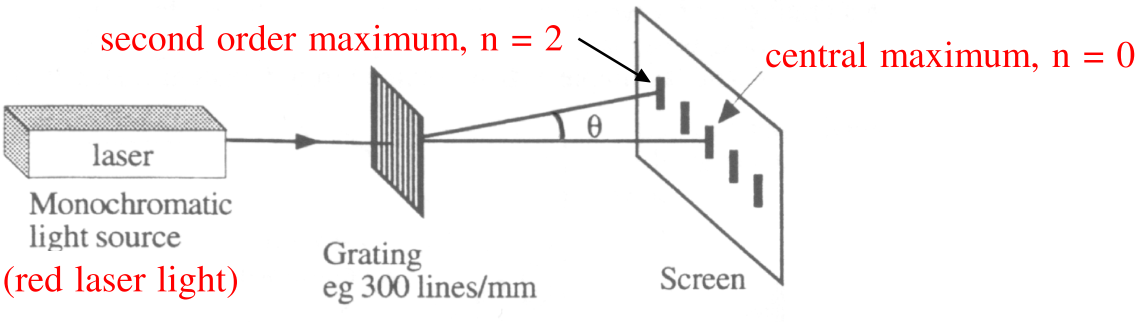
Diffraction Grating for the Interference of Light

To produce a ***bright*** and ***sharp*** **interference pattern** for **light**, a **diffraction grating** is used in preference to a Young's double slit.

A **diffraction grating** consists of many equally-spaced slits placed extremely close together, e.g., 300 lines per millimetre.

Light is diffracted through each slit, causing **constructive** and **destructive interference**.

Monochromatic light (light of a single colour, and hence one frequency/wavelength) or **white light** can be used.



This equation (the **grating equation**) applies:

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

n = order of maximum

λ = wavelength of light (in metres)

d = distance between slits on diffraction grating (in metres)

θ = angle between central maximum and maximum of order n (in degrees)

EXAMPLE - Experimental determination of the wavelength of red light

Matthew used the apparatus shown above to measure the wavelength of red laser light. With a protractor, Matthew measured the angle between the central maximum and second order maximum to be 25°.

n = 2.

λ = ?

d = 3.33×10^{-6} m

$\sin \theta = \sin 25° = 0.423$

To determine value for d in metres:

Grating has 300 slits (lines) per mm

= 300 x 1 000 = 300 000 slits per m

distance between slits (d) = $\frac{1}{300\ 000}$

= (3.33×10^{-6}) m

$n\lambda = d \sin \theta$

$2\lambda = (3.33 \times 10^{-6}) \times 0.423$

$2\lambda = 1.41 \times 10^{-6}$

$\lambda = \frac{1.41 \times 10^{-6}}{2}$

$= 7.05 \times 10^{-7}$ m (705 nm)

Changing the distance between maxima

The **grating equation** can be rearranged to give $\sin\theta = \frac{n\lambda}{d}$

θ gives an indication of the separation of the maxima on the interference pattern.

To make the maxima **further apart**, you could:

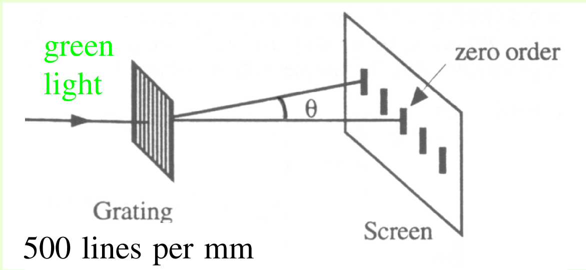
1) **Use light of a longer wavelength - towards the red end of the visible spectrum;**
2) **Decrease the slit separation - have more lines per mm.**

You could also:

3) **Move the screen further away from the diffraction grating.**

EXAMPLE

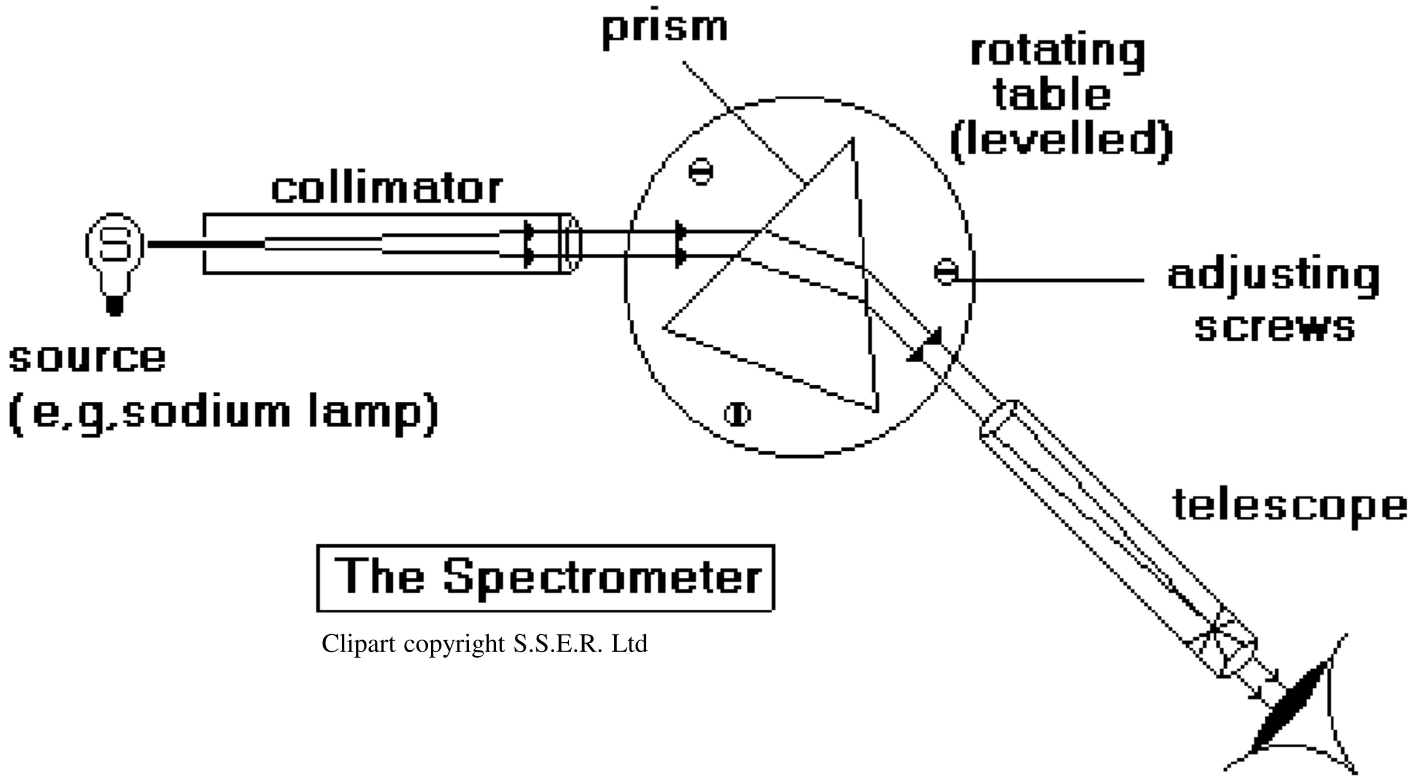
Emma sets up this apparatus to measure the wavelength of green light. She measures the angle θ between the central (zero order) maximum and second order maximum with a protractor and finds it to be 33°. Calculate the wavelength value Emma will obtain:



What affect will there be on the separation of the maxima on the screen if Emma :

Uses red light (wavelength 7 x 10^{-7} m);	Uses a diffraction grating with 700 lines per mm;	Increases the distance between the diffraction grating and screen?

Use of SPECTROMETER to measure angles between maxima



In order to obtain an extremely accurate value for the angle between maxima in a light interference pattern, a device called a **spectrometer** is often used.

A diffraction grating or prism are positioned on a level turntable which can be turned through very small angles. These angles can be measured from a very fine scale on the turntable.

The collimator ensures light coming from the source is parallel.

The telescope is used to obtain the exact position of each maxima, so the angle from the central maximum can be measured accurately.

Approximate Wavelength of blue, green and red light

You must be able to quote an approximate value for the wavelength of blue, green and red light.

Wavelength of blue light = 4.9×10^{-7} m = 490 nm

Wavelength of green light = 5.4×10^{-7} m = 540 nm

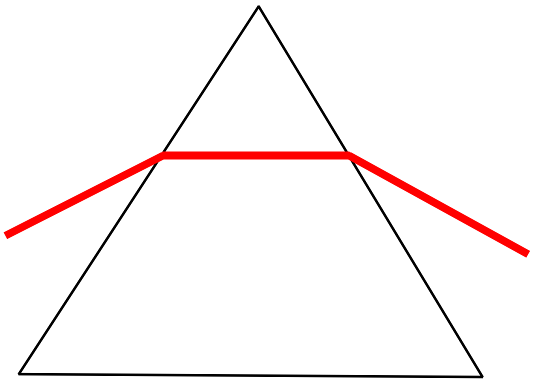
Wavelength of red light = 7.0×10^{-7} m = 700 nm

*** 1 nanometer (nm) = 1×10^{-9} m**

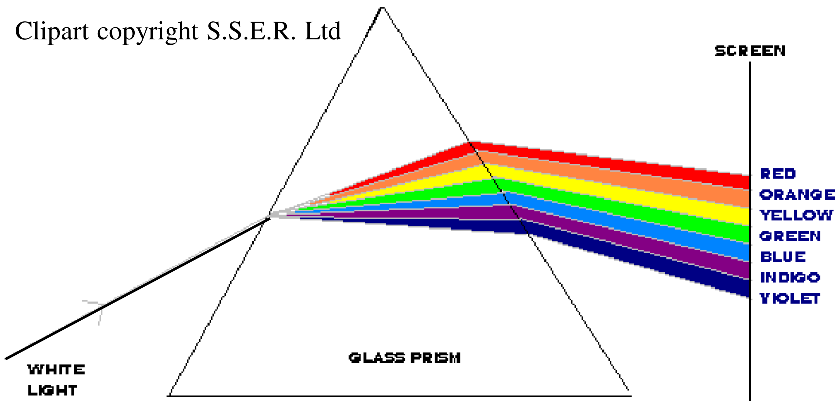
If you can't remember these values, similar values will be quoted in the data sheet you receive with your final exam paper - The data on this sheet refers to the wavelength of the red, green and blue spectral lines of the element cadmium.

Comparing White Light Spectra from Prisms and Gratings

When a ray of **monochromatic** (e.g., **red**) light is passed through a glass prism, the ray is **refracted**:

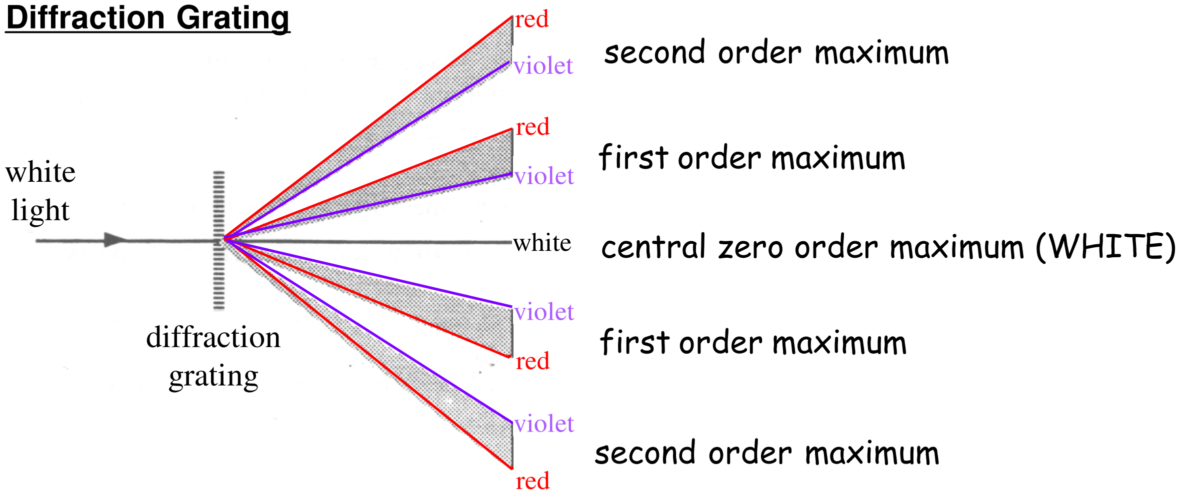


When a ray of **white** light is passed through a glass prism, a **visible spectrum** is produced:



DISPERSION OF WHITE LIGHT BY A PRISM

Diffraction Grating



PRISM	DIFFRACTION GRATING
Only one spectrum is produced (by refraction).	Many spectra are produced (by interference), symmetrically about a central white maximum. At central white maximum, path difference is zero, so all wavelengths (colours) of the visible spectra arrive in phase - They recombine to give white light.
Red light is deviated least. Violet light is deviated most.	Red light is deviated most. Violet light is deviated least. Red light has the longer wavelength, so is deviated most according to the **grating equation**: $\sin\theta = \frac{n\lambda}{d}$
Spectrum is brighter.	Spectra are less bright. The energy is divided between several spectra.
Colours in spectrum are close together.	Colours in spectra are more spread out.