Chapter 35, Polarization
Simple Spectrometer

\[ \lambda = \frac{d}{m} \sin \theta \]

Resolving power, to separate two lines closely spaced in wavelength by \( \Delta \lambda \):

\[ R = \frac{\lambda}{\Delta \lambda} = mN \]
Resolving Power

Two lines not resolved.

Two lines barely resolved.

Example of resolving two lines at order $m=2$, using a grating with $N$ only equal to 9.

$R \equiv \frac{\lambda}{\Delta \lambda} = mN$

$\lambda_1 = 0.55 \quad \lambda_2 = 0.581 \quad \Delta \lambda = \lambda_2 - \lambda_1 \quad \frac{\lambda_1}{\Delta \lambda} = 18 \quad$ Resolving power

$2N = 18 \quad$ Theoretical value
Resolving Power

With the number of slits increased to $N=19$ the same two lines are easily resolved, even in first order, $m=1$. 

\[ R \equiv \frac{\lambda}{\Delta \lambda} = mN \]
Problem 35-47

• A diffraction grating has 16,000 rulings in its 1.9 cm width. Determine
  
  a) Its resolving power in first and second orders,
  
  b) And the minimum wavelength resolution it can yield for $\lambda = 410$ nm.

$$R = \frac{\lambda}{\Delta \lambda} = mN$$

R=mN, so for part (a) $R=16,000$ and 32,000

For part (b), $\Delta \lambda = \frac{\lambda}{R} = 0.026$ nm or 0.013 nm
Polarization (Transverse Waves)

Wave on a string

Electromagnetic wave: perpendicular oscillating electric and magnetic fields. The polarization is taken to be the direction of the electric field vector.
Plane Polarization

Polarization by absorption:

\[ \langle \cos^2 \theta \rangle = \frac{1}{2} \]

\[ I = I_0 \cdot \cos^2 \theta \]
Crossed Polarizers

(a) [Diagram showing crossed polarizers and light passes through them]

(b) [Diagram showing intensity reduction through crossed polarizers]

Vertical polarizer 45° Horizontal polarizer

Light direction

$I_0$ $\frac{1}{2}I_0$ $\frac{1}{4}I_0$ $\frac{1}{8}I_0$
Circular Polarization

The $x$ and $y$ components of the electric field vector differ in phase by $90^\circ$.

At a given location along the direction of propagation the electric field vector remains a constant length but rotates in a circle.

http://webphysics.davidson.edu/physlet_resources/dav_optics/Examples/polarization.html
Circular Polarization

• Modern 3D movies usually employ circular polarization.
• The scene is projected from two slightly different viewpoints, with a different circular polarization for each of the views.
• The right eye sees right-handed polarized light, while the left eye sees left-handed polarized light (or vice-versa).
Producing Circular Polarization

Some crystals slow down light with one polarization more than with the orthogonal polarization.

In a quarter wave plate, one polarization is delayed with respect to the other by exactly one quarter oscillation.

If linear polarization is input as shown, then the output light is circularly polarized.
Polarization by Reflection

100% polarization of the reflected light results when the reflected and refracted rays are at a right angle with respect to each other.

\[
\frac{\sin \theta_p}{\sin \theta_r} = \frac{n_2}{n_1}
\]

\[
\sin \theta_p \left( \frac{\pi}{2} - \theta_p \right) = \frac{\sin \theta_p}{\cos \theta_p} = \tan \theta_p = \frac{n_2}{n_1}
\]

Brewster’s Angle

This reflected ray is radiated only by charges oscillating in and out of the page in the water.

The electric field of the refracted light causes charge in the water to oscillate. The oscillating charges radiate the reflected wave.

But light is not radiated along the direction of motion of the charge.
Electromagnetic waves (light, radio, etc.) are always produced by accelerating charges.
Brewster’s Angle Demo
Polaroid Sunglasses

To reduce the glare from the concrete road while you are driving, the polarizer in your sunglasses should be oriented to:

A. block vertically polarized light.

B. **block horizontally polarized light.**

C. block light polarized along the direction of propagation.
Polarization by Scattering

Light from the blue sky is partially polarized because of this effect.

Vertical oscillation of charge in a gas molecule cannot transmit light directly downward.
Polarization by Scattering Demo
Polarization and Photography

A Polaroid filter over the lens of a camera will reduce the light from the blue sky, thus preventing overexposure and enhancing the image of unpolarized light from clouds. It will also reduce light reflected from a smooth surface.

Above, a photo taken without any filter.

Right, the same scene photographed through a Polaroid filter.
In the early evening on a clear day as the sun is setting directly to the west, you look straight upward into the blue sky. The light that you see is

A. polarized in the East-West orientation.

B. polarized in the North-South orientation.

C. polarized in the up-down orientation.

D. unpolarized.
Final Exam

- Next Monday, March 19th, 8:00 am
  - DRC in Thimann 391 (not 397!)
- Same rules as for the midterm
  - Bring a calculator and straightedge.
  - The exam is comprehensive but will emphasize somewhat material covered after the 2nd midterm.
- A practice exam with solutions is posted on eCommons (last year’s exam).
  - Your exam will have more, but shorter, problems.
- Homework #10 is due this evening, after which I will post the solutions.
- Remember that all of the lecture notes, including clicker questions, are posted on the web.
The End!