Physics Light and Waves Summary

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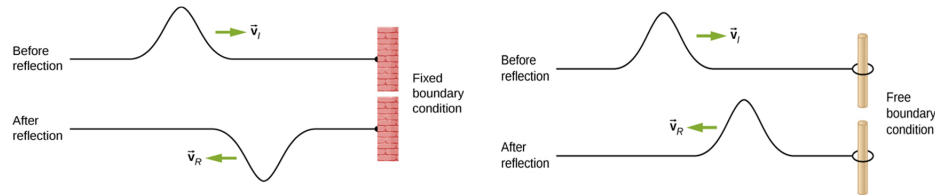
Contents

1   Bubbles and Films

1.1   Fixed and Free Ends

When a wave hits a fixed end, the reflecting wave (phase) is inverted. When a wave hits a free end, the reflecting wave is originially oriented. When a wave hits either a fixed or free end, the wave does NOT get transmitted (no wave on the other side).

1.2   Mediums

So what is a medium? A medium is the material that the wave is travelling through. A great example of mediums, directly correlating to this unit, are air and water. Air is a fast medium, water is a slow medium, and the sunlight is the wave.

1.3   Fast to Slow Mediums

The transmitted wave is ALWAYS originally oriented!

- Reflected wave is inverted

- Transmitted wave is originally oriented

- The amplitudes of transmitted and reflected wave are smaller than the original wave. Though if both their amplitudes were added together, they would equal the amplitude of the original wave.

1.4   Slow to Fast Mediums

The transmitted wave is ALWAYS originally oriented!

- Reflected wave is originally oriented

- Transmitted wave is originally oriented

- The amplitudes of transmitted and reflected wave are smaller than the original wave. Though if both their amplitudes were added together, they would equal the amplitude of the original wave.

1.5   Bubbles as a Film

As the light wave travels from the air medium (n_{air}) to the soap medium (n_{soap}), the phase is reflected back to the persons eye and the original wave is inverted into the bubble. The original wave is then reflected back to the persons eye

after bouncing around inside the bubble. The person now see's two reflected lights. Depending on the thickness of the film (t), the reflected light (R) and the original light (O) will either constructively or deconstructively interfere.
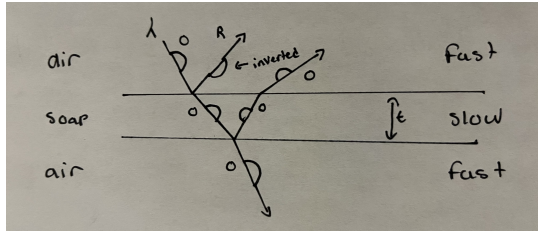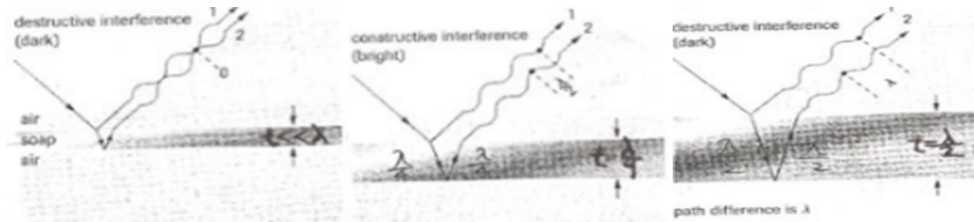

1.6   Reflected Film Light

If a second wave is out of sync with the original wave, the two waves will either deconstructively or constructively interfere by the time they reach a screen (eye, screen, table, etc.) which will result in seeing either a bright or dark spot.

If the thickness of a film is very, very thin, (practically zero), then the waves will be in sync because the distance is negligible.

If the thickness of a film is thicker, then the waves, depending on the thickness of the film, will potentially be out of sync.

This is because $Wave_2$ has to travel farther than $Wave_1$ post it's reflection on the bottom of the film, to reach the screen.
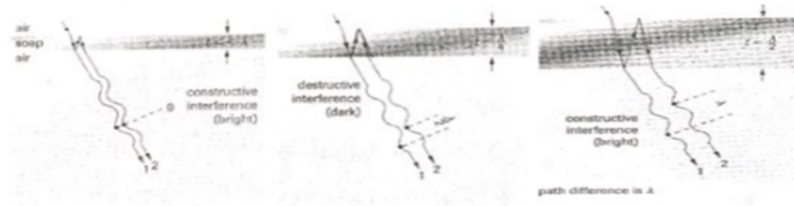

Reflection Constructive Interference (Bright): $\frac{\lambda}{4}$, $\frac{3\lambda}{4}$, $\frac{\lambda}{4}$

Reflection Deconstructive Interference (Dark): 0, $\frac{\lambda}{2}$, λ, $\frac{3\lambda}{2}$

1.7 Transmitted Film Light

The transmitted film light constructive and deconstructive interference equations are the exact opposite of the reflected film light constructive and deconstructive interference equations.

Reflection Constructive Interference (Bright): 0, $\frac{\lambda}{2}$, λ, $\frac{3\lambda}{2}$

Reflection Deconstructive Interference (Dark): $\frac{\lambda}{4}$, $\frac{3\lambda}{4}$, $\frac{\lambda}{4}$

2 Single and Double Slits

2.1 Theory

If Young's Double Slit Experiment were to be submerged in water, how would the fringe pattern change?

The length of a wave (λ) is strongly dependant on it's medium. If the experiment was to be submerged in water (a slower medium than air), then the wavelength of the light would decrease and the fringe pattern would become closer together.

2. For diffraction by a single slit, what is the effect of increasing (a) the slit width, and (b) the wavelength?

(a) Increasing the slit width (d) would decrease the width of the central maxima. This is proven by the equation: $\Delta y = \left(\frac{(\lambda)(L)}{d} \right)$

(b) Increasing the wavelength (λ) would increase the sie of the central maxima. This is proven by the equation: $\Delta y = \left(\frac{(\lambda)(L)}{d} \right)$

2.2 Wavelets

Christiaan Huygens use of "wavelets" describes the interference pattern created by a single slit. Wavelets are a wave split into multiple miniatures lines and depending on the θ of these lines, the screen (or eye, etc.) will experience either constructive or deconstructive interference.
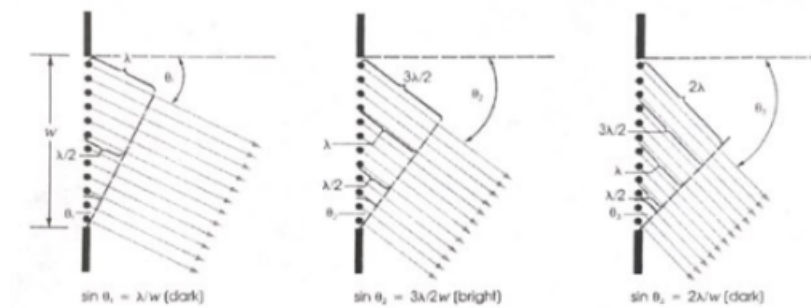
Deconstructive Interference
If the path difference from one side of the slit to the other is a multiple of λ (eg. 2λ, 3λ, ...), then there will be deconstructive interference.

$$\therefore y_m = \left(\frac{m\lambda L}{w} \right) \quad where \ (m = \pm 1, \ \pm 2, \ \pm 3, \ \pm 4, \ ...)$$

Constructive Interference
If the path difference from one side of the slit is off by half a wave length (eg. $\lambda + \frac{1}{2}$, $\lambda - \frac{1}{2}$, ...), then there will be constructive interference.
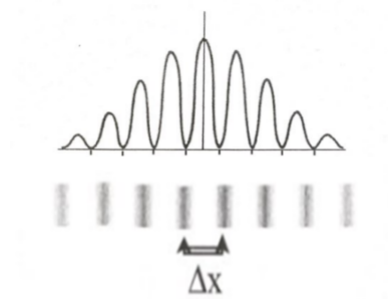
$$\therefore y_m = \left(\frac{(m + \frac{1}{2})\lambda L}{w} \right) \quad where \ (m = \pm 1, \ \pm 2, \ \pm 3, \ \pm 4, \ ...)$$
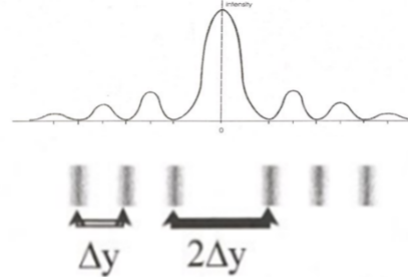

2.3 Patterns

The patterns below are the result of a single slit and a double slit. The intensity's of the fringes are also shown. The highest points of the intensities are called the maximas, and the lowest points of the intensities are called the minimas.

6

**Double Slit Pattern** $\Delta x = \frac{(\lambda)(d)}{L}$ **Single Slit Pattern** $\Delta y = \frac{(\lambda)(d)}{L}$

2.4 Diffraction

When a light wave passes through a narrow slit, the wave diffracts. This diffraction is only noticeable by the human eye when $\frac{\lambda}{d} \geq 1$

The interference pattern created by the single slit is from wavelets. The interference pattern created by the double slit is from the waves overlapping eachother, causing constructive and deconstructive interference.
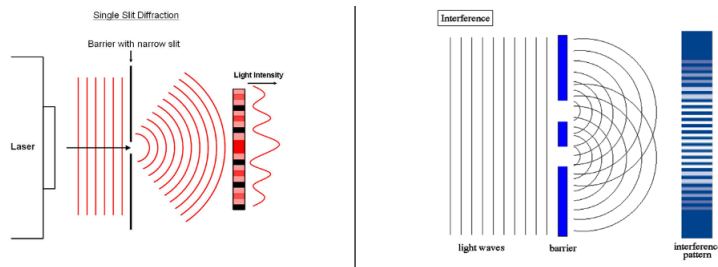

3 Diffraction Gratings

Young's Double Slit apparatus inspired the diffraction grating. The diffraction grating is a series of NUMEROUS slits (not just the two from young's "double" slit) that are very close together.

- Diffraction Gratings gave physisists a much more accurate measurement of the wavelength of the light source.

- The name "Diffraction Grating" comes from the fact that the light waves diffract when as they travel through the tiny slits cut into the apparatus.

- Holding a diffraction grating to a source of **white light** easily splits the light into a rainbow of colors.

- The patterns created by a diffraction grating still consist of maximas (bright regions / high intensities) and minimas (dark regions / low intensities) except the maximas become very narrow and well defined.

- Using monochromatic light you can see very distinct bright and dark fringes.

Image of Diffraction Grating: The light doesn't travel through the black lines. The light travels through the white lines. These lines act as mini slits.
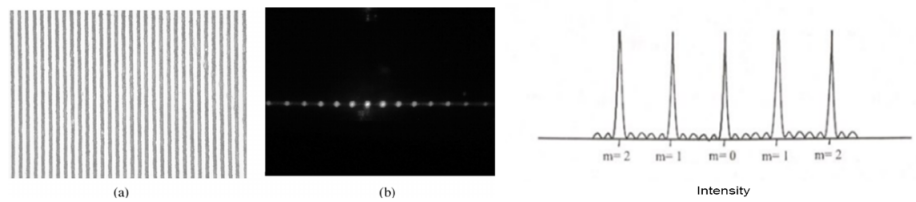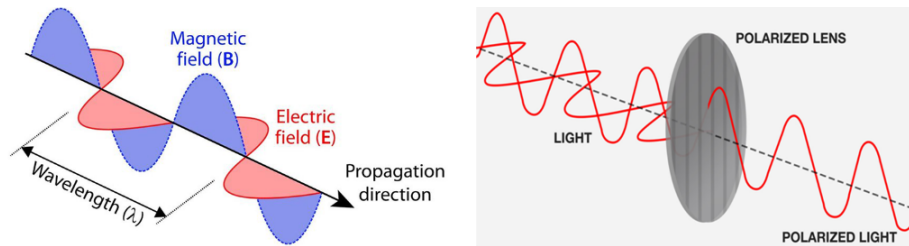

4 Polarization

Polarization is the splitting of waves into their components.

4.1 Components

Light waves have both vertical and horizontal components. The horizontal component is called the "electric field oscillation" and the vertical component is called the "magnetic field oscillation".

4.2 Lens

As a light wave travels through a polarized lens, either the magnetic field component or the electric field component is eliminated, leaving only one of the two components. For example, if you put together vertically polarized lens and a horizontally polarized lens in their corresponding directions, the light will not be able to move through the lens.

If you rotate one of the lens by 90°, the light will be able to pass through both of the lens since the polarized component is now the same as the other lens.

4.3 3D Glasses

When recording a 3D film, one camera records only the x components, and another camera records only the y components. Both cameras record at slightly different positions. When you put on the 3D Glasses (which have polarized lenses), each eye sees a different image. Your brain then tries to put together the image which creates the 3D effect.

4.4 Circular Polarization

A Circularly polarized wave radiates energy in a horizontal plane, vertical plane and any other possible plane. The reflection of electromagnetic (x) waves is a major factor in transmission and reception. Electromagnetic waves undergo multiple reflections before they're received at a receiver (antenna). In a linearly polarized antenna the signal is transmitted and received in only one plane.
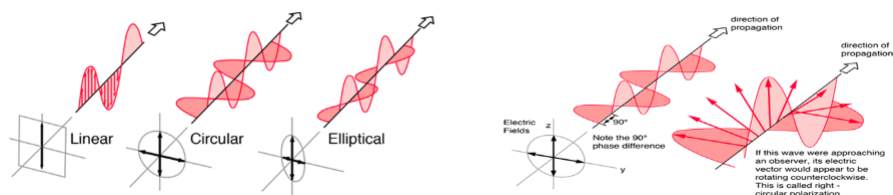
5 Double Slit Solve Example 1

Monochromatic light falls on two slits 0.024 mm apart. The fringes on a screen 3.00 m away are 6.7 cm apart. What is the wavelength of light?

Givens

- $d = 2.4 \times 20^{-5} \ m$

- $L = 3.00 \ m$

- $\Delta x = 6.7 \times 10^{-2} \ m$

Solve

To solve for the wavelength of the light, we can use the equation $\lambda = \left(\frac{(\Delta x)(d)}{L} \right)$ Our result should be in meters, but if converted, the result should be in nanometers.

$$\lambda = \left(\frac{(\Delta x)(d)}{L} \right) = \left(\frac{(6.7 \times 10^{-2})(2.4 \times 10^{-5})}{3.00} \right) \approx 5.20 \times 10^{-7} \ m$$

6 Double Slit Solve Example 2

A parallel beam of 700 nm light falls on two small slits 6.0×10^{-2} mm apart. How wide would a pattern of eight bright fringes be on a screen 3.0 m away?

Givens

- $d = 6.0 \times 10^{-5} \ m$

- $\lambda = 7.0 \times 10^{-7} \ m$

- $L = 3.0 \ m$

Solve

To solve for the width of the pattern of eight bright fringes, we must first solve for the distance between two (Δx). After solving for Δx we can multiply it's value by eight to get the final distance.

$$\Delta x = \frac{(\lambda)(L)}{d} = \left(\frac{(7.0 \times 10^{-7})(3.0)}{6.0 \times 10^{-5}} \right) \approx 3.5 \times 10^{-2} \ m$$

$$\therefore \ (8)\Delta x = (8)(3.5 \times 10^{-2}) \approx 2.8 \times 10^{-1}$$

7 Single Slit Solve Example 1

How wide is the central diffraction peak on a screen 2.50 m behind a 0.0212 mm wide slit illuminated by 550 nm light?

Givens

- $L = 2.50 \ m$

- $d = 2.12 \times 10^{-5} \ m$

- $\lambda = 5.5 \times 10^{-7} \ m$

Solve

To solve for the width of the central maxima we use a formula very similar to the one used in the double slit calculations: $\Delta y = \left(\frac{(\lambda)(L)}{d} \right)$ Where Δy is the width of the central maxima.

$$\therefore \ \Delta y = \left(\frac{(\lambda)(L)}{d} \right) = \left(\frac{(5.5 \times 10^{-7})(2.50)}{2.12 \times 10^{-5}} \right) \approx 6.5 \times 10^{-2} \ m$$

8 Single Slit Solve Example 2

How wide is a slit if it diffracts 690 nm light so that its central peak is 3.0 cm wide on a screen 2.80 m away?

Givens

- $L = 2.80 \ m$

- $\Delta y = 3.0 \times 10^{-2} \ m$

- $\lambda = 6.9 \times 10^{-7} \ m$

Solve

To solve for the width of the single slit we can rearrange the formula from the solve above. $\Delta y = \left(\frac{(\lambda)(L)}{d} \right) \rightarrow d = \left(\frac{(\lambda)(L)}{\Delta y} \right).$

$$\therefore \ \ d = \left(\frac{(\lambda)(L)}{\Delta y} \right) = \left(\frac{(6.9 \times 10^{-7})(2.80)}{3.0 \times 10^{-2}} \right) \approx 6.44 \times 10^{-5} \ m$$