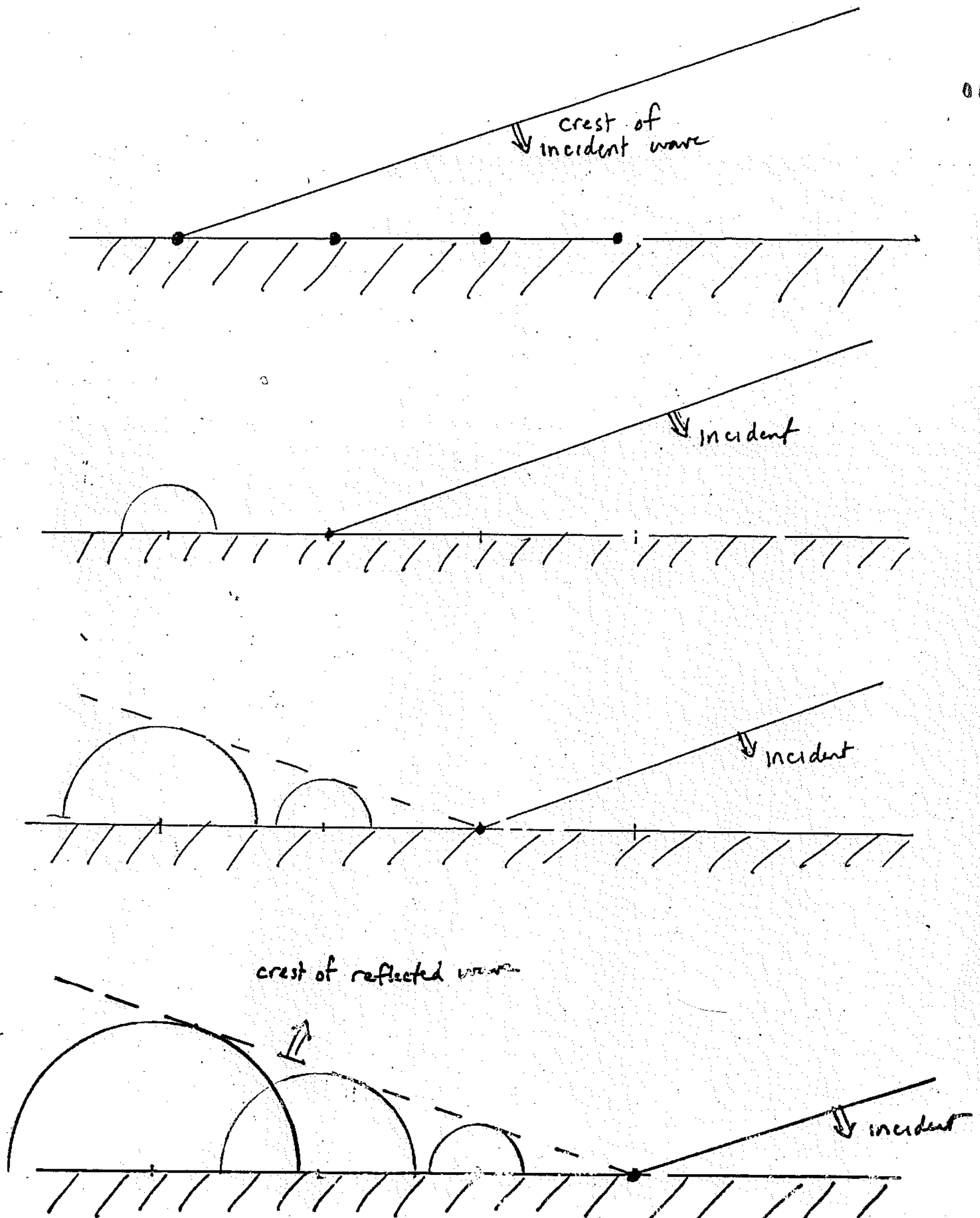
$\Longrightarrow \Delta\phi = 0 \Rightarrow$ constructive interference

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

Law of specular reflection is due to constructive interference of all the atoms on a surface.

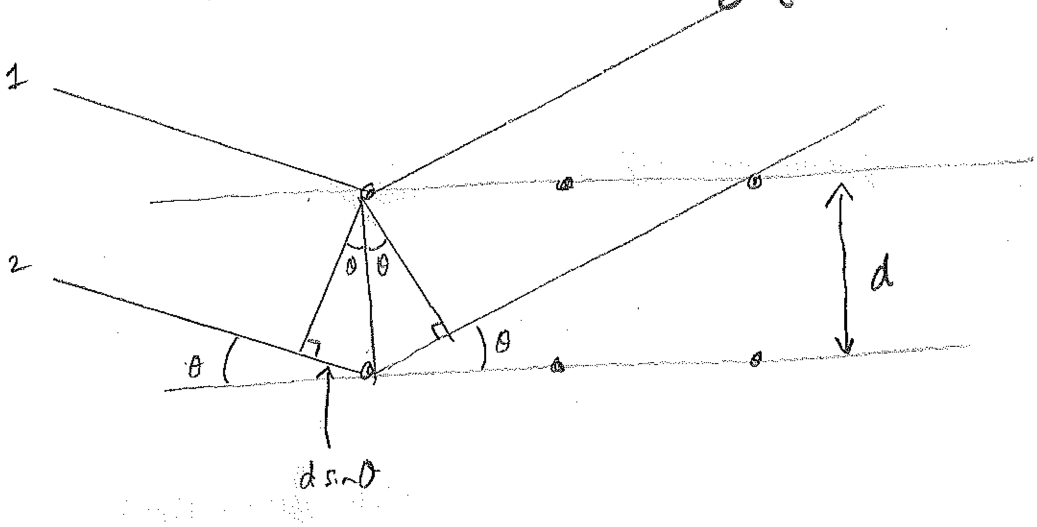
[alternative to Fermat principle of least time. can be shown to be equivalent.]

see also OH, QC6


crest of incident wave
incident
incident
crest of reflected
incident

Bragg scattering (X-rays from crystals) QC7

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.

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

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