9.3 INTERFERENCE PART 1 (HL)

Pages 192-196 in the Pearson book

Young's double-slit experiment

- Laser is diffracted at two slits
  - The lightwaves from each slit interfere
  - The interference pattern is created since the waves have different distances to travel
    - →phase difference
    - →constructive or destructive interference
- Evidence of the wave nature of light

Video on young's double slit by veritasium:
https://youtu.be/Iuv6hY6zsd0?t=254

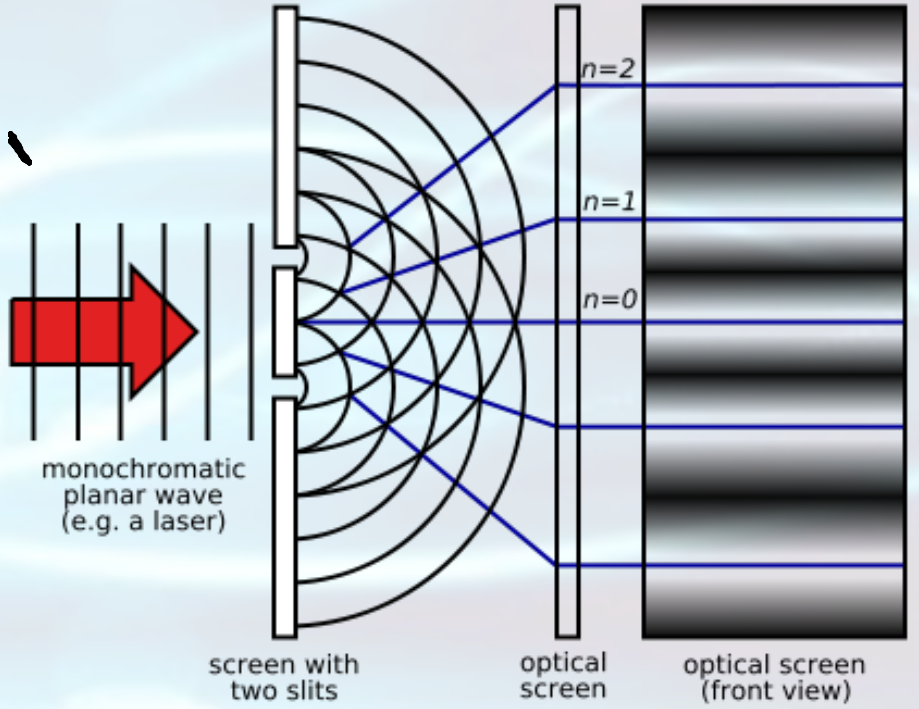
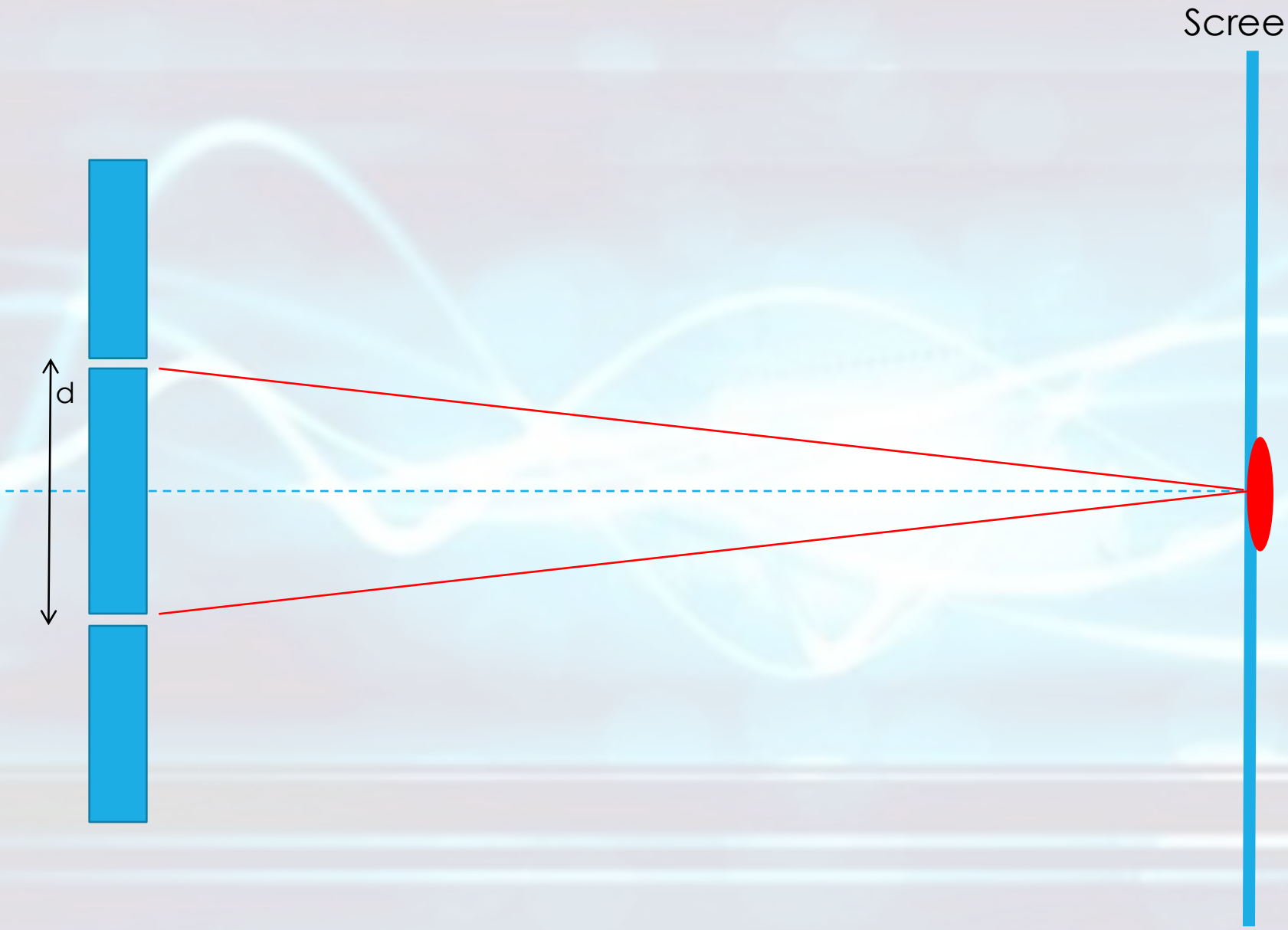


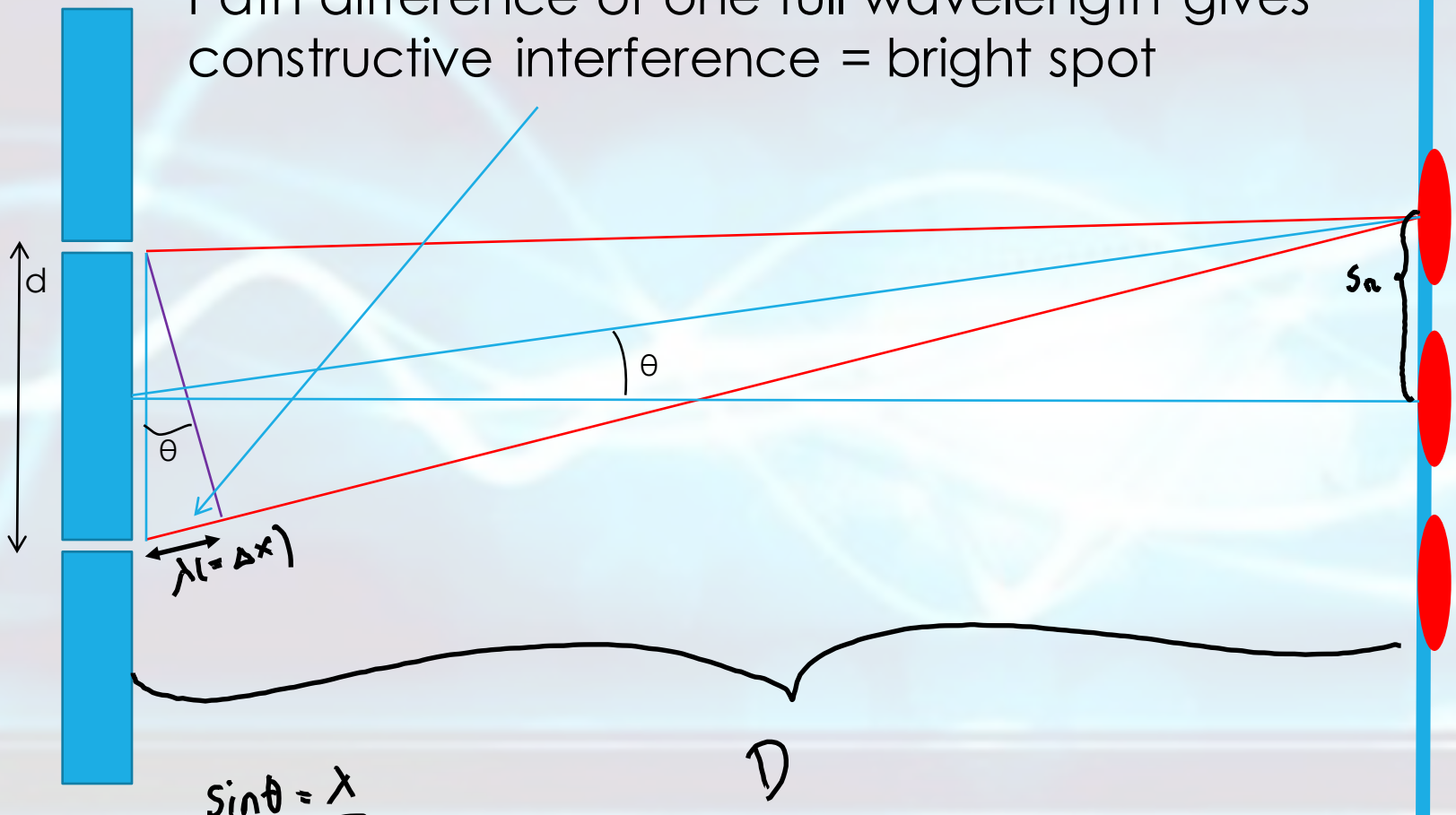
Image:
http://www.fuff.org/interference/



- Same path length
- No phase difference
- Constructive interference
- Bright spot in the middle

Screen

Path difference of one full wavelength gives constructive interference = bright spot



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

$\frac{\lambda}{d} = \frac{s_n}{D} \iff s_n = \frac{\lambda D}{d}$

For constructive interference:

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

order of maxima

From figure and from the fact that $tan\theta \approx sin\theta$ for small angles, we get:

$$tan\theta = \frac{s_n}{D} \approx sin\theta$$

Combining these two we get:

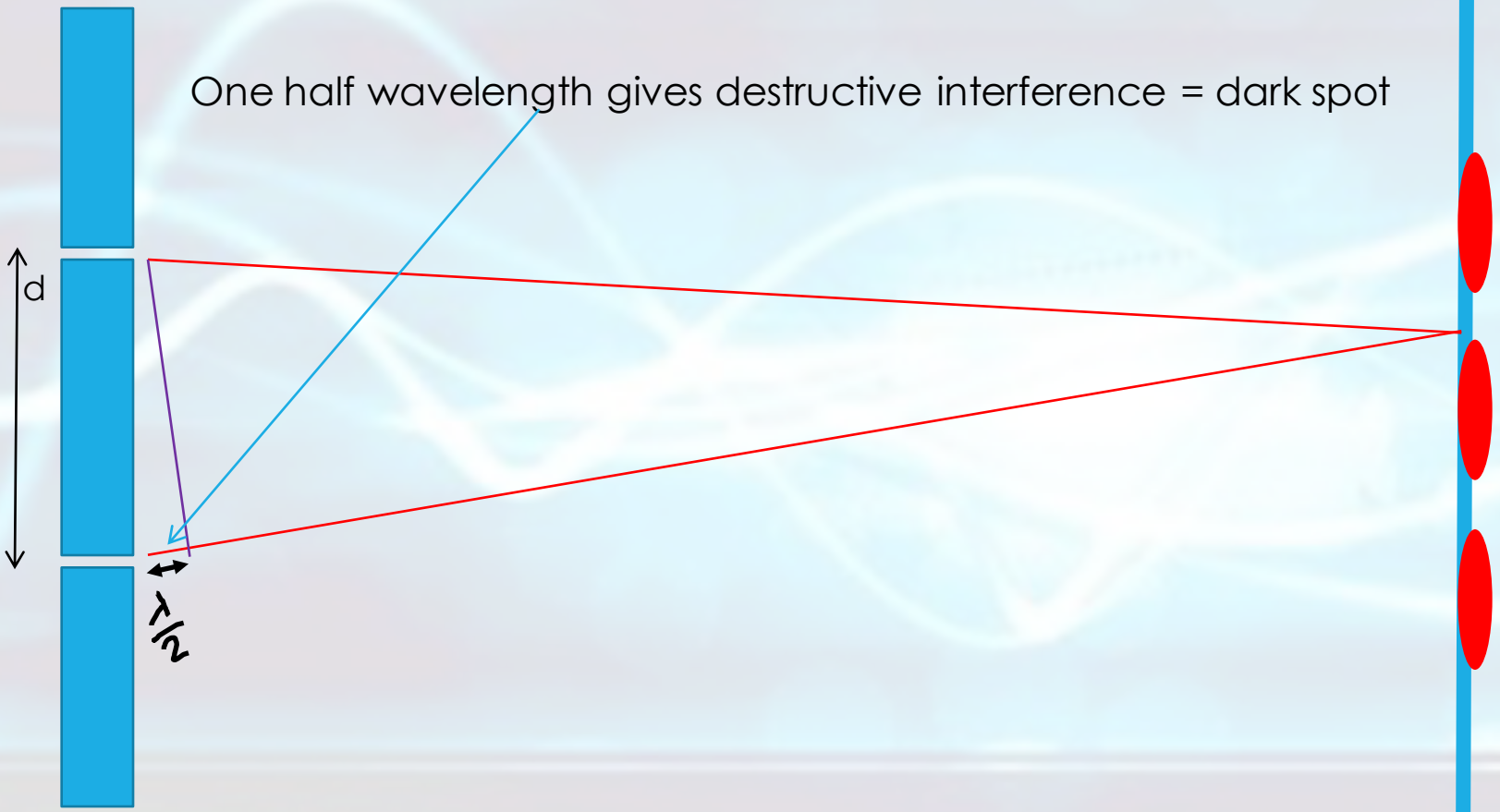
$$s_n = \frac{n\lambda D}{d}$$

In the booklet (chapt 4): $\mathbf{s} = \frac{\lambda D}{d}$

Screen

Double slit

One half wavelength gives destructive interference = dark spot

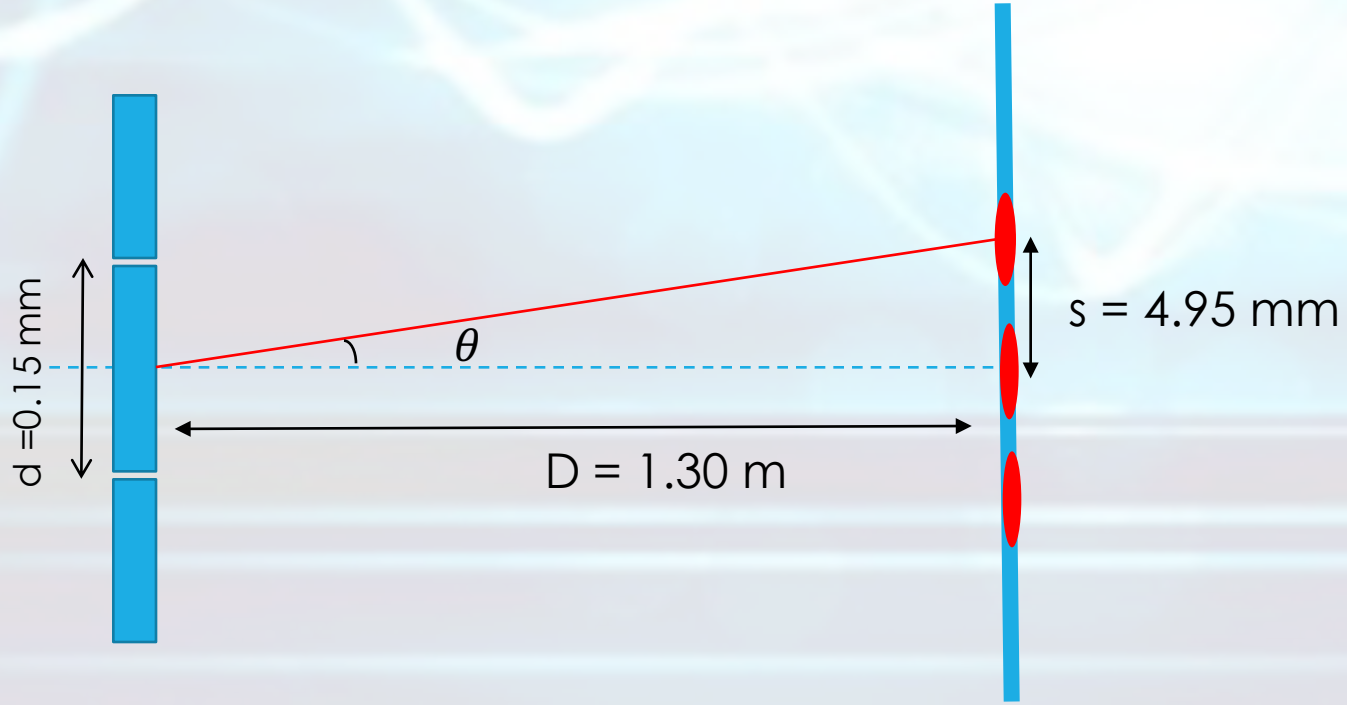


See video on Khan academy double slit equation:
https://www.khanacademy.org/science/physics/light-waves/interference-of-light-waves/v/youngs-double-slit-part-2

- **Constructive interference** when path difference is an integer multiple of the wavelength, path difference $= n\lambda$, n = 0, ±1, ±2, ±3
- **Destructive interference** when path difference is a half-integer multiple of the wavelength, path-difference $= (n + \frac{1}{2})\lambda$, n = 0, ±1, ±2, ±3
- When monochromatic light (with only one wavelength) falls on the two slits the light is split into two sources of coherent light (same frequency, similar amplitude, constant phase difference).
- Distance between slits and screen is MUCH larger than distance between slits D>>d

Example

In a Young's two-slit experiment, a source of light of unknown wavelength is used to illuminate two very narrow slits a distance of 0.15 mm apart. On a screen at a distance of 1.30 m from the slits, bright spots are observed separated by a distance of 4.95 mm. What is the wavelength of light being used?



$$s = \frac{\lambda D}{d} \Leftrightarrow \lambda = \frac{sd}{D}$$

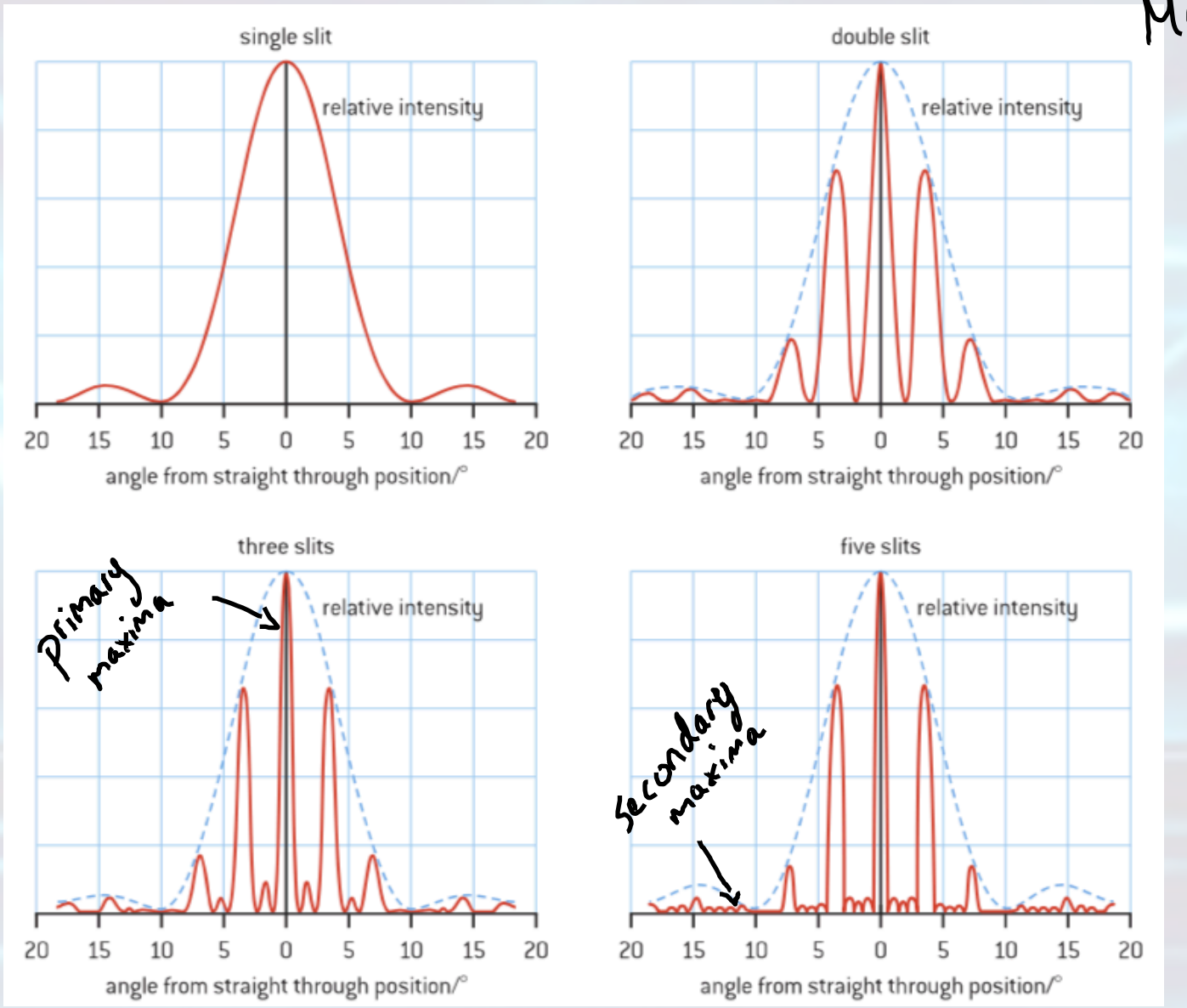
$$\lambda = \frac{4.95\times10^{-3}\times1.5\times10^{-4}}{1.30}$$

$$\lambda = 5.71\times10^{-7} m$$

The wavelength is 571 nm

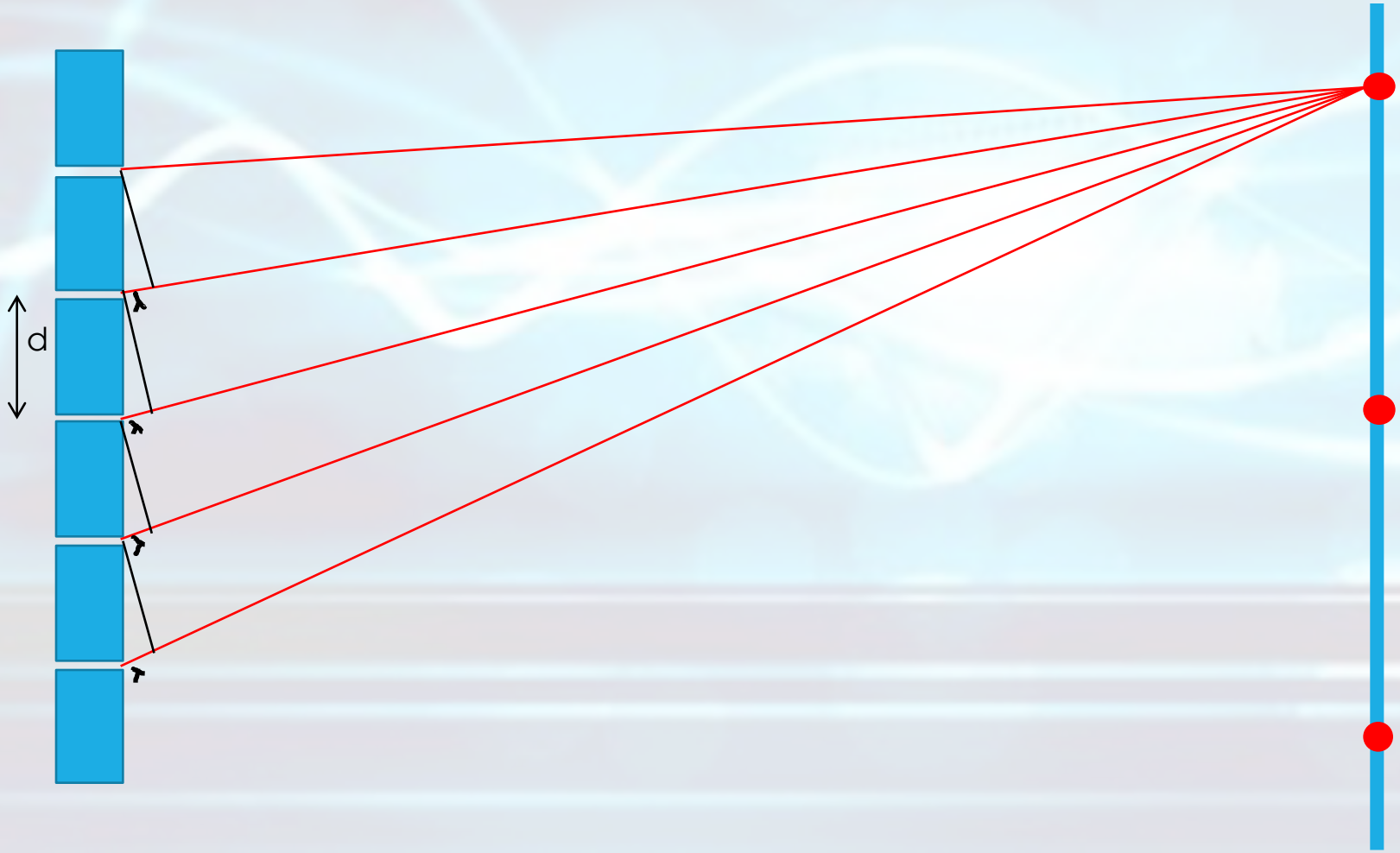
Multiple slits

Intensity in the graphs is relative!



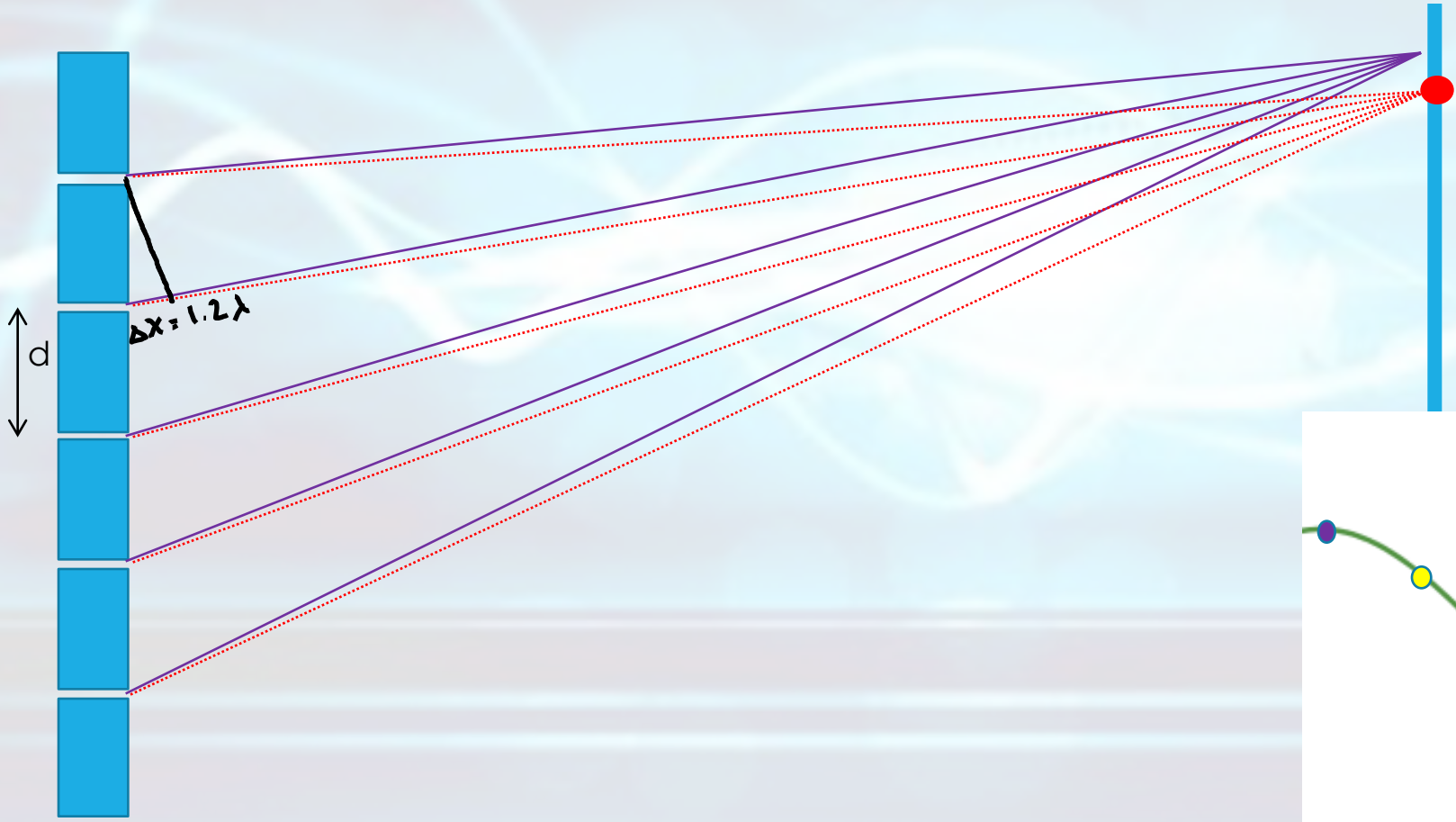
Modulated by the single slit pattern

Picture from: IB Physics, Oxford course book



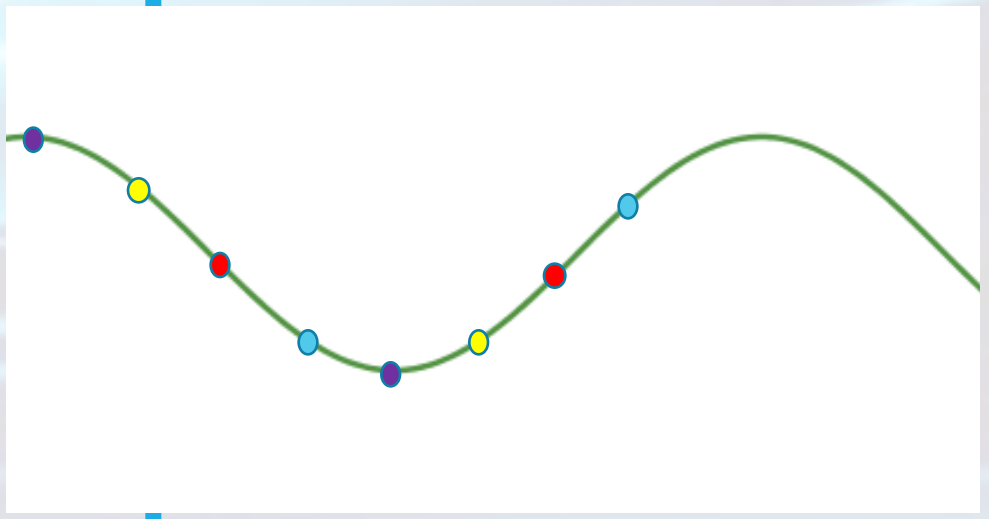
If $\Delta x = \lambda$

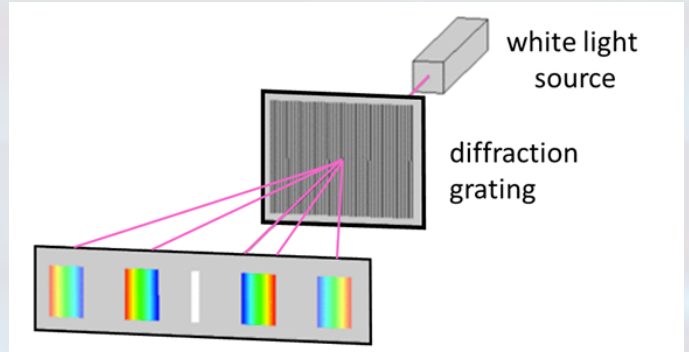
- constructive interference



If $\Delta x \neq n\lambda$

- Destructive interference!
- There will be complete destructive interference as soon as you move just a little bit from the maxima





Picture from:
http://www.physics.usyd.edu.au/teach_res/hsp/sp/mod31/m31_Grating.htm

- Many slits together are called **a grating**.
- Multiple slit maximum (same formula as for double slit):
- $d \sin\theta = n\lambda$ n = 0, ±1, ±2, ±3...
- Here d is the distance between two successive slits.
- Increased number of slits N:
  - Primary maxima thinner and sharper (easier to read)
    - Width proportional to $\frac{1}{N}$
  - The secondary maxima will become unimportant
  - Intensity of central maximum is proportional to N^2

Don't remember what the teacher explained? Check out this video on diffraction grating:
https://www.khanacademy.org/science/physics/light-waves/interference-of-light-waves/v/diffraction-grating

Minilab

Determine how many lines per centimeter there are in the grating given by the teacher.

$s = 0.75\ cm = 0.0075\ m = 7.5 \times 10^{-3}$

$D = 213\ cm = 2.13\ m$

$\lambda = 632.8\ nm = 632.8 \times 10^{-9}\ m$

$= 6.328 \times 10^{-7}\ m$

$$\boxed{s = \frac{\lambda D}{d}}$$

$$d = \frac{\lambda D}{s} = \frac{6.328 \times 10^{-7}\ m \times 2.13\ m}{7.5 \times 10^{-3}}$$

$$= 1.797\ldots \times 10^{-4}\ m$$

$$\approx 0.18\ mm$$

Example

Light of wavelength 680 nm falls normally on a diffraction grating that has 600 rulings per mm. What is the angle separating the central maximum (n=0) from the next (n=1)? How many maxima can be seen?

$d \sin\theta = n\lambda$ λ=680 nm, $d = \frac{1\times10^{-3}m}{600} = 1.66\ldots\times10^{-6}$

For n=1

$$sin\theta = \frac{n\lambda}{d} = \frac{1\times6.80\times10^{-7}}{1.66\ldots\times10^{-6}}$$

$$\theta = 24.1°$$

For n=2: $\theta = 54.7°$

For n=3: No solution can be found ($sin\theta > 1$).

Answer: We can see the central maximum and two orders of maxima on either side.