Physics 2c Lecture 30

Exam Preparation II

Examples we covered on Thursday:

- Degrees of freedom and the ideal gas law.
- Heat transfer.
- Macroscopic & microscopic states
- PV diagrams
- Reversible vs irreversible processes
- Latent heat, phase transitions
- Pumping water from wells and alike

More examples …

- Things that swim or sink
- Intensity vs distance for spherical waves
- Doppler effect
- Optical imaging and its properties
- Mirrors and lenses
- Refraction, Snell’s law & total internal reflection
- Standing waves at open and fixed boundary cond.

Things that swim or sink

- A 500g circular pan 20cm in diameter has straight sides 6cm high and is made from metal of negligible thickness. To what maximum depth can the pan be filled with water and still float on water? The density of water is 1g/cubic-cm.

What's a wave pulse?

A wave pulse is a superposition of many frequencies that
leads to a wave form that is localized in space rather than periodic.

What happens when a wave pulse travels from a medium with $n=1$
to a medium with $n=1.5$?

Intensity for spherical waves as a function of distance.

- How far do you have to go away from the source to experience a factor 2 drop in wave intensity?

Decibel

- Assume the intensity drops by a factor 2.
- What's the change in decibel?

$$\beta = 10\log\frac{I_{after}}{I_{before}} = 10\log\frac{1}{2}$$

$$\beta = -10\cdot 0.3 = -3$$

Doppler Effect

- You need to be able to apply the equations.
- Go through some simple examples, but also the radar gun example we talked about in class at some point.

Take a look at problems 59, 60, 77, and 79, 80 in the book.

Shock Waves

A supersonic plane is passing at Mach 2.2 right above you.

You hear the sonic boom 19s later. What is the plane's altitude assuming a constant 340m/s sound speed?

$$\theta = \sin^{-1}\left(\frac{1}{2.2}\right) = 27^o$$

$$h = u \cdot \Delta t \cdot \tan\theta = 2.2 \cdot 340 m/s \cdot 19 s \cdot \tan 27^o$$

$$h = 7.25 km$$

Lensmakers formula

$$\frac{1}{f} = (n-1)\left(\frac{1}{R_1} - \frac{1}{R_2}\right)$$

Snell's law

- Speed of wave changes as you cross medium boundary.
- Frequency of wave stays the same.
- Therefore, wavelength and angle of wave propagation change.

$$\mathbf{n_1 \sin theta_1 = n_2 \sin theta_2}$$

Total internal reflection

- Assume you are at the bottom of a 3m swimming pool. What’s the radius of the circle at the water surface that you can see through?
- Index of refraction for water = 1.333

Solution

$$n_1 = 1.33; n_2 = 1; \theta_2 = 90^\circ; h = 3m$$

$$\theta_1 = \sin^{-1}\frac{1}{1.33} = 48.8^\circ$$

$$R = h \cdot \tan\theta_1 = 3.4m$$

Standing waves

- Standing waves don’t propagate.
  - In what sense are they then waves?

- Organ pipes, string instruments, and other standing wave phenomena.
- What does it mean to have two instruments resonate with each other?

… and more examples

- Conditions for various interference effects
- Diffraction limit
- Polarization of light
- Radiation pressure

Summary of interference: Max, Min

- Simplest interference example: CD player
  - Phase difference due to path length difference!
- More complex examples of path length differences causing phase differences:
  - Double slit: **$d \sin\theta = m\lambda$** **---** **$d \sin\theta = (m+1/2)\,\lambda$**
  - Many slits, including diffraction gratings (measuring λ): **$d \sin\theta = m\lambda$**
    - Resolving power: $$\frac{\lambda}{\Delta\lambda} = mN$$
  - X-Ray diffraction (measuring Xtal spacing): **$2d \sin\theta = m\lambda$**
  - Michelson Interferometer (measuring length differences)
- Still more complex example including boundary and path length differences:
  - Thin films: **$2nd = (m+1/2)\,\lambda$** **---** **$2nd = m\,\lambda$**
- Single slit as a limit to angular resolution: **$\theta_{min} = 1.22\,\lambda/D$**

Crystallography

X-ray diffraction on Potassium Chloride (Kcl) results in a first-order maximum when X-rays of 97pm graze the crystal plane at 8.5 degrees.

What's the spacing between crystal planes?

Answer:

$$2d\sin\theta = m\lambda$$

$$d = \frac{\lambda}{2\sin 8.5^o} = 328\,pm$$

Separating "colors"

Take hydrogen lines: α = 656.3nm β = 486.1nm

Assume grating of 6000/cm.

What's the angular separation between m = 1 maxima ?

Answer:

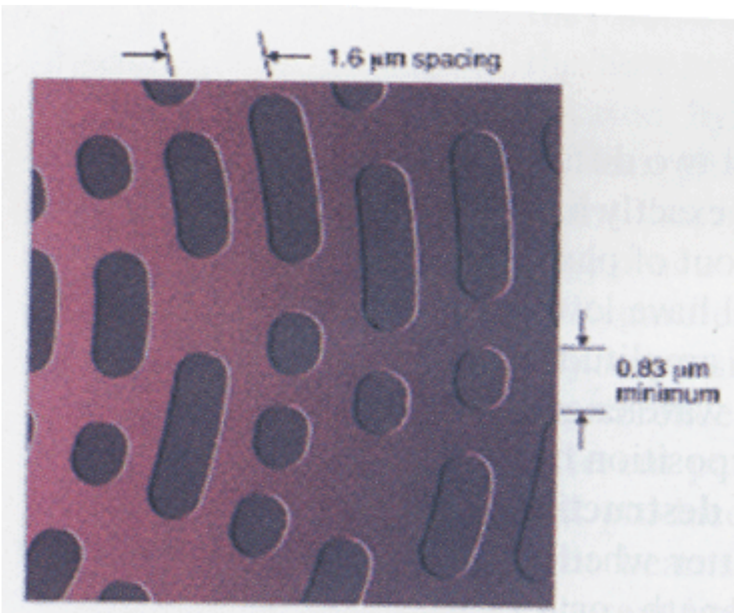
$$d \sin\theta_i = \lambda_i$$

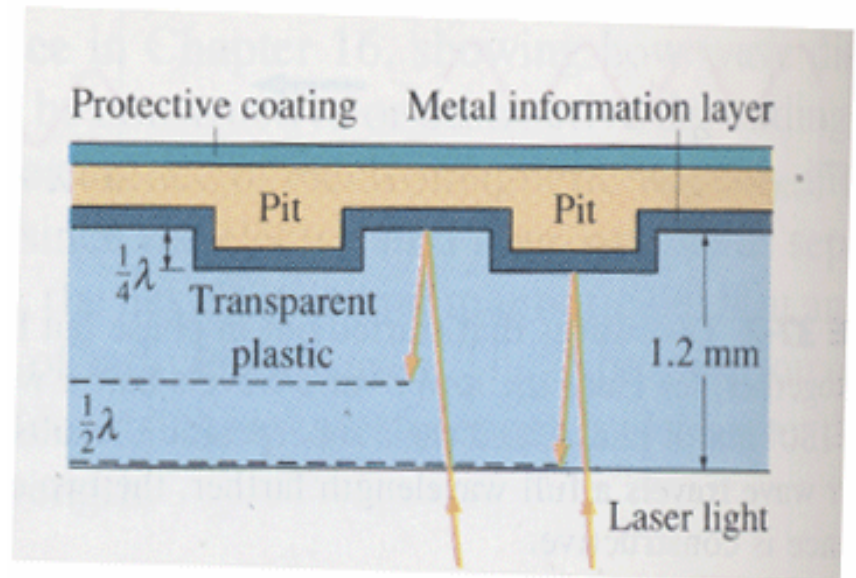
$$\theta_i = \sin^{-1}\frac{\lambda_i}{d}$$

$$\theta_{1\alpha} = 23.2^o$$

$$\theta_{1\beta} = 17.0^o$$

Example: CD player





Bits are encoded as ¼ wavelength deep depressions.
Laser beam overlaps track of bits, and interferes with itself.
Bits are thus observed as light intensity lows and highs.

Diffraction Limit

- **Rayleigh criterion:**
  - $\theta_{min} = 1.22\ \lambda/D$

Q to ponder:

- You have unpolarized light that traverses a sequence of two polarizers whose polarization axes form an angle of 60 degrees.
- What fraction of the intensity of the unpolarized light makes it through both polarizers?

Answer:

- Unpolarized light drops by factor 2 when going through first polarizer.
- $\cos^2 60^o = 0.5^2 = 0.25$
- The remaining intensity after both polarizers is 12.5% of the initial intensity of the unpolarized light.

Exercise 34-6

A laser delivers 5MW/m^2.
It is pointed on a black 100micron diameter particle.

What’s the maximum mass the laser can lift?

Solution

$$\frac{\langle S \rangle}{c} = \frac{5\,\frac{MW}{m^2}}{3 \cdot 10^8\, m/s} = \frac{mass \cdot 10 m/s^2}{\pi\left(50 \mu m\right)^2} = \frac{mg}{\pi R^2}$$

$$mass = 1.3 \cdot 10^{-11}\, kg$$

That's it!

Best of luck!