PH2233 Fox : Lecture 19
Chapter 35 : Diffraction

(NOTE : The first bits of this were done on Tuesday.)

Light (or any wave) passing through a small opening behaves very differently than if it were simply particles of light (photons) travelling a straight lines, and we'll find later that this impacts the resolution of telescopes and cameras (and our eyes), and also impacts things like how many pixels you actually 'need' in a phone or TV screen before you can't see the pixels anymore.

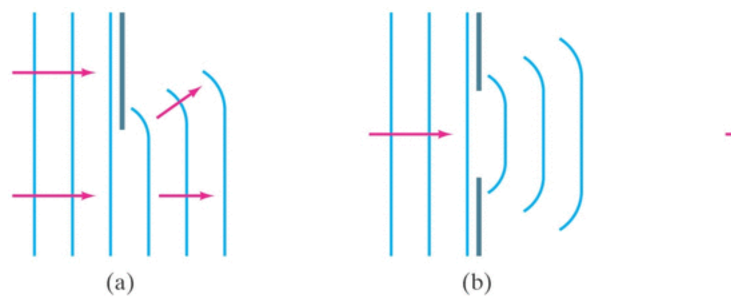
Please watch the first few minutes of this video, which shows waves passing through a narrow opening:

`https://www.youtube.com/watch?v=NazBRcMDOOo`

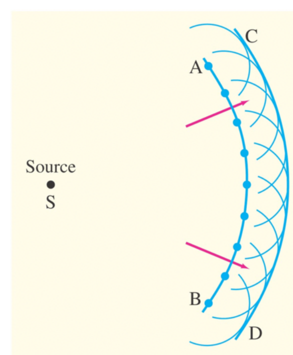
This short video shows actual water waves passing through single and double-slit openings in a barrier:

`https://www.youtube.com/watch?v=egRFqSKFmWQ`

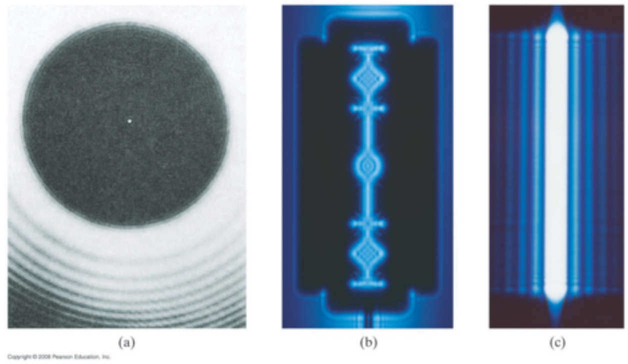
We see from the video and section 34.1 that the waves tend to spread out as they pass through the slit or hole ('aperture' is a good generic name).



The Huygen's Wavelet method (from chapter 34) is a good way to visualize what's going on. We essentially treat the wave front passing through the aperture as an infinite number of infinitesimally small sources: each point on the wave front becomes the source of a wave, and the combination of all these sources is what's producing the wavefront at some later point in time.



If we're treating the wave front passing through the aperture as a bunch of tiny sources, that means we have the possibility of the waves produced by all those sources interfering with one another, and that's exactly what happens:



On the left, we have a beam of light that's falling on a SOLID, opaque disk. If we let the light then fall on a screen or wall behind the disk, what do we see? Along with the round shadow we expect, we also see bright and dark fringes around the shadow, AND weirdly enough we see a tiny bright spot right in the middle of the shadow! How in the world is light reaching that point when it's completely blocked by the disk?

In the middle, light is shown through a razorblade and we see those little odd dark and light fringes.

On the right, the light is being sent through an opaque screen that has a tiny slit cut in it, again producing these extra bright and dark lines.

If the light were simply photons travelling in straight lines, we shouldn't see these fringes at all: a photon should either pass through the opening or not, so this is another case where light is behaving as a wave.

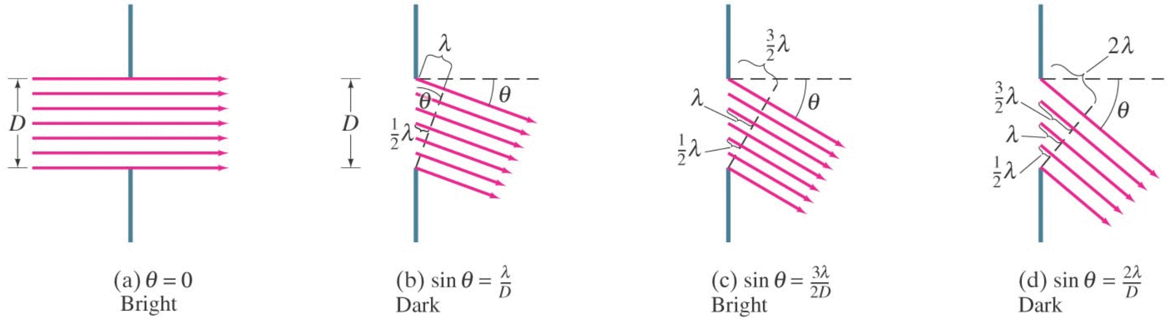
At Home Diffraction Experiment : If you hold two fingers up to your eye and open up a tiny slit between them (as small as you can so that the light just starts coming through), you'll see a number of thin dark fringes. This is another example of 'single slit' type diffraction.

Where are these fringes coming from?

This video from Khan Academy goes through the same process I'll cover, illustrating where (and why) constructive and destructive interference occurs:

`https://www.khanacademy.org/science/physics/light-waves/interference-of-light-waves/v/single-slit-interference?modal=1`

Essentially the light waves passing through the slit act (via Huygen's method) as an infinite number of infinitesimal wave sources, diffracting out in all directions to create the 'next' wave front. In any direction θ, think of these as an infinite number of sine waves, all slightly shifted from one another. There are going to be certain angles where they'll perfectly interfere destructively, and other angles where we'll have at least partial constructive interference, leading to this pattern of intensity as a function of the (sine of the) angle.

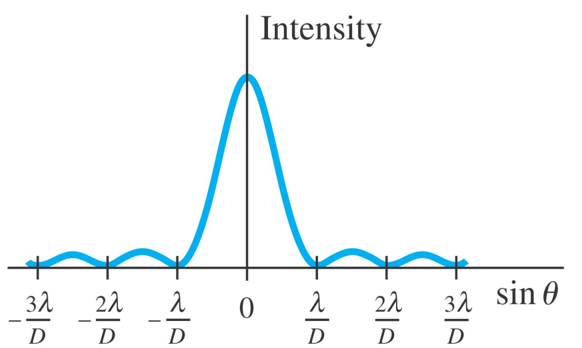


In the left figure, all the ‘rays’ from these sources will make it straight through the aperture, leading to a nice bright spot at $\theta = 0$.

In the second figure, we’re looking at an angle such that waves from the ‘top-most’ source has to travel exactly one wavelength further than waves from the bottom-most source. Pro-rating this extra pathlength, we see that the point-source right in the middle would have an extra path length of $\lambda/2$, which means the sine wave from that point will exactly cancel out the sine wave coming from the bottom-most point source. In fact we can ‘pair up’ all the sources in the same way yielding a net result of ZERO. If we look in a direction where $D \sin\theta = (1)(\lambda)$, we’ll see no light (or waves, or sound, or whatever other type of wave this is).

In the third figure, we increase the angle a little bit so that waves from the top source have to travel an extra 1.5λ relative to the bottom point source. If we equally divide the sources in thirds, we can again pair up sources in the bottom third with sources in the middle third and cancel all those out, but we’re still left with the sources in the top third. They’ll all be slightly out of phase with one another, but we’ll get **some** intensity still remaining at that angle.

I’m not going to go into too much gory detail with the hand-waving argument because we’ll look at the actual integral involved for the intensity as a function of angle next week. The result is this pattern:



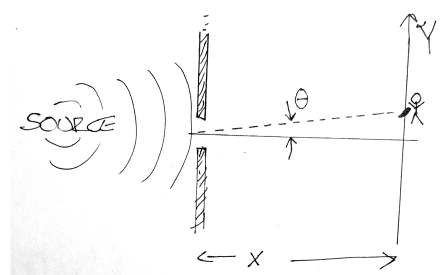
The result is that the angles where **complete destructive interference** occurs (zero intensity) are related to the wavelength λ and the width of the slit D by:

$\boxed{D \sin\theta = m\lambda \text{ for } m = \pm1, \pm2, \pm3, ...}$ (single slit; DARK angles)

Be careful here: $m = 0$ provides a PEAK of intensity, not a dead spot, so only the non-zero integer m values yields dead spots. (Also, this equation looks very much like our TWO SLIT equation, but in that case we had $d\sin\theta = m\lambda$ giving us the locations of the PEAKS (high intensity), instead of the dead spots we see in the SINGLE SLIT scenario.)

> **Example :** An aircraft maintenance technician walks past a tall (partly open) hangar door that acts like a single slit for sound entering the hangar. Outside the door, on a line perpendicular to the opening in the door, a jet engine makes a 600 Hz sound. At what angle with the door will the technician observe the first minimum in sound intensity if the vertical opening is 0.800 m wide and the speed of sound is 340 m/s?

The figure shows the situation looking down from above: we have the source of sound (the jet engine), the slit, and then somewhere on the other side of the opening we have the person hearing this sound. Let's extend the problem given and also ask for the physical locations (the Y coordinate) where these dead spots will be found if the path the person is taking runs parallel to the wall but 10 meters away from the opening.



The quiet spots will occur where the intensity drops to 0, meaning the points where we have complete destructive interference, and those occur when: $D\sin\theta = m\lambda$ for $m = \pm1, \pm2, \pm3, ...$

Here $D = 0.8\ m$ and we can determine the wavelength since $v = \lambda/T = \lambda f$ so $(340\ m/s) = (\lambda)(600\ s^{-1})$ from which $\lambda = 0.5667\ m$.

Destructive interference then will occur when $D\sin\theta = m\lambda$ or $(0.8\ m)\sin\theta = (m)(0.5667\ m$ or rearranging: $\sin\theta = (m)(0.5667/0.800) = (m)(0.708333...)$

Remember $m = 0$ (straight in front of the opening) will be a high intensity spot, so looking at the other possibilities: $m = 1$ yields $\sin\theta = 0.70833...$ or $\theta = 45.1^o$, $m = -1$ yields $\theta = -45.1^o$ and there aren't any other solutions since higher values of m give us a RHS that exceeds 1.00 and we can't do the inverse sine anymore.

If the path the person is taking is 10 m away from the wall with the opening, that means that physically the spots are located where $\tan\theta = y/x = y/(10\ m)$ so $y = (10\ m)\tan\theta$ and using the angles we just found that puts the dead spots at $y = \pm10.03\ m$.

Some final bits: the dead spots are located where $D\sin\theta = m\lambda$ (for non-zero integer values of m) or rearranging slightly: $\sin\theta = m\frac{\lambda}{D}$.

If the width of the slit D is actually any smaller than the wavelength λ, that fraction λ/D will be larger than 1 which means there won't be any solutions to that equation: there won't be any dead spots. Once the opening becomes small enough, the waves on the other side of the slit will just spread out as if the opening were a point source of the sound (or light, or whatever other waves we're dealing with).

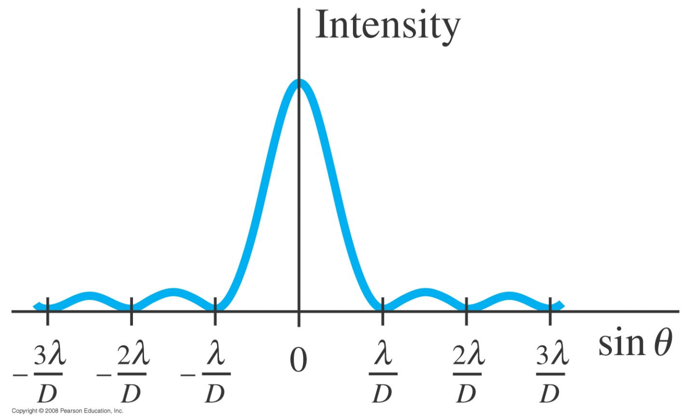
This diffraction effect is really only of interest when the opening is larger than the wavelength involved. That occurs at the macroscale all the time though: light landing on our retina has to pass through the pupil, in a camera the light passes through the lens on the way to the film or image sensor, and so on. We'll see the practical impact of this later in this chapter.

(35-8) Diffraction Grating (NOTE: already covered this a couple of days ago due to the lab schedule, so will just very briefly go over it in class.)

I've put some links on Canvas on diffraction gratings that cover the same material we'll be doing here:

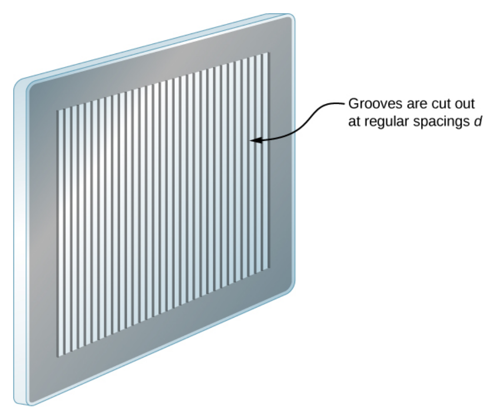
`https://www.khanacademy.org/science/physics/light-waves/interference-of-light-waves/v/diffraction-grating`

We saw that in the case of a single slit, we can reproduce the observed diffraction pattern by breaking up the waves passing through the slit into an infinite number of infinitesimal sources and then pairing them up to determine the angles where perfect destructive interference would occur. The resulting intensity pattern is not very sharp though, which makes it difficult to make actual measurements.



Single Slit Intensity

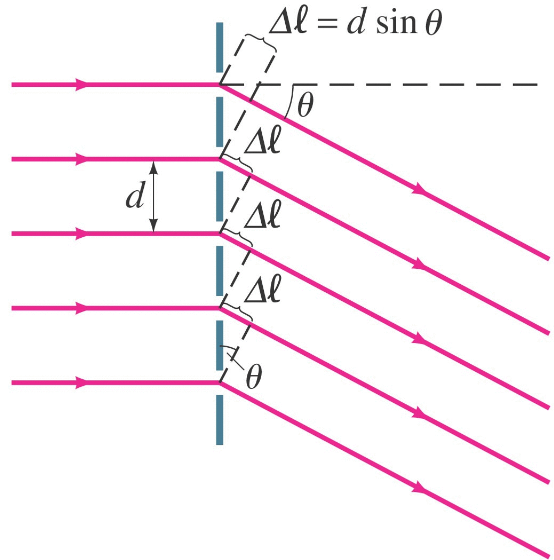
What if we construct a situation where we actually **do** have a huge number of sources. This is a **diffraction grating**. It looks nearly transparent, but is actually tens of thousands of tiny parallel slits. These are created photographically by drawing tens of thousands of parallel dark lines with a tiny separation between each line, then shrinking down the image. This particular grating has 1000 lines **per millimeter**, and in between each line there is a slit, so each little slit is a thousandth of a millimeter from the next one.



If we let light pass through this grating, each slit will act as a source, just like we had with the double-slit (aka two-source) interference situation. That means there will be special angles where (in this case) constructive interference will occur.

(NOTE the label on the slide that reads 1000 *lines/mm*. That's a thousand parallel lines in each single millimeter across the slide. These have to be made using a photographic process.)

We need to limit our attention to the **far field** again. We need to do that so that we can draw all our 'rays' as if they're parallel to one another, making it easy to compute the extra path lengths involved. So here, we're going to examine the interference on a screen that is 'far away' relative to the size of the grating. This particular grating is a few cm in size, so we'll want to be at least 10 or 20 times that (maybe a meter) away to maximize this effect.)



If we look at the light diffracted through each slit heading off at some angle θ, then we see that each 'ray' travels an extra $d \sin\theta$ farther than the next ray down in the figure.

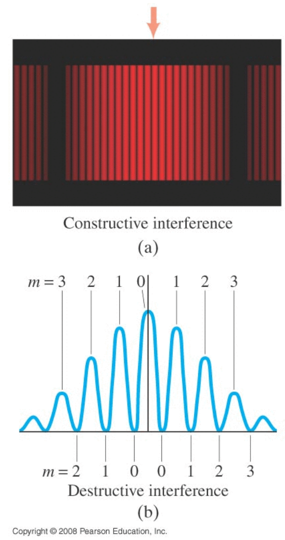
CONVENTION : for the single slit geometry, this book used a capital D to represent the width of the slit. For this many-slit diffraction grating type of geometry, the parameter d (lower case) is used to represent the physical distance from the center of one slit to the center of the next slit. If we have 1000 $lines/mm$, then each line is a thousandth of a millimeter from the next, so the slit-to-slit distance for this diffraction grating will be $d = 0.001\ mm$. Note that we basically just inverted the $lines/mm$ value. 1000 $lines/mm$ means we have 0.001 $mm/line$: each line (and thus each slit) is 0.001 mm from it's neighbor.

Referring back to the figure then, if we rig the angle so that the extra path length on each ray is exactly an integer multiple of the wavelength, every one of these tens of thousands of 'sources' will arrive at the screen in phase with one another. That means we'll have **constructive** interference at every angle where:

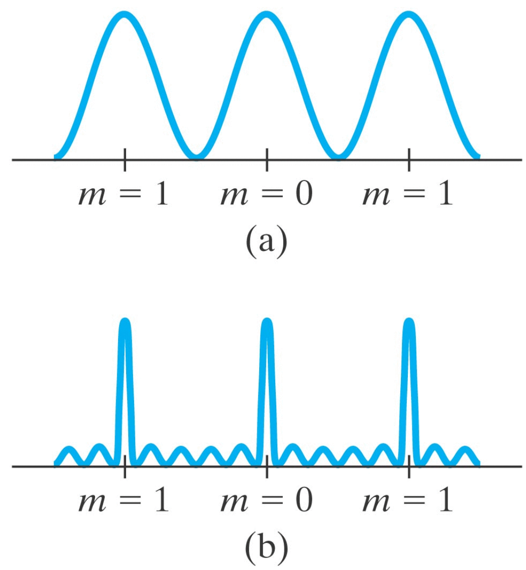
$$\boxed{d \sin\theta = m\lambda \text{ for } m = 0, \pm1, \pm2, ...} \quad \text{Diffraction Grating (bright spots; far field)}$$

WARNING : we've encountered three far-field interference situations now: double slit (2 source, in general), single slit, and now diffraction grating, and all three have very similar looking equations, so it's important to know what situation we are in to know which to use and what it represents.

TWO-SOURCE INTENSITY : When we looked at 2-source interference (two sources separated by a distance d, see section 34-3 in the text book, in particular Figure 34-7), we found that when $d \sin\theta = m\lambda$ (all m), one 'ray' travelled exactly an integer number of wavelengths farther than the other, so the two sine waves arrive in phase and create a bright spot (or loud sound, or high intensity water wave, etc, depending on whatever wave type we were dealing with). When $d \sin\theta = (m + \frac{1}{2})\lambda$, one of the waves was exactly 1/2 a wavelength delayed so the result was the sum of a sine wave and a sine wave shifted by exactly half it's length, resulting in perfect cancellation. Anywhere between those two sets of angles, we have two sine waves at some other shift and the result was that we had an intensity between 0 and it's maximum value.



DIFFRACTION GRATING INTENSITY : This isn't the full story, but for now let's make an initial look at what happens when we're not adding just TWO sine waves, but more. We know that for a diffraction grating, when $d \sin\theta = m\lambda$ we'll have a strong signal (all the waves are arriving in phase) but what about angles in between? We're basically now adding not just 2 sine waves that are out of phase, but many. This figure shows the result of varying the viewing angle or screen position continuously and then adding up the resulting actual sine waves, accounting for the slight delays each has relative to the previous. The top figure is for when we only have two sources, the bottom is for 6 sources. As the number of sources increases, we have more and more cancellation when we add all those shifted sine waves, except at the special spots where $d \sin\theta = m\lambda$ (at the special angles where all the waves arrive in phase).



The result is that a diffraction grating creates a very sharp pattern on the screen: very bright spots right where constructive interference of all the tens of thousands of rays arrive in sync, and almost nothing in between those sharp spots, making the locations of the spots very easy to measure.

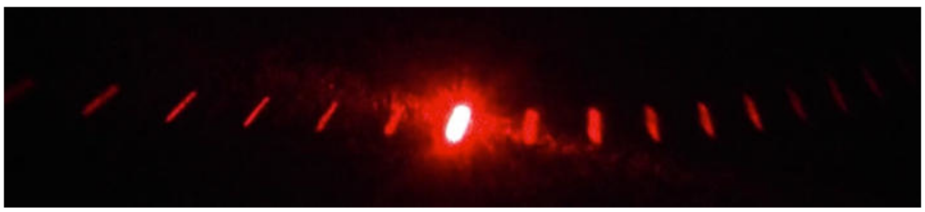
Class Demo : In glass, I pointed a helium-neon laser emitting a red beam with $\lambda = 632.8\ nm$ at one of these 1000 $lines/mm$ diffraction grating slides.

The spacing between the openings would be 0.001 mm or $1 \times 10^{-6}\ m$ or 1000 nm, so we should see bright red spots where:

$$d \sin\theta = m\lambda \text{ or where } \sin\theta = (m)\frac{\lambda}{d} = (m)(0.6328)$$

$m = 0$ works, so we see a bright line at $\theta = 0$ (the laser passing straight through the grating).

$m = \pm 1$ yields $\theta = \pm 39.26^o$, and any higher m values yields a RHS larger than 1 so we can't do the inverse sine step anymore. We should (and did) see the one line in the middle and one additional line on each side, about that far angularly away from the central spot.



In this figure, there are many more bright lines than what we saw in class. If the same $\lambda = 632.8\ nm$ laser produced this, what can we say about the line spacing for **this** diffraction grating? Does it have more or fewer lines per millimeter?

$\sin\theta = (m)\frac{\lambda}{d}$ so the only way for this to have additional solutions if for the λ/d factor to be smaller (so we can still multiply it by a larger m value and be able to get a solution). That means we need a larger d value - a larger distance from one slit to the next, which means **fewer** slits per millimeter. We can see at least 8 lines on each side of the central bright line so we have to be able to multiply by at least 8 and still get a solution. The slit separation d has to be at least 8 times larger than λ (at least $d = (8)(632.8\ nm) = 5062\ nm$ per slit). That's about 5 times what the filter in class had, so the filter that made this picture has to have at least 5 times fewer lines/mm, or less than 200 $lines/mm$.

$\boxed{\textbf{Example : Visible Light Spectrum}}$: Let's use the 1000 $lines/mm$ grating mentioned at the beginning and see what happens to visible light wavelengths passing through it. We have 1000 $slits/mm$, so the slits are separated by 0.001 mm (a thousandth of a millimeter), making $d = (0.001\ mm) \times \frac{1\ m}{1000\ mm} = 1 \times 10^{-6}\ m$. We usually work with visible light in units of nanometers, so let's convert d to nanometers: $d = (1 \times 10^{-6}\ m) \times \frac{1\ nm}{1 \times 10^{-9}\ m} = 1000\ nm$.

Our slit separation here is $d = 1000\ nm$.

For a wavelength λ, the **bright** (constructive interference) angles will occur at $d \sin\theta = m\lambda$ or $\sin\theta = m\frac{\lambda}{d}$.

Let's see what this diffraction grating does to visible light by using wavelengths at the ends of the visible light spectrum, which roughly covers wavelengths from 400 nm (violet) to about 700 nm (red).

Violet end of spectrum

- $\lambda = 400\ nm$ so peaks will form at $\sin\theta = (m)\frac{400\ nm}{1000\ nm} = (0.4)(m)$.
- $m = 0$ yields $\theta = 0$ so this violet light will fall in the center of the pattern on the screen
- $m = \pm 1$ yields $\sin\theta = \pm 0.4$ or $\theta = \pm 23.6^o$
- $m = \pm 2$ yields $\sin\theta = \pm 0.8$ or $\theta = \pm 53.1^o$
- $m = \pm 3$ yields $\sin\theta = \pm 1.2$ which has no solution; same with any higher m values

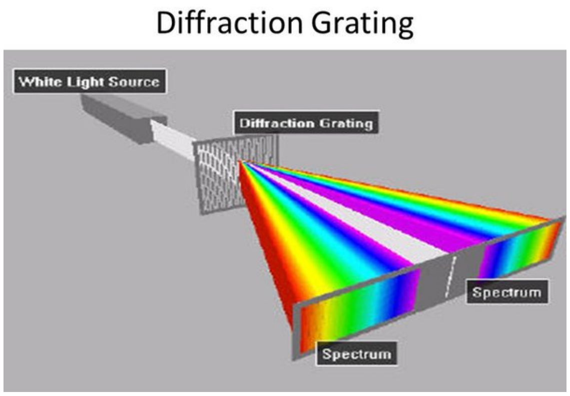
Red end of spectrum

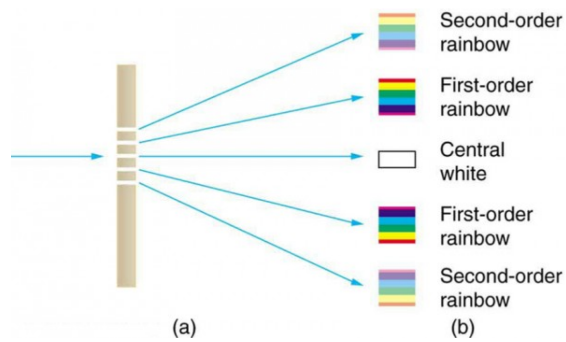
- $\lambda = 750\ nm$ so peaks will form at $\sin\theta = (m)\frac{750\ nm}{1000\ nm} = (0.75)(m)$.
- $m = 0$ yields $\theta = 0$ so this red light will fall in the center of the pattern on the screen
- $m = \pm 1$ yields $\sin\theta = \pm 0.75$ or $\theta = \pm 48.59^o$
- $m = \pm 2$ yields $\sin\theta = \pm 1.5$ which has no solution; same with any higher m values

Note that's happening here:

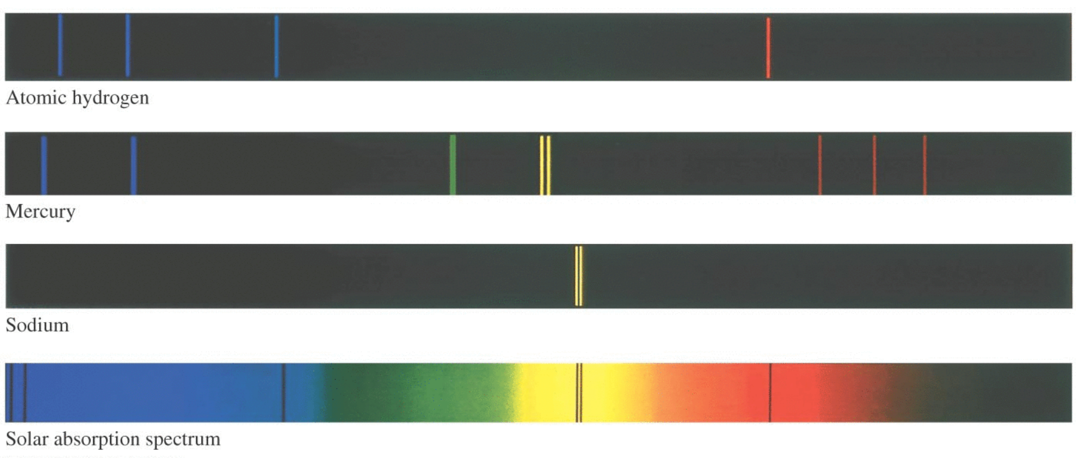
- All wavelengths will have a peak at 0^o : they all land on top of one another there
- The $m = 1$ case spreads visible light between 23.6^o and 48.59^o
- The $m = 2$ case 'starts' at 53.1^o, so doesn't overlap with the range of angles 'used' by the $m = 1$ case.

Thus if we send light from a white light source (an incandescent lightbulb perhaps) that spans the entire visible spectrum, each wavelength in the light will constructively interfere at particular angles, but the entire spectrum will spread out over a range (here 23.6^o to 48.59^o), and then we'll get a second copy of that spectrum that doesn't start until 53.1^o and therefore doesn't overlap with the first copy.

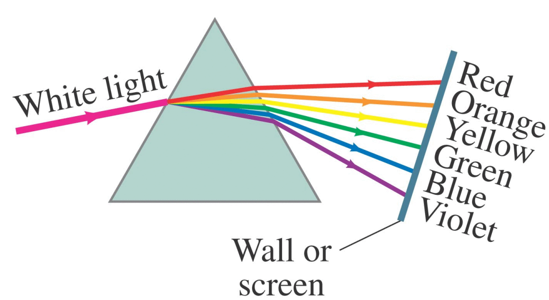




More importantly, note that this gives us a new way to generate a **spectrum** of a light source and determine what wavelengths it contains. The figure below shows spectra for hydrogen, mercury and sodium. The bottom panel shows a spectrum of the Sun, which emits a continuous spectrum but notice that a few specific wavelengths are missing, representing wavelengths generated by the Sun that end up being absorbed by various atoms in the Sun's 'atmosphere' and don't reach us.

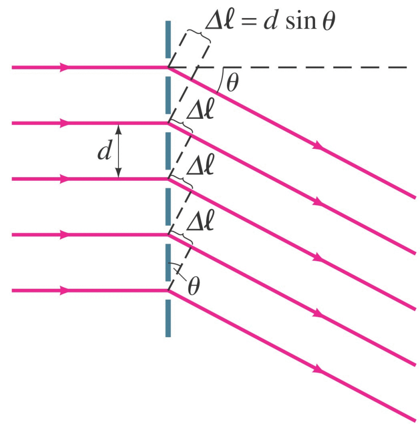


Back in chapter 32, we found that a **prism** can also be used to separate a light source into its different wavelength components. A super clear glass prism is almost certainly more expensive than the little diffraction grating slides though.



Example : Picket Fence and Sound

This is a general wave phenomenon and can occur with sound and water waves also. Let's borrow an earlier figure and say that over on the left we have a source of **sound** putting out a pure 6000 Hz tone. I'm over on the right listening and between me and the sound there is a tall picket fence where the gaps in the fence (the 'slits') are located 15 cm apart. At what angles relative to the normal will the sound be especially loud?



The fence has many openings, so we can treat this as a diffraction grating for sound waves, with a 'slit separation' distance (center of one gap to the center of the next gap) of $d = 15\ cm = 0.15\ m$.

We'll need the wavelength, but $v = \lambda/T = \lambda f$ so $\lambda = v/f$ and here we're dealing with sound, so let's say the speed of sound here is $v = 343\ m/s$.

$\lambda = v/f = (343\ m/s)/(6000\ s^{-1}) = 0.057167\ m$

The peaks (loud sound in this case) will occur when $d\sin\theta = m\lambda$ for all integer m values so $\sin\theta = m\frac{\lambda}{d} = (m)\frac{0.057167\ m}{0.15} = (m)(0.38111...)$.

$m = 0$ means $\theta = 0$ so if we stand such that a line from the speaker to our ears is perpendicular to the fence itself, it'll be loud - whether we can actually **see** the speaker or not! Even if there's a fence slat in the way, the sound is diffracting around it and all the other slats and those sine waves are constructively interfering when they arrive at our ears.

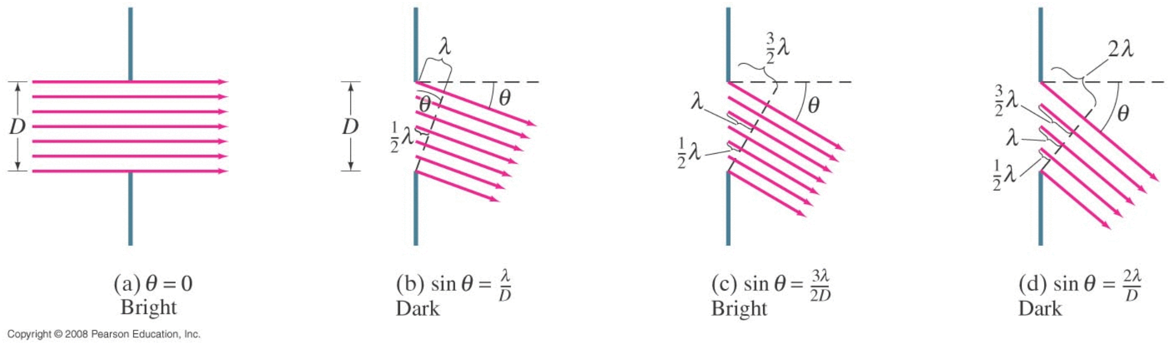
$m = \pm 1$ means $\sin\theta = \pm 0.38111$ or $\theta = \pm 22.4^o$. At that point the sound will be loud again (again, doesn't matter if we can see the speaker or not - the combination of all the sound diffracting through the openings is combining constructively at this angle). Finally, $m = \pm 2$ yields an angle of 49.7^o and any higher m values have no solution.

What other frequencies will we hear at that first location?

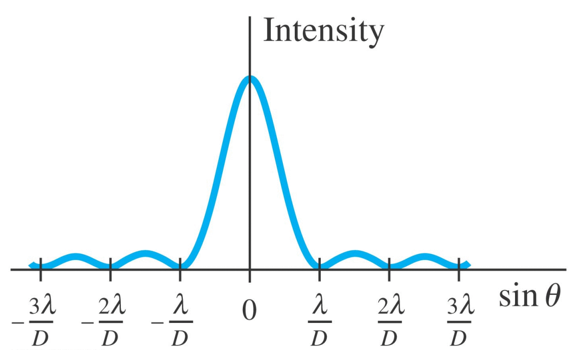
Peaks occur where $d\sin\theta = m\lambda$ for all integer m values, and $v = \lambda/T = \lambda f$ so $\lambda = v/f$ so we can rearrange this into: $f = (m)\frac{v}{d\sin\theta} = (m)\frac{343\ m/s}{(0.15\ m)\sin 22.4^o} = (m)(6000\ Hz)$ so looks like the only audible frequencies that will make it through the fence will be 6000 Hz, $12,000\ Hz$ and $18,000\ Hz$.

Appendix : Actual Single-slit diffraction intensity

Earlier, we hand-waved an argument to justify roughly what the intensity as a function of angle should be. We broke the wave front into an infinite number of infinitesimal sources and then 'paired-up' each source to see which ones would constructively or destructively interfere at what angles.



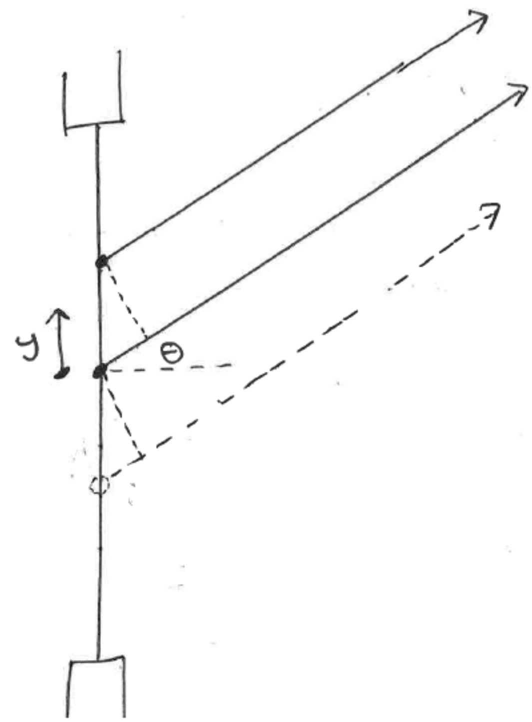
I claimed the actual result would look like this, so let's actually set up the integral involved here and see how this works. We'll end up with what's called the **sinc** function which occurs in various places, so it's worth showing how it appears.



Derivation of Single-Slit Intensity

(I didn't do this in class; you're welcome to skip this section but I'm leaving it here in case you're curious about how the integral is set up and handled.)

Plane waves coming in from the left in this figure pass through the slit of width D. We're going to calculate the actual intensity pattern seen on a screen far away, so we'll break the wave into an infinite number of infintesimal sources, each with an **amplitude** that is a sine wave wave with the same wavelength (frequency) as the actual wave and then sum up all those sine waves (accounting for the different path lengths each will take) at some point at θ. (Remember, we're in the 'far field' regime here, so the distance to the screen is far larger than the size of the slit, so all these rays are nearly parallel to one another.)
Let's put an origin $y = 0$ right at the midpoint of the slit and draw the ray that goes from that point to the screen. Above and below that, I've drawn two rays, each the same distance from the center point. The upper ray takes a path that is $y \sin\theta$ shorter than the ray in the middle; the lower (dotted) ray takes a path that is $y \sin\theta$ longer than the ray in the middle.



Each of these rays is basically a sine wave of (angular) frequency ω shifted by some phase, so they're all of the form $\sin(\omega t + \phi)$ where the phase shift ϕ will depend on y.

I know the **physical** path difference at a point y is $y \sin\theta$ but what **phase shift** does that represent? Well, a physical path difference of exactly one wavelength represents a phase shift of exactly 2π radians so we can just map the physical path difference into the equivalent phase shift: $\phi = (y \sin\theta) \times \frac{2\pi}{\lambda}$.

We can write this as $\phi = \alpha y$ where $\alpha = 2\pi \sin\theta / \lambda$.

Note that ϕ is directly proportional to y.

All these waves combine on the screen, so I'm going to want to sum them all up, that is integrate from $y = -D/2$ to $y = +D/2$. I'm not looking at the actual time-varying intensity though, just some overall RMS value, so let's expand out one of these sine waves:

$\sin(\omega t + \phi) = \sin(\omega t)\cos\phi + \cos(\omega t)\sin\phi$

Now as noted just above, ϕ is directly proportional to y, so when we integrate from $y = -D/2$ to $y = +D/2$ the integral of $\sin\phi$ will be zero since sine is an odd function that we're integrating over this range.

Ultimately then, the only integral we'll need to do is over $\cos\phi$ which will produce **something** and then when we look at the intensity represented by that resulting amplitude, we'll be doing an RMS which will eliminate the $\sin(\omega t)$ part of that term.

At the end of the day, I need to integrate $\cos\phi$ and then square it to get something that's proportional to the intensity.

The sum of all these phase-shifted sine waves when they combine on the screen will be the integral over all these, from $y = -D/2$ to $y = +D/2$, so:

$E \propto \int_{-D/2}^{D/2} \cos{(\alpha y)} dy$

(Our ultimate formula for $I(\theta)$ doesn't have an **actual** intensity in W/m^2 at each angle, it just relates the intensity to whatever the intensity at $\theta = 0$ is, so I'll toss out any constant multiplier that fall out in front of this integral, just keeping stuff involving the angle, the wavelength, and the slit size D.)

Now, the integral of $\cos{(\alpha y)}$ is just $\frac{1}{\alpha}\sin{(\alpha y)}$ and the limits of integration are $y = -D/2$ to $y = +D/2$ so we end up with something **proportional** to $\frac{\sin{(\alpha D/2)}}{\alpha}$ where remember $\alpha = 2\pi \sin\theta/\lambda$.

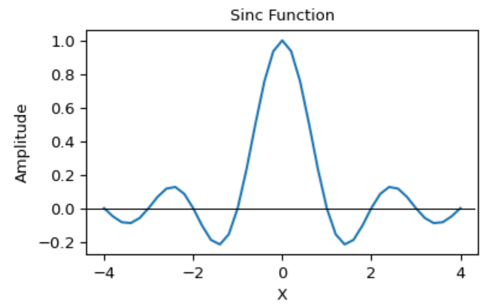
The book defines a new symbol $\beta = \alpha D = 2\pi D \sin\theta/\lambda$ so they can write this as $\sin{(\beta/2)}/(\beta/2)$. This is just (proportional to) the rms amplitude of the underlying wave that arrives at the screen, and the intensity will be the square of the amplitude, so the square of that blob, normalized so that the intensity as $\theta = 0$ is some value I_o.

SINGLE SLIT INTENSITY

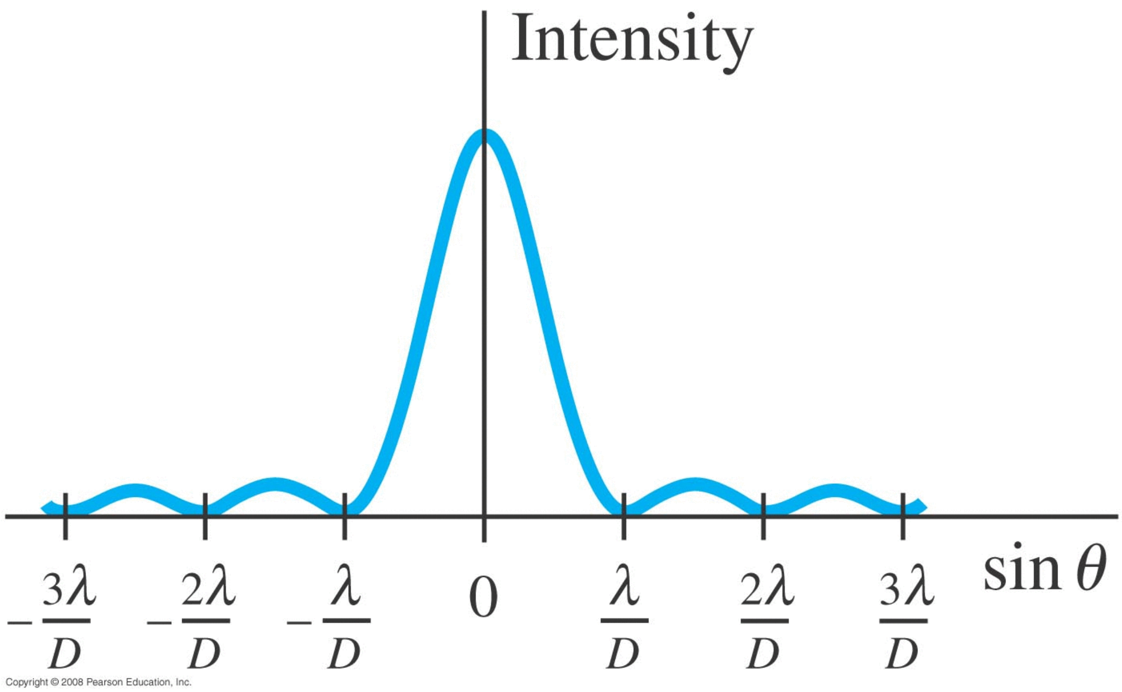
We broke our slit into an infinite number of infinitesimal sources, evenly dividing the total intensity among them. This will involve an in integral then, which results in an intensity pattern of (using the symbols as the textbook defines them):

$$\boxed{I(\theta) = I_o sinc^2(\beta/2)}$$

where $\boxed{sinc(x) = \frac{sin(x)}{x}}$ is called the 'sinc' function, and where $\beta = \frac{2\pi}{\lambda} D \sin\theta$.



$$\boxed{sinc(x) = \frac{\sin(x)}{x}}$$



Impact on Double-Slit and Gratings

In the double-slit scenario, we basically have two sources interfering with one another, but each of those sources is itself a single-slit.

In a diffraction grating, we have a vast number of sources but each of them is itself a single-slit.

The resulting diffraction patterns for both double-slit and diffraction gratings will show **both** effects. We see relative peaks where the 2 (or more) sources say they should be but an overall single-slit 'envelope' will also appear.

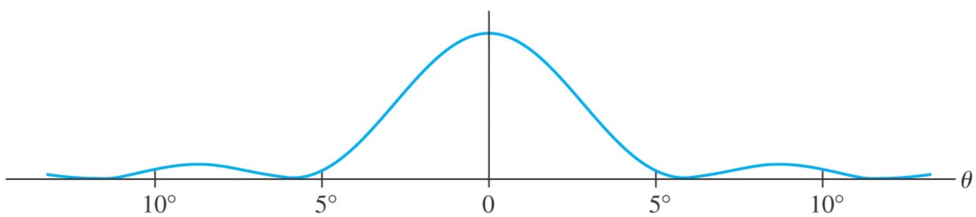
ACTUAL DOUBLE SLIT INTENSITY

Here we have light of some wavelength passing through two slits, each of width D and separated by a distance d, and this set of pictures was generated for $d = 6D = 60\lambda$, so each slit has a width of $D = 10\lambda$ and the two slits are then separated by $d = 60\lambda$.

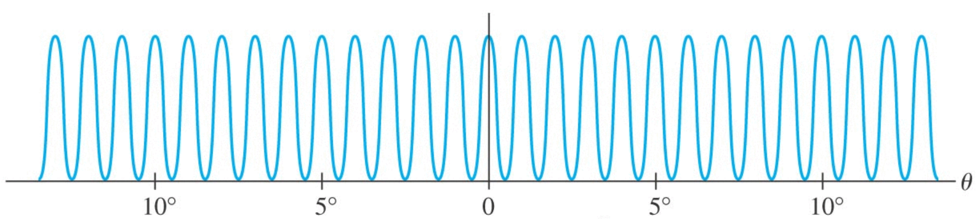
The top figure shows the resulting envelope of intensity that each single-slit is creating.

The middle figure is the ideal double-slit intensity (ignoring the single-slit diffraction effect).

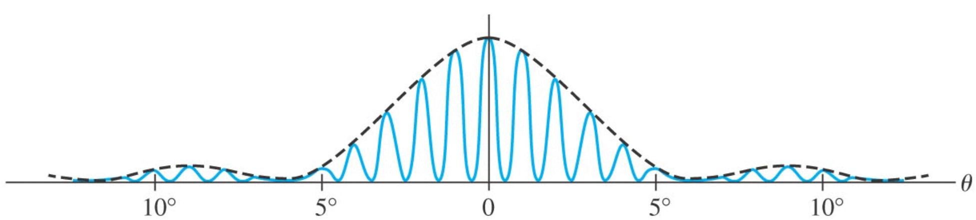
Finally, the bottom figure shows the actual diffraction pattern that will created.



(a) Diffraction factor, $(\sin^2\beta/2)/(\beta/2)^2$ vs. θ



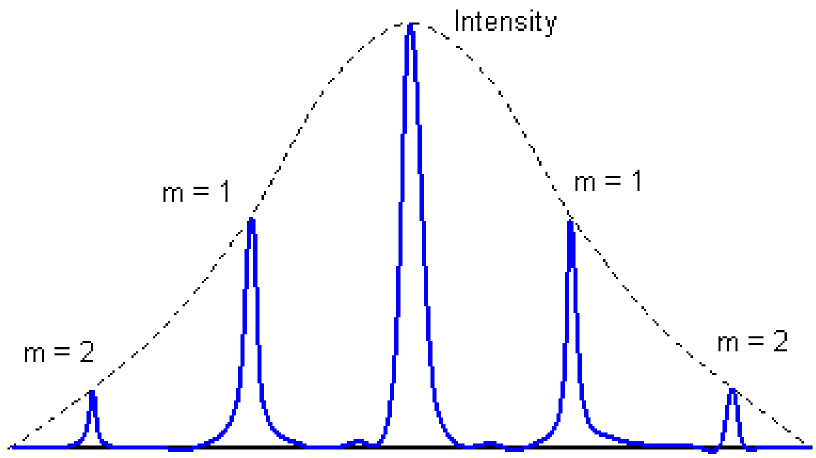
(b) Interference factor, $\cos^2 \dfrac{\delta}{2}$ vs. θ



(c) Intensity, I_θ vs. θ

ACTUAL DIFFRACTION GRATING INTENSITY

This affects the DIFFRACTION GRATING results as well. The ideal diffraction grating with equal peaks where $d \sin\theta = m\lambda$ gets that $sinc^2$ envelope that depends on the width of each individual slit.



One side effect of this is that when these are used as a spectrometer, the higher-order 'copies' of the spectrum can be much weaker (less bright) than the $m = 1$ version of the spectrum.