4. Fine dust via interference from light.

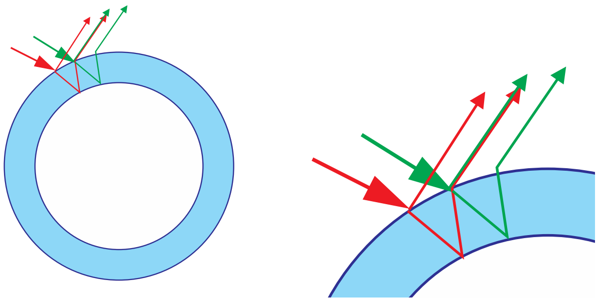
Content

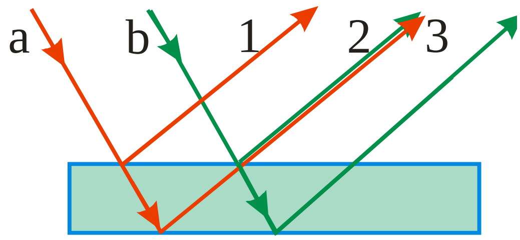
4.1. A play of many colors

In conducting the M&M experiment, interference of light was used for the first time in history, we said. The term “interference” may scare us somewhat, but with the matter itself we are confronted almost daily. Mostly, however, without thinking about it. Let's first try to explain the phenomenon.

For example, the play of colors in a soap bubble or in a film of oil on a pool of water are the result of optical interference, of the interplay of many rays of light.

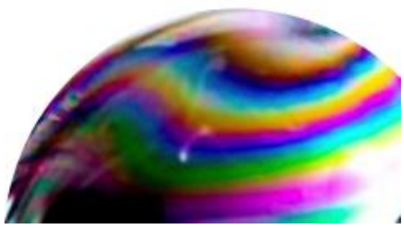
We seek to clarify. The drawing below on the left represents a bubble. The second drawing gives us a detail of it. The blue rectangle in the drawing on the right also represents a piece of the soap bubble, or a piece of a layer of oil on water, or of a very thin transparent substance on our cell phone. Let the light strike it at an angle, using rays of light a and b.

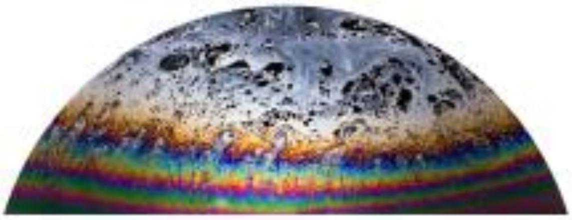




Let's look at the drawing above on the right. The rays of light from a (in red color) and from b (in green color) that fall on it can partly reflect on the top of the layer, but also on the bottom. Let's look at the path that the incident rays a and b can follow. Rays (a)1 and (b)3 reflect on the top side, rays (a)2 and (b)4 on the bottom side of the layer. It can be seen that the reflected rays 2 (green) and 3 (red) coincide with each other. However, ray a2 has traveled a longer path than ray b3. However, this minimal difference in path length leads to a noticeable difference in color. And this process repeats itself for the many rays of light incident on the layer, hence the beautiful color effects.

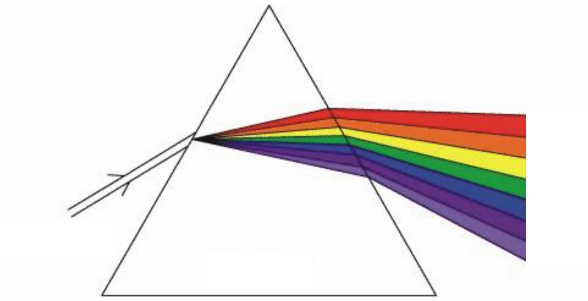
Looking even more carefully at our bubble. We observe in its so short and colorful life that the hues are constantly changing. These changes are caused by gravity.





The water in the bubble is gradually drawn to the lowest point, sometimes causing several nearly horizontal bands to show themselves in varying colors. Finally, too much water has accumulated at the bottom of the bubble and elsewhere it has become so thin that it bursts. Gone are our beautiful colors. Our bubble could possibly prolong its existence and we could study its color changes a little longer if one were to blow it in a gravity-free field. An experiment to perform in a space capsule? The extra cost of a pipe and some suds will probably not put too much of a strain on the space budget.

4.2. Diffraction colors are not interference colors



Notice the difference between diffraction and interference. A rainbow is a diffraction phenomenon, the light there decomposes into its constituent colors. The many raindrops are like so many prisms that “decompose” light into pure colors.

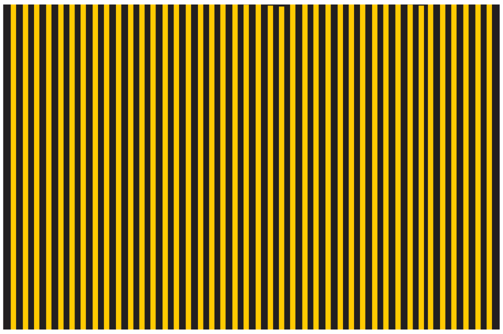
Interference is the opposite: coherent light rays coming from the same light source, such as the sun for example, unite to form an interplay, a mixture of many colors.

Interference colors = mixing colors

A rainbow shows us pure colors, interference gives us a mixture of colors.

4.3. A first experiment

Years ago we did our very first interference experiment. We wanted to redo Young's two-slit experiment (see below) and used an old sodium lamp, i.e., a monochromatic light source, with light of one color. It was the type commonly used on our highways at the time. The lamp itself is as much as a meter high and uses barely 90 watts. We wrapped it completely with silver paper. Then we poked two holes in it on the light side and barely one mm apart with a fine pin. We then darkened the room. And lo and behold, on the wall, about 5 meters away, thousands of yellow lines emerged, all nesting parallel to each other. We realized that light waves are extremely small; there are two thousands of them in a single millimeter.



4.4. A second experiment

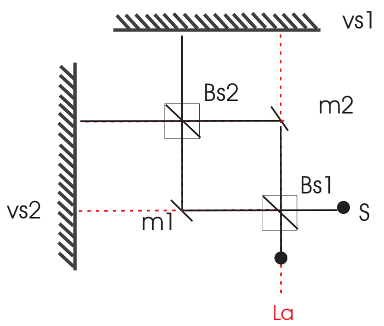
Next, we experimented with white light, light that still contains all the colors of the rainbow. A fiber optic led the light from our light source, a simple lamp, to our “point light source,” a metal plate with a hole poked in it, located just in front of a beamsplitter Bs1. There the light was split into two partial beams. One partial beam went via the flat mirror m1 to a second splitter, Bs2. The second partial beam passed through m2 to Bs2.

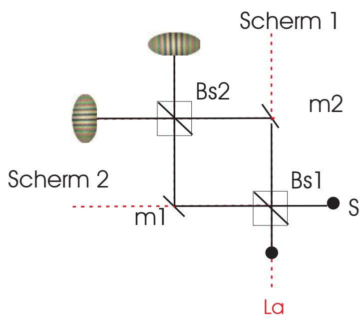
On the planar screens vs1 and vs2 we expected to see interference lines as well, lines in colors. After all, we were working with white light. But none of it. Our setup was not aligned at all. So starting over, with a laser, and replacing the flat screens with flat mirrors. Then remove the mirrors m1 and m2 and place the plane mirrors vs1 and vs2 so that the reflected laser beam went back accurately to Bs1. Then place m1 so that the reflected laser light on vs1 also went back to the laser. Afterwards, the same for mirror m2 on vs2.

Then place a piece of paper in front of mirrors vs1 and vs2 so that they do not reflect the laser light. Only then can splitter Bs2 be placed. Each exposed side of Bs2 reflects about 4% of the light. Again, these reflections must be directed very precisely to the laser. If this is all done very carefully, you will see a number of interference lines in laser light on both screens. If you extinguish the laser and use white light, you will indeed notice some colored lines neatly side by side, as shown in the drawing on the right.

Placing all the parts correctly by hand just doesn't work. You must provide each optical part with levers with set screws, so that you can accurately slow down and control its movements according to the three axes. Rebuilding the setup as shown schematically below is thus really not an easy task. It gives food for thought with what degree of accuracy we will have to build our further setups.

We call such a type of interferometer an “open” type. The two sub-beams each take a different path. You can never really be sure whether the path Bs1, m1, Bs2 is indeed as long as the path Bs1, m2, Bs2, to the nearest part of a mm. We wonder if some kind of interferometer exists or can be devised, where the two sub-beams remain separated in a way and still travel the same path. It seems like a contradiction, but maybe there is something to it? So are we looking for a “closed” type of interferometer.





4.5. A third experiment

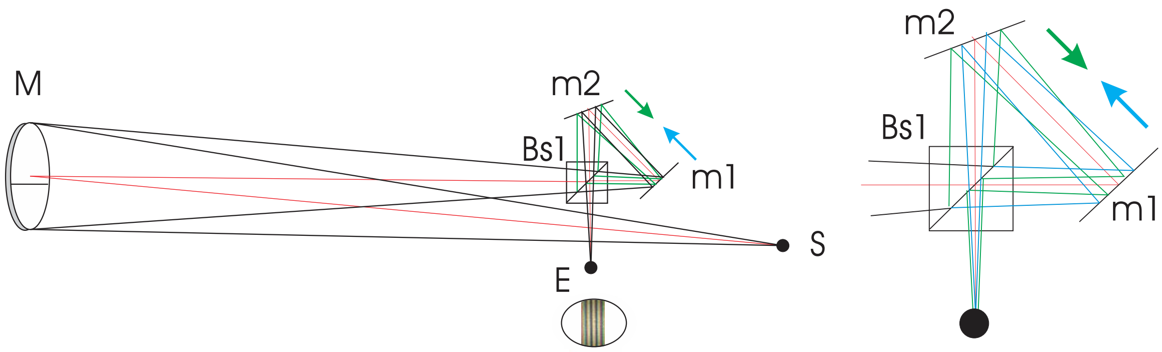
Consider the drawing below on the left. The point light source S illuminates the mirror M. The reflected beam reaches the splitter BS where jet light splits into two partial beams.

Let's look at the detail drawing on the right. One partial beam goes in clockwise direction via the plane mirrors m2 and m1 again to Bs, and finally to the observer in E.

The other partial beam goes in counterclockwise direction via the plane mirror m1 and m2 again to Bs, and finally to the observer in E.

In fact, both partial beams travel identically the same path, but in opposite directions. That means that, by definition, they are equally long. But with that we no longer have an “open” arrangement where the sub-bundles can differ in length a part of a mm, but a “closed” arrangement. This means that achieving an interference image may no longer be so difficult.

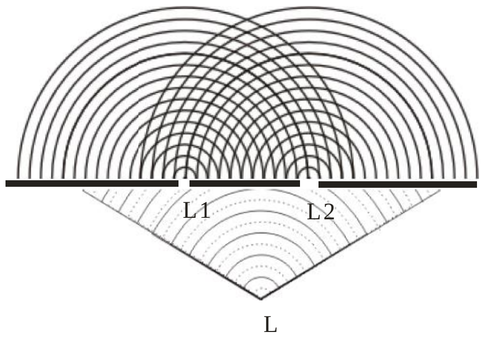
We effectively construct this arrangement and find that a number of interference lines do indeed show themselves in E. Thus, the task is successful. Perhaps we can take advantage of such a 'closed' arrangement, an arrangement in the form of a triangle - B1, m2, m1 - later on.



4.6. Thomas Young's “two-slit experiment.

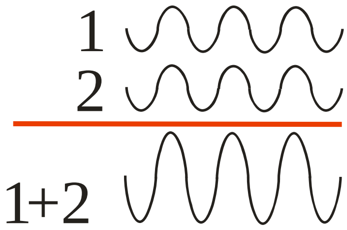
Refer to our first interference experiment in which we used a large monochromatic lamp. Two pinholes just side by side in the silver paper each served as a light source and both projected thousands of thin interference streaks on a wall about five meters away.

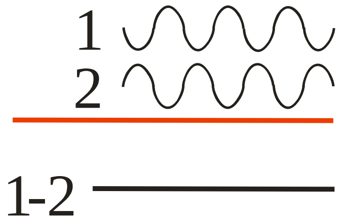
It is a variation on Thomas Young's two-slit experiment of 1805. In the drawing below, we can compare the light source L to the sodium lamp and the two light sources L1 and L2 to our pinholes in the silver paper.



The drawing represents all this in a flat plane. But in reality these are parts of a series of concentric spheres that are constantly expanding and whose waves from one light source are constantly penetrating into another.

Compare it to waves in water. If one throws two stones into the water at the same time and at a short distance from each other, one sees the waves caused by one stone "penetrate" the waves of the other.





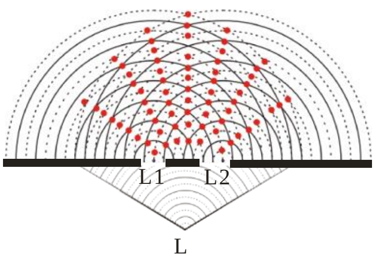
Where two wave tops merge one has a higher top, where two wave valleys merge one obtains a deeper valley. Where a crest fills a valley, the water remains at its original level.

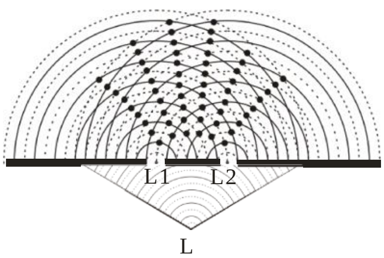
Light is also a wave motion, but two thousand waves go into one mm. If one has two coinciding wave tops here, or two coinciding valleys, then the light is twice as intense. If, however, a crest coincides with a valley, then one has the curious phenomenon that light added to light, leads to ... darkness.

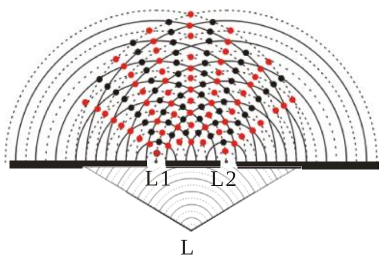
Let's look at the drawing below on the left. The waves in dotted line indicate the valleys, the waves in solid line the tops. Where two wave tops or two wave valleys meet, a red dot was placed. The light intensity there is double.

The black dots on the drawing in the middle indicates quite analogously the places where a peak fills a valley. There they neutralize each other and there is no light.

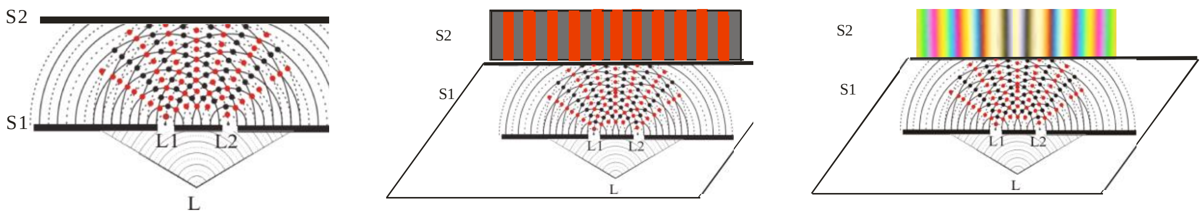
The drawing on the far right brings the two previous ones together.



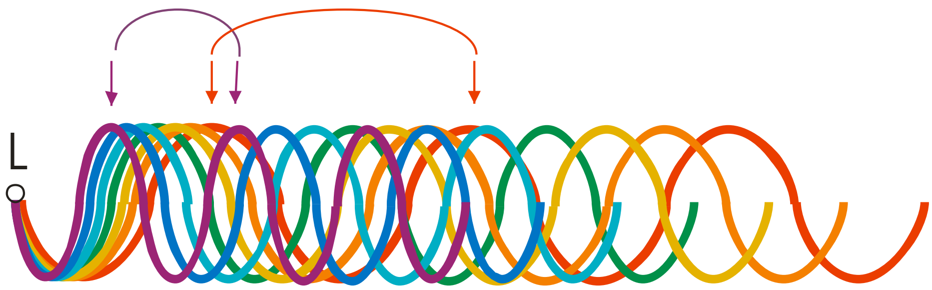




Keep in mind that in reality they are not circles but spheres that keep expanding. Imagine that the black line at the top in the drawing below on the left is a screen we see in top view. Look at it in the drawing in the middle in front view. We see on it the projections of the various lines, as we saw on our wall in the experiment with the large sodium lamp. If we do not work with monochromatic light, but with white light, stripes in interference colors will appear, as shown on the far right.



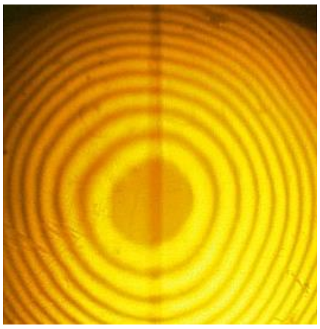
In white light, only a few interference lines can be seen. The different colors each have a different wavelength. For example, the wavelength of red light is almost double the wavelength of violet light.

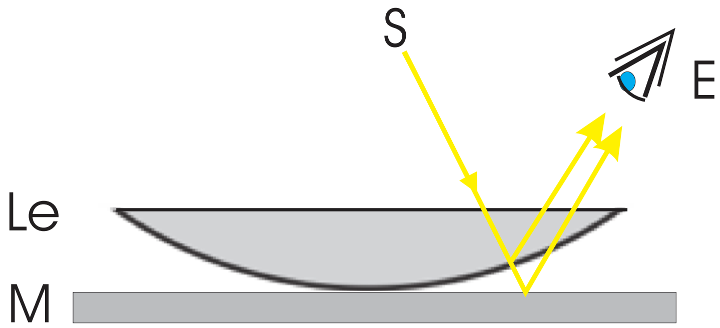


After a few wavelengths, they are quickly “out of sync” with each other so that the distinct colors overlap again. Their colors mix and together give back white light. Interference experiments with white light therefore require greater accuracy than experiment with light of only one color.

4.7. The rings of I. Newton

The so-called rings of Newton are also an interference phenomenon. Newton reported them but could not explain them because he did not see light as a wave motion but corpuscularly, as small particles. The picture on the left gives us a top view, the drawing on the right a cross section. In the drawing we see a flat convex lens Le lying on the mirror M. A beam from the light source S illuminates the entire mirror. Only a small part of this is shown. One beam of light passes through the lens and reflects on its underside. Another part passes through and reflects on the mirror. Both light rays are received by the eye in E.





[1]

One must imagine that, in fact, numerous light rays across the entire lens surface do this, and that there are light rays reflecting off the underside of the lens that will coincide with other light rays nearby, reflecting off the glass just next to it. Such rays unite and form the various circles of interference.

We could compare it somewhat to the piece of bubble where light reflects from both the surface and the bottom. Here the piece of bubble is replaced by the open space between lens and mirror. The "piece" here consists of the open space of air between lens and mirror. But the principle remains the same.

[1] https://nl.wikipedia.org/wiki/Newtonring#/media/Bestand:Newton-rings.jpg