Thin Film Interference:
An activity with nail polish
**Thin Film Interference**

**Prerequisites**

Eight grade science.

**Correlation**

**Science Concepts**

Geometric optics

Refraction and Snell’s Law

Index of refraction

Relationship between wavelength and color

Constructive and destructive interference

**Nanoscience Concepts**

The priority of forces and interactions depends upon the scale of the material.

The priority of the forces and interactions will impact the observed phenomena.

The arrangement of the atoms or molecules will impact the physical properties of the material.

**Background Information**

**Thin Film Interference**

There are several overlapping concepts that contribute to the phenomena called thin film interference. These concepts are being applied at the micro and nano scale to create more secure computer screens, biological sensors and measurement devices as well as beautiful gift ribbons.

The first concept is that of refraction and the associated index of refraction. The index of refraction is designated “n” and is the ratio of the speed of light in a vacuum to the speed of light in a medium { $n = c/v$ }. Refraction is the term used to define the “bending” of light as it passes through one medium (perhaps air) into another medium (perhaps glass or water).

The amount of bending of the light is determined by Snell’s Law $n_1 \sin \theta_1 = n_2 \sin \theta_2$. Where $n_1$ and $n_2$ represent the index of refraction of the two mediums and $\theta_1$ and $\theta_2$ represent the angles of the light with respect to the perpendicular interface bisector.
As any light moves through a medium, the amount of bending will also be dependent on the wavelength of the light and is related to the index of refraction \( \lambda = \lambda_0 / n \), where \( \lambda_0 \) is the wavelength in a vacuum.

Finally the thickness of the material and its relationship to the wavelength of light will define the refraction angle as shown in the figure to the right. The two angles shown, \( \pi \) and \( \theta \) (the 'O') are different dependent upon the thickness of the material, in this diagram, water.

In summary the precise interaction of light with a material is dependent upon:

- The index of refraction of the material
- The wavelength of the light interacting
- The thickness of the material

At any interface light may be refracted, reflected or transmitted. The light that contributes to the thin film interference effect is the light that is reflected from the interface between the water and the oil and the light that is reflected directly from the top surface of the oil.

1. **Interference - Thin film interference and reflections**: Physclips - Light

   www.animations.physics.unsw.edu.au/.../thin-film-interference-and-refle...

1. **Thin Film Reflection and Interference**

   hyperphysics.phy-astr.gsu.edu/hbase/phyopt/soapfilm.html ---- This website contains an interactive window where students can change multiple parameters and observe the impact.

Because how light interacts with a material is dependent upon the wavelength of light most often this interaction will result in different colors (wavelengths) being reflected at different angles. So light that enters a system of say oil and water – or nail polish on water – as white light will be refracted at different angles and appear no longer as while light (a mixture of multiple wavelengths) but will appear as a rainbow of separate colors. The exact colors seen at a specific angle will be dependent on the thickness of the material.

The colors seen in the thin film by nail polish on water that is exposed to a broadband light source (i.e. white light) are the product of a phenomenon called thin film interference. Thin film interference occurs when incident light waves reflect off of the upper and lower boundaries of a thin film and interfere with one another. As the light that reflects off of the lower boundary must travel a longer distance than that from the upper boundary it may no longer be in phase. When the two waves remain in synch (Peaks matching peaks) – constructive interference occurs.
When the waves are 180 degrees out of synch (peaks matching troughs) then destructive interference occurs. For all other phase separations various “blurring” of the light will occur.

NOTE Billie – I deleted the original picture because it showed identical interaction within the material – the only difference was the title on the image --- which was incorrect for one of them -- this image is better it shows a difference based on the thickness --- am still looking for a complete picture with wavelength dependence --- but perhaps that is not necessary.

The ref. for the pic above is wikipeidea.org/optical interference

As a broadband light source is made up of many separate wavelengths of light, individual wavelengths will interact with the thin film on their own which is why distinct colors can be seen based on the thickness of a particular area of the thin film.

As the incident light hits the thin film, part of it is immediately reflected, part passes through the thin film and is reflected off of the lower boundary, and part continues on in to the water below.

If the thickness of the thin film is such that the distance a wave must travel to reflect off of the lower boundary matches exactly the wavelength of the wave, when the wave exits the thin film
after reflection it will be in phase with the reflection off of the upper boundary. Such constructive interference acts to amplify the intensity of a wave, making it seem brighter to a photo detector such as the human eye. The other wavelengths that are part of the incident light, each having different wavelengths, are out of phase with the waves that reflected off of the upper boundary and act as destructive interference, either reducing the intensity or canceling entirely. Thus, as the thickness of the thin film varies so will the color of the reflected light.

Sources:


**Hands-On Learning**

Thin Films Activity

**PowerPoint Notes**
Questions & Answers

Questions

Multimedia Resources

YouTube

Simulations

Readings
Additional Sources