Phys 132 2022

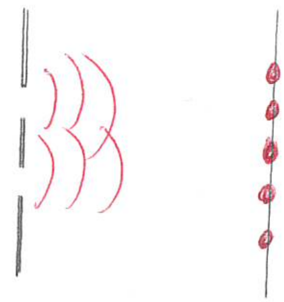
Lecture 132

Weds: Discussion /quiz

Ex 201, 202, 205, 206, 208, 209, 210, 211

Thurs: Warm Up 13

Interference of light



The double slit interference pattern indicates that light at least partly behaves as a wave. In this case

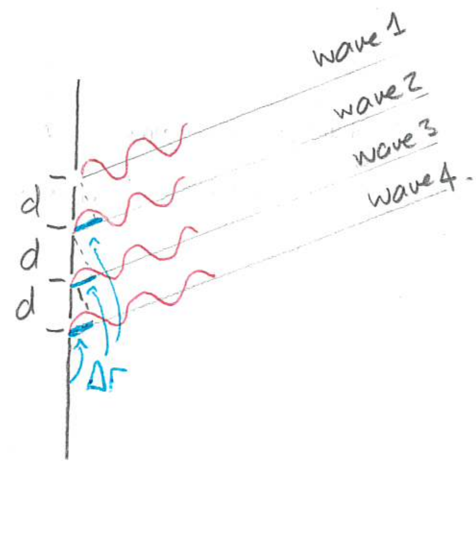
bright fringes ⟶ constructive interference $\Delta r = 0, \lambda, 2\lambda$

dark fringes ⟶ destructive interference $\Delta r = \frac{\lambda}{2}, \frac{3\lambda}{2}, \ldots$

Between these extremes there will be intermediate types of interference resulting in intermediate intensities.

We note that with a typical double slit, there is a pattern superimposed on the idealized pattern. Why is this? What happens when there are more than two slits?

Multiple slit interference



Consider a four-slit barrier, where the slits are equally spaced. Then there will be four waves that interfere. We can analyze this interference in terms of

Δr = extra distance for wave 4 vs 3

Δr = " " " wave 3 vs 2

Δr = " " " wave 2 vs 1

We would then be adding four such shifted sinusoidal functions. There is a maximal interference condition which we can easily assess. We need to consider the relative shift between all four waves.

Quiz 1 70% - 100%

Clearly if

wave 1, 2 relative shift $= \Delta r$

wave 2, 3 " " $= \Delta r$

then

wave 1, 3 " " $= 2\Delta r$ etc,...

In such a case all four waves add constructively. So if $\Delta r = \lambda$ the we still get a bright fringe. This is the same as for a double slit.

Slide 1

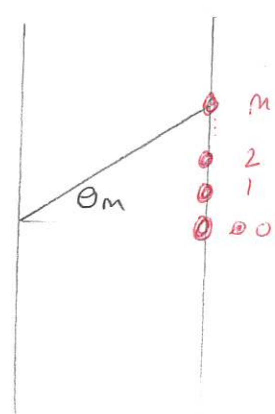
The same applies when $\Delta r = m\lambda$ for any integer m. Thus.

For a four slit barrier there will be bright fringes at angles θ_m given by

$$d \sin \theta_m = m\lambda$$

for $m = 0, 1, 2, \ldots$ Here d is the spacing between adjacent slits

We can consider other angles.



Quiz 2 50% - 80%

Thus when the separation between adjacent waves is $\Delta r = \lambda/2$ there will be perfect destructive interference and a dark fringe. These two results are the same for double slits

Slide 2

Now consider an intermediate angle

Quiz 3 60% –

Slide 3

The relative shift by $\Delta r = \lambda/4$ also gives perfect cancellation. It did not for a double slit. Comparing gives:

Relative shift	Angle condition	Double Slit	Four slits.
$\Delta r = 0, \lambda, 2\lambda, \ldots$	$d \sin\theta = m\lambda$	bright	bright
$\Delta r = \frac{\lambda}{2}, \frac{3\lambda}{2}, \ldots$	$d \sin\theta = \frac{\lambda}{2}, \frac{3\lambda}{2}, \ldots$	dark	dark.
$\Delta r = \frac{\lambda}{4}, \frac{5\lambda}{4}, \ldots$	$d \sin\theta = \frac{\lambda}{4}, \frac{5\lambda}{4}, \ldots$	intermediate.	dark
$\Delta r = \frac{3\lambda}{4}, \frac{7\lambda}{4}, \ldots$	$d \sin\theta = \frac{3\lambda}{4}, \frac{5\lambda}{4}, \ldots$	intermediate	dark

Thus the four slit pattern produces intermediate dark fringes where these would not have existed in a two slit pattern.

Slide 4

We see that:

As more slits are added

1) the locations of the primary bright fringes are the same: $d \sin\theta_m = m\lambda$

2) There are increasing numbers of dark fringes between the maximum bright fringe locations. They are separated by secondary fringes

Diffraction grating

A diffraction grating is an extreme version in which there are thousands of parallel slits. Nearly every point on the screen will be dark except for a few bright points that are highly localized.

Since it is easy to locate the bright fringes with good precision, diffraction gratings are good for measuring wavelengths of light.

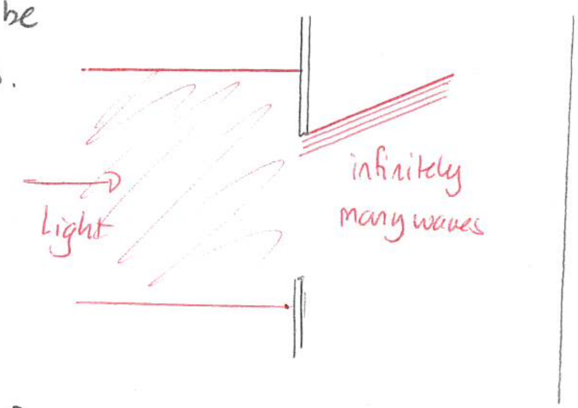
Quiz 4 10% –50%

Single slit diffraction

Why does the double slit pattern fade in and out? To answer this consider a single slit. Light passing through such a slit also displays interference effects – in this case diffraction. The origin of this is in the bending of waves around an opening.

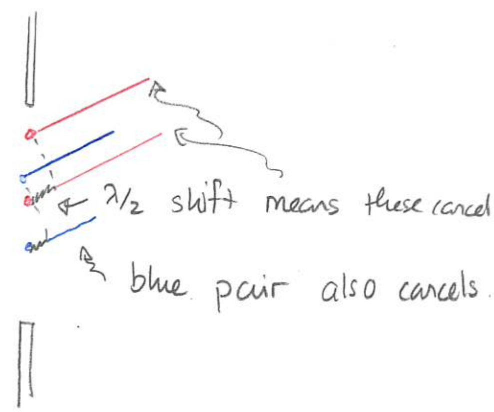
Demo: HMC image

We can explain this by assuming that one wave emanates from each point in the slit opening. There will be interference between infinitely many waves. We can describe when perfect cancellation occurs. To do this we need to "pair" waves that are shifted by an odd multiple of half a wave length. If every wave has such a partner then there will be perfect cancellation.

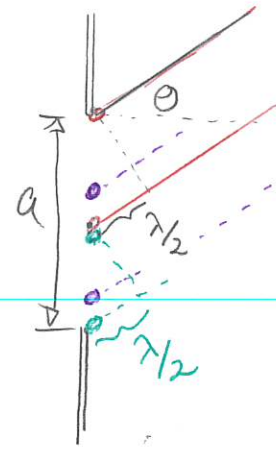


Perfect cancellation will occur when

All the waves can be paired, each with one partner shifted by $\lambda/2$



Now suppose that the slit width is a and we observe at angle θ. Perfect pairing will occur when the wave from the top and midpoint are shifted by $\lambda/2$. In this case the wave from the top and bottom are shifted by λ. Thus we get



$$a \sin\theta = \lambda$$

The same will occur when top and bottom are shifted by $p\lambda$ where $p = \pm1, \pm2, \ldots$ Thus we get

> For a single slit with width a, dark fringes occur when
>
> $$a \sin\theta_p = p\lambda$$
>
> and $p = \pm1, \pm2, \pm3, \ldots$