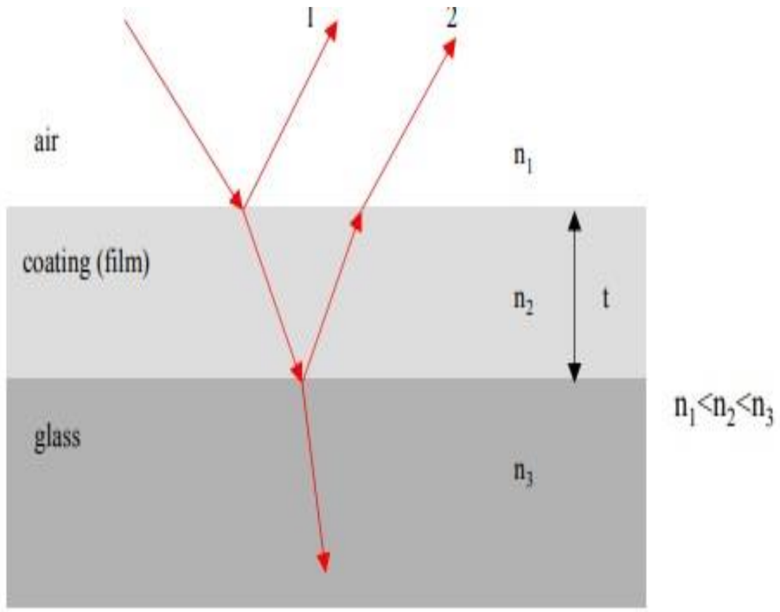
Reflection from a plane-parallel film

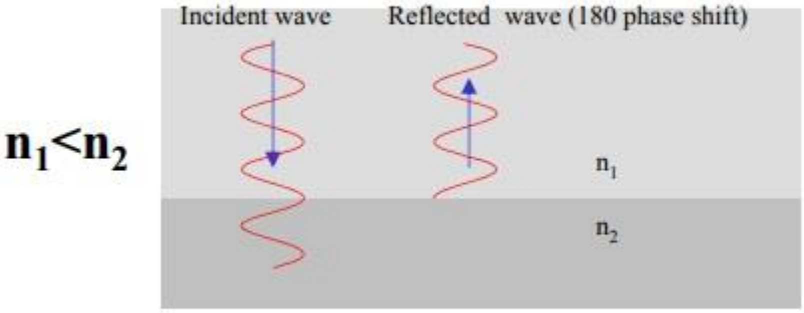
When light hits a surface, it can be absorbed, transmitted or reflected.

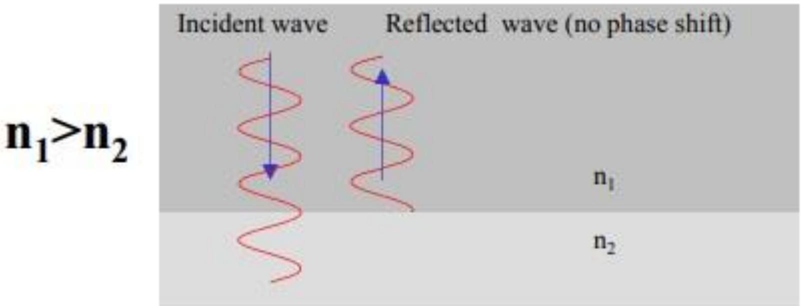
Light can reflect from any interface where there is a change in refractive index. When light hits a material that has multiple layers, each layer can reflect light. The light reflected from any one of these layers might interfere with the light that has reflected off any of the other layers. Each layer creates its own image of a point source. These sources will be mutually coherent because they all arise from a single original source. The basic idea is illustrated in the figure below, which shows a glass surface with a thin coating. There are two main sources of reflection from the surface (ignoring multiple internal reflections) labeled 1 and 2. These two reflections will interfere. The phase difference depended on the index of refraction of the coating, the thickness of the coating and what happens to the phase upon reflection.



The rule for reflection is that when the index of refraction after the interface is higher than the index of refraction before the interface then the light, upon reflection, undergoes a 180 degree phase shift.

When the index of refraction after the interface is less than the index before thin interface, then there is no phase.





Because each interface is at a transition from a lower to a higher refractive index, there is 180 degrees phase shift at each reflection (for 1 and 2).

تداخل اتلافي 2nt=	تداخل بناء 2nt=	نوع التداخل
m λ **m=1,2,3,**	**(m+1/2) λ** **m=0,1,2,**	احدى الموجتين مقلوبة
(m+1/2) λ **m=0,1,2**	**m λ** **m=1,2,3,**	الموجتان مقلوبتان او غير مقلوبتين

EX1: what is the minimum value of thin film thickness

(n=1.33) to for constructive interference of light (λ=521nm)

Sol.:

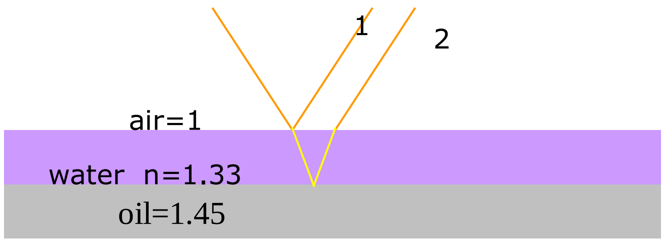
هنا احدى الموجتين مقلوبة والاخرى غير مقلوبة والتداخل بناء

2nt= (m+1/2) λ

m=0

$$t=\frac{521}{4n} = \frac{521}{4*1.333}=979nm$$

Ex2: Because of the presence of a layer of oil(n=1.45) on the surface of a pool of water, colored rings were observed and when looking down the pool was observed yellowish green area Calculated minimum value of thickness for the oil layer because of the appearance of this color.(λ =555nm)



هنا الموجتين مقلوبتان والتداخل بناء

2nt=mλ

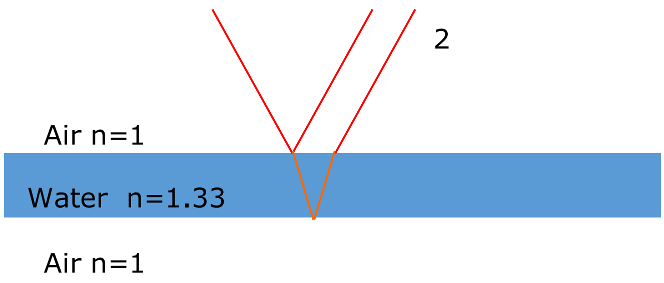
t=m λ/2n=1*555/ 2*1.45

t=192nm

EX3: a) What is the minimum soap-film thickness (n=1.33) in air that will produce constructive interference in reflection for red (λ=652nm) light? (assume normal incidence)

b) Which visible wavelength(s) will destructively interfere when reflected from a soap film of thickness 613nm? Assume a range of 350nm to 750nm for visible light.

Sol.:



a- for constructive int.: $2nt = (m+1/2)\lambda$

$2nt = (m+1/2)\lambda$

We want thinnest film possible (m=0)

$2*1.33*t = (0+1/2)*(652)$

$t= 652/4*1.33$

t=123nm

b-for destructive int.

$2nt=m*\lambda$

$\lambda=2t\, n / m$

When m=1: λ=2*613*1.33/ 1 =1630 nm out of range.

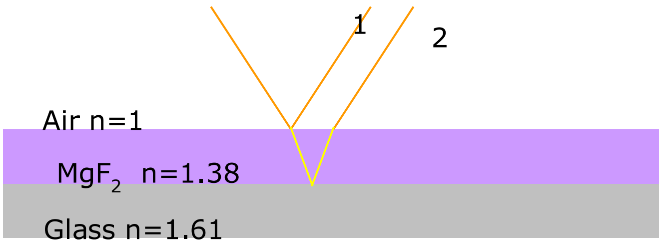
When m=2: λ=2*613*1.33 /2=815nm out of range

When m=3: λ=544nm in the range

When m=4: λ=407nm in the range

EX4: A thin layer of magnesium fluoride (n=1.38) is used to coat a flint-glass lens (n=1.61).

What thickness should the MgF_2 coating be to suppress the reflection of 595nm light?



We need destructive interference (no reflection). In this case both outgoing rays reflect from a higher index, so there is no relative phase shift.

Sol:

2nt = (m+1/2) λ

With m=0 and solve for t, this will give the minimum thickness

2*1.38*t= (0+1/2) λ

2*1.38*t=595/2

t=595/4*1.38

t= 108nm

To get other possible thicknesses that will work, just use

larger values for m:

$$m = 1 \Rightarrow t = 323nm$$
$$m = 2 \Rightarrow t = 539nm$$
$$etc...$$