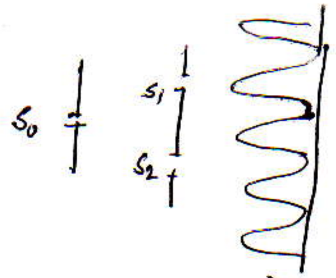
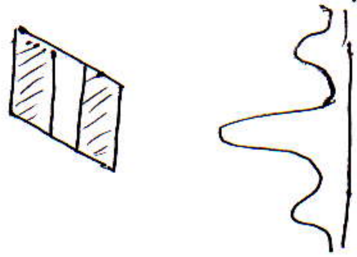
Interference, Diffraction & Grating.

Let us understand the basic difference between interference & diffraction. The three experiment that we know are.

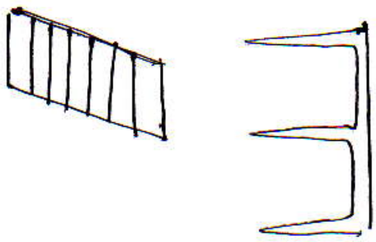
1) Youngs Double Slit ~~Interference~~ experiment.



2) Single slit Experiment



3). Grating Experiment



Now the first experiment is usually called interference experiment, second one diffraction experiment and third one is also called Diffraction grating. Actually calling them as interference experiment or diffraction experiment ~~are~~ is Wrong. Because in all the three experiment both interference and diffraction is there. Interference means when two or more Coherent rays superimpose that is adding. Diffraction on the other hand means spreading or bending. So we find that in all the three experiment both this phenomena are involved. Let us see these phenomena in little detail.

Interference
- → Superposition
- → Coherent
  - Same Source
  - Same frequency (why)
- → Redistribution of energy.
- → Possible for waves only & not for particles.

(1) Superposition - Adding of two or more waves.

(2) Coherent - When phase relations remain Constant with time in rays.

Mostly they are created from the Same Source when we speak about light.
In case of sound waves two independent Sources may act as Coherent and in that case their frequency should be Same (why?). Why not wavelength?

(3). Redistribution of energy

We need to remember that there is always a redistribution of energy in case of interference phenomena. At one place it is maximum known as maxima (Constructive interference) and other place is minima (destructive

For example, suppose there are two sources. Then we have studied earlier the resultant of many waves. For two wave superposition.

$$a^2 = a_1^2 + a_2^2 + 2a_1 a_2 \cos\delta$$ $\Rightarrow$ often known as interference term. (Why)

a_1 and a_2 are amplitudes of individual waves and δ is the phase difference. In terms of intensity

$$I = I_1 + I_2 + 2\sqrt{I_1 I_2}\cos\delta$$ $\Rightarrow$ often known as interference term. (Why)

If both amplitudes are equal & $\cos\delta = 1$. (maxima)

$\Downarrow$

$$I = (\sqrt{I_1} + \sqrt{I_2})^2 = (2\sqrt{I})^2 = 4I$$ Constructive Interference.

For minima. $\cos\delta = -1 \Rightarrow$ destructive Interference.

$$I = (\sqrt{I_1} - \sqrt{I_2})^2 = 0. \quad (I_1 = I_2)$$

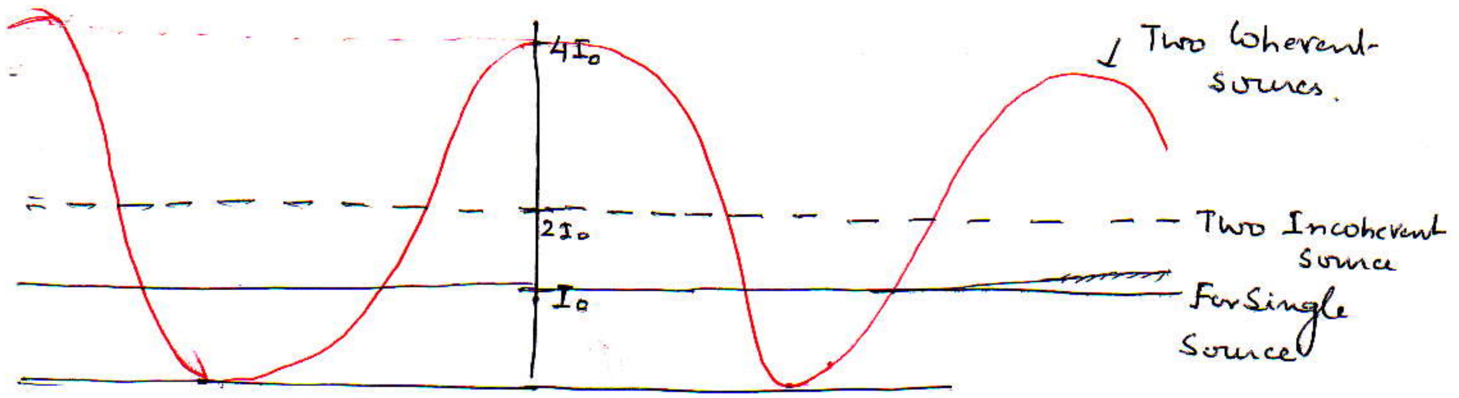
Here the concept of redistribution of energy will be very clear if we take two incoherent sources.

Suppose you are asked to plot a distribution of ~~Insity~~ Intensity versus distance in a double slit interference experiment for two cases. —

(a) if the light coming from both the sources are incoherent. Then $I = I_1 + I_2 = 2I$ $\quad \cos\delta = 0$

(b) If they are coherent.

Each source intensity $= I_0$.



This is a very very important figure. It should tell you ~~that~~ what is basically an interference pattern — the red Colour one. See how the intensity got redistributed which is not the case when it is incoherent.

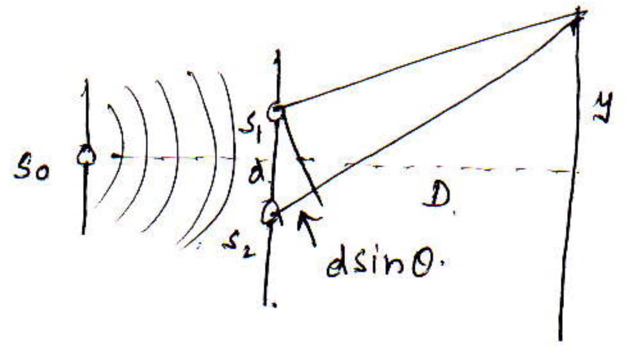
(4) Interference is a Wave Phenomena.

One cannot explain the interference effect without Wave theory. The dark bands are getting light from both the holes, still how the intensity of the dark band becomes 0 — It is possible only because of destructive interference.

How to find the bright and dark bands.

In case of interference phenomena we always calculate the path difference between two rays or sometimes more if they are parallel. If that path diff is equal to integral multiple of wavelength then it is the case of maxima. ~~If it is~~ — They are reaching in phase.

Mathematically.



* $d \sin\theta = m\lambda$ maxima.

$d \sin\theta = (m + 1/2)\lambda$ minima.

$\sin\theta \simeq \tan\theta = y/D$.

Now this technique is being followed in every case of interference.

Second Important point to remember here is the relation between phase difference and path difference.

Path difference of λ = Phase diff of 2π.

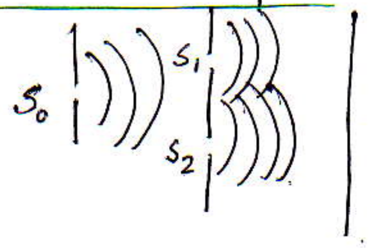
* We will see some case where this is opposite. Can you guess in advance?

How to create Coherent Sources.

Interference
- Division of Wavefront
- Division of amplitude.

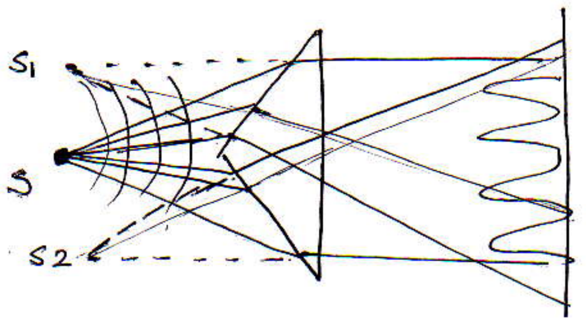
Division of Wavefront

(1) Double Slit Experiment by Young.



Wavefront dividing into two.. and two Coherent Sources are created.

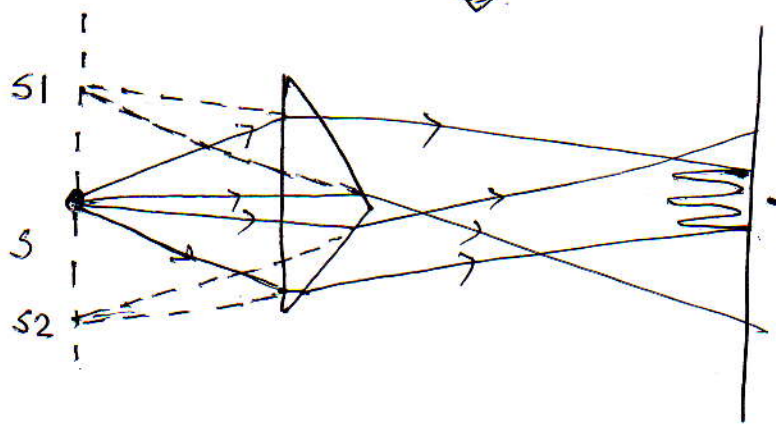
(2) Fresnels Biprism.



Two virtual images Caused due to ~~d~~ refraction

A Better picture & opposite Set up.

⇓



→ Interference fringes in the region of overlap.

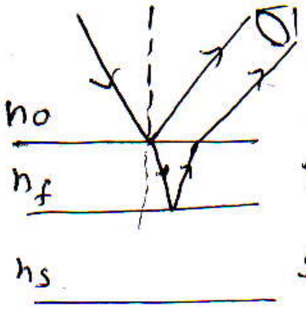
How to create Coherent Sources.

⇓

Division of Amplitude.

(1) Interference in Dielectric films:

appearance of colors on the surface of oily water and soap films result from interference in ~~da~~ films.

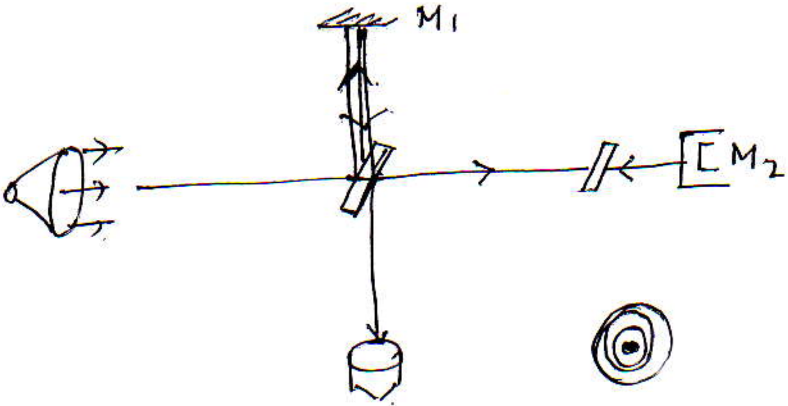


Transparent films.

Substrate.

Double beam interference from a film.

(2). Michelson Interferometer



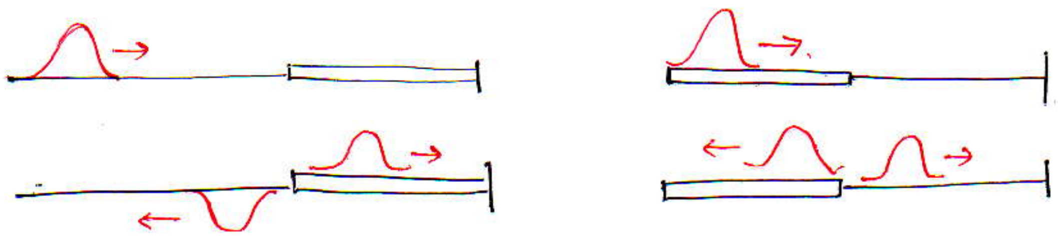
It can be used for

1) measure λ
2) refractive Index of transparent materials
3) - - - -

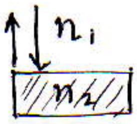
(3). Newton Rings.

Newton Rings.

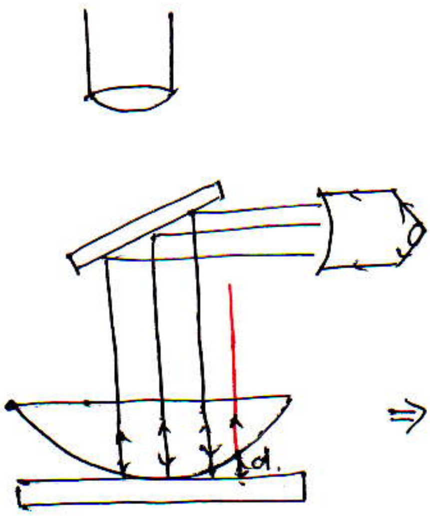
In order to understand Newton Rings we need to know the Physics of 'Phase change' on reflection. Here one needs to revise the Concept of 2 attached strings of Variable mass per unit length.



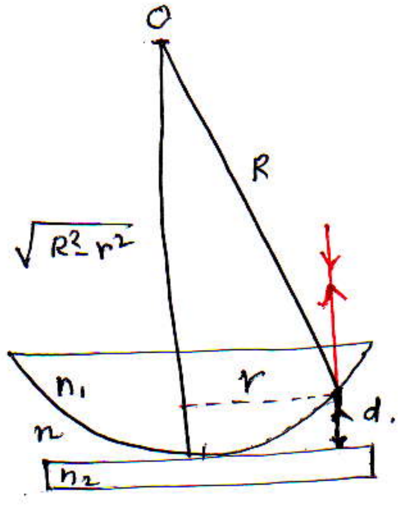
I hope this picture is clear to you. Exactly the same way when light is reflected from an interface that is two mediums are present with refractive index n_1 and n_2, if $n_1 > n_2$ the reflected ray does not undergo any phase change otherwise if $n_1 < n_2$ then the reflected wave will undergo a phase change of π.



Newton Rings -



$\Rightarrow$ enlarged.



Crucial Point: Here light is reflected from two Surfaces one from the lower surface of the plano convex lens and again from the lower glass plate. Now in between there is air interface. (There can be any liquid also)

Which ray will undergo a phase change of π = ?

If the refractive index is such.

$n_1 > n$ & $n_2 > n$.

Then the light reflected from the glass Prism will get a phase change of π (see the rope picture) So the path difference between the two reflected waves will be

maxima condition.

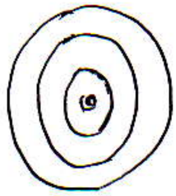
$$\cancel{2nt} \quad 2nd = (m + 1/2)\lambda \qquad m = 0, 1, 2.$$

will be the condition of maxima.

m = 0 first ring.

Now it is not $m\lambda$ because of phase change of π.

So a large number of circular frings will be observed starting with a dark central fringe.



One can measure the diameter (radius) of these rings & find out the wavelength of light or radius of curvature of the plano convex lens, or the thickness of the film at radius r

Derivation of the formula.

$$d = R - \sqrt{R^2 - r^2} = R - R\left(1 - \frac{r^2}{R^2}\right)^{1/2}$$

$$= R - R\left(1 - \frac{r^2}{R^2} \cdot \frac{1}{2} + \cdots\right) = \frac{r^2}{2R}.$$

So $\quad 2nd = (m + 1/2)\lambda.$

$$\cancel{2} n \times \frac{r^2}{\cancel{2}R} = (m + 1/2)\lambda$$

$$\boxed{r = \sqrt{\frac{1}{n}(m + 1/2)\lambda R}} \qquad m = 0, 1, 2 \ldots$$

So measuring the radius of the bright fringe one can find out any of the unknown quantities. Generally a mono chromatic source of light i.e Sodium lamp is used to see the rings. So one gets bright and dark fringes.