Phys 112 2019

Lecture 27

Mon: Warm Up 11

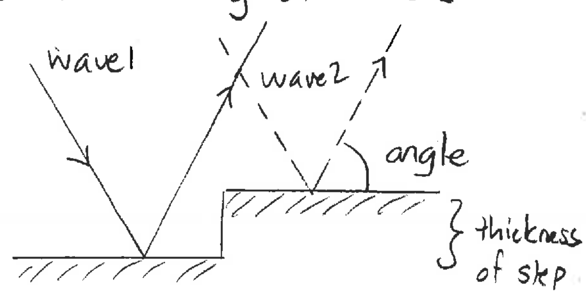
Tues: Discussion /quiz

Interference by reflection

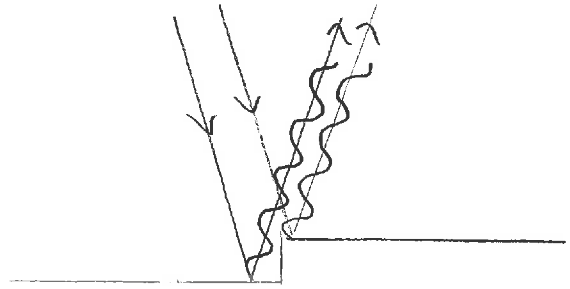
Various optical phenomena can be explained in terms of interference with the presence of double or multiple slits

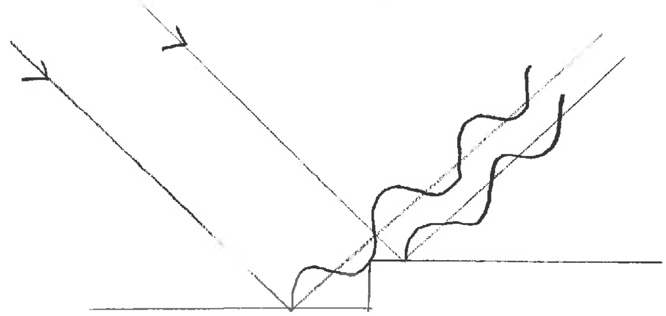
Demo: U Hanover

In these situations there are multiple reflections occurring off various surfaces. We can explain this in terms of reflections off the various surfaces. These will produce two or more reflected waves. The diagram illustrates



that the waves will travel different distances. Therefore they will be shifted relative to each other. Such shifts will produce interference. Constructive interference occurs when the shift is a multiple of the wavelength of the light. Thus at one particular angle a certain wavelength will produce constructive interference. At a different angle another wavelength will produce constructive interference. So we will obtain a rainbow type of pattern

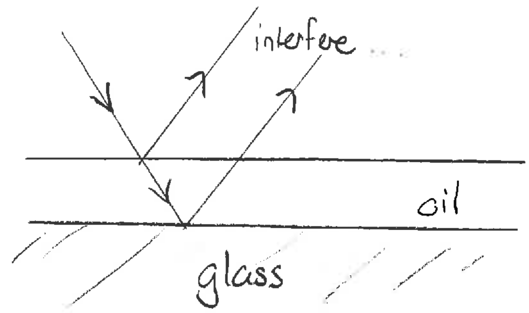




Shorter wavelength interferes constructively - longer does not
⇒ blue dominant

longer wavelength interferes constructively - shorter does not
⇒ red dominant.

The same phenomenon occurs when a thin transparent film covers a surface. There will be multiple reflections and these can be analyzed in the same way as above



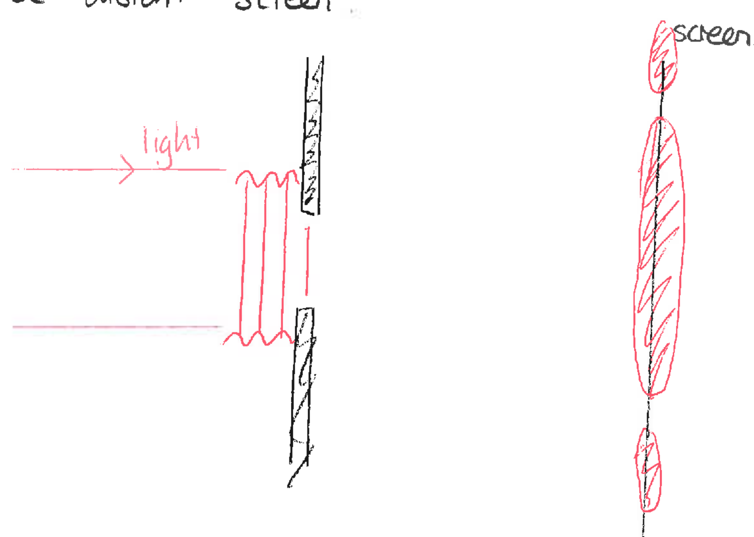
Demo: Hyperphysics

Demo: UNSW Physclips → Interference → Newton's rings

Single slit diffraction

Consider light (or any other wave) passing through one slit. What will be observed on a distant screen.

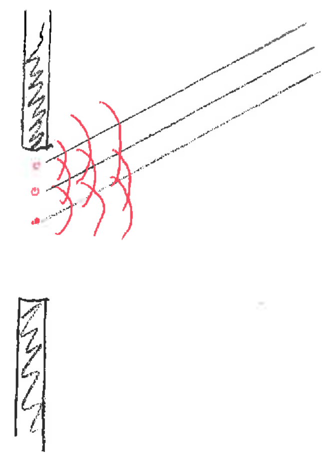
The first observation is that waves can bend around any opening.



Demo: Google water wave diffraction images

Demo Laser / single slit

The explanation for this is that each point within the opening produces a circular wave. There are then infinitely many overlapping waves traveling toward the screen. It turns out that it is easiest to determine the location of the dark fringes. Typically there are multiple waves shift relative to each other by small amounts



Demo: Slides on single slit interference

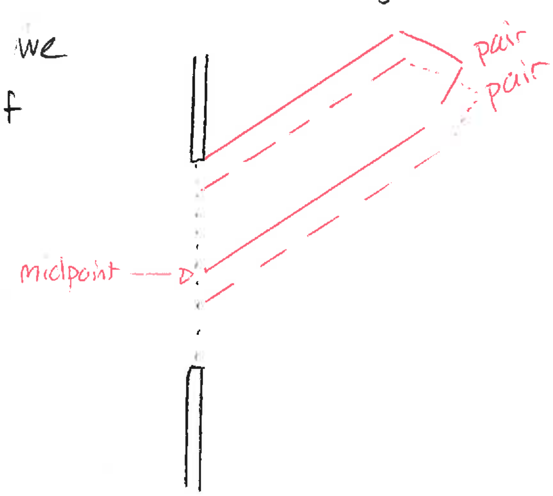
Consider twelve waves each shifted by $\Delta r = \lambda/12$.

wave #	1	2	3	4	5	6	7	8	9	......	12
shift from wave 1	0	$\lambda/12$	$2\lambda/12$	$\frac{3\lambda}{12}$	$\frac{4\lambda}{12}$	$\frac{5\lambda}{12}$	$\frac{6\lambda}{12}$	$\frac{7\lambda}{12}$	$\frac{8\lambda}{12}$		$\frac{11\lambda}{12}$

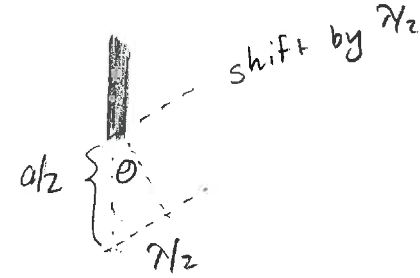
differ by $\lambda/2$ ⇒ wave 1 cancels wave 7

differ by $\lambda/2$ ⇒ wave 2 cancels wave 8 ...

So if we can pair waves like this we can get perfect cancellation. So for the single slit we can pair the waves as illustrated. If each pair, Whenever every pair is shifted by exactly $\lambda/2$ then there will be destructive interference

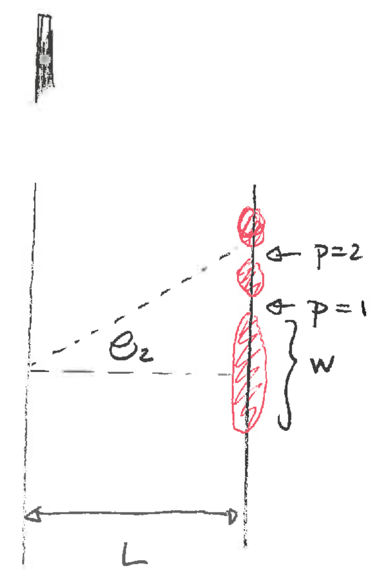


Let a be the slit width. Then we get perfect destructive interference when



$$\lambda/2 = a/2 \sin\theta$$

In general if we label the dark fringes with $p = 1, 2, 3, \ldots$ Then



> Dark fringes are located at θ_p such that
>
> $$a \sin\theta_p = p\lambda$$
>
> where $p = \pm 1, \pm 2, \ldots$

The central bright fringe is called the central maximum and its width is given approximately by

$$w = 2\frac{\lambda L}{a}$$

if $w \ll L$.

Quiz 1

Example: Light with wavelength 650nm is incident on a single slit. The light produces a pattern on a screen 0.80m away. The central maximum is 1.75cm wide. Determine the slit width

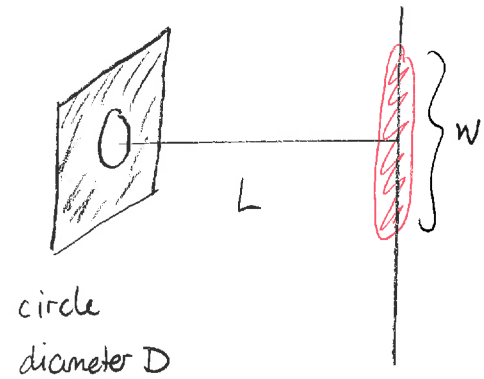
Answer: $w = 2\frac{\lambda L}{a} \Rightarrow wa = 2\lambda L \Rightarrow a = \frac{2\lambda L}{w}$

$$\Rightarrow a = \frac{2 \times 650 \times 10^{-9} m \times 0.80 m}{0.0175 m} = 5.9 \times 10^{-5} m = 59 \mu m.$$

Circular openings

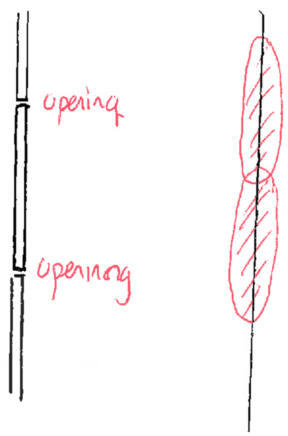
A circular opening will also produce a diffraction pattern. A mathematical analysis gives:

$$W \cong 2.44 \frac{\lambda L}{D}$$



Demo Hyperphysics

This has implications for imaging as small apertures and sources will produce diffraction patterns that can overlap and produce poor image resolution



overlapping images - how many openings?

Quiz 2

Demo: Poisson spot