Preparation Notes for Chapter 38 (Diffraction and Polarization; 3-4 classes)

Introduction to Diffraction

Reading is 38.1, first 2 pages of 38.2; problems 38.1, 38.51

(1) Introduction by instructor; waves spread out from slits; this is called diffraction; get it when we have small openings or sharp edges; don't get a single sharp shadow, rather light and dark fringes; pencil shadow: sharper when close to surface, but obviously fuzzy when far away; sketch diffraction pattern for a single slit

(2) Presentation: Diffraction between your fingers

(3) Geometry of diffraction (if not in report, or summing up report): divide slit in half; ray 1 and 3 interfere destructively when $(a/2)sin\theta = \lambda/2$; divide into quarters; ray 1 and 2 interfere destructively when $(a/4)sin\theta = \lambda/2$; etc; note dark bands separated by $y = Ltan\theta \simeq Lsin\theta = L\lambda/a$; central maximum is twice as wide as secondary maxima

(4) Discussion (small groups): "What happens to the distance between the dark bands if I make the slit width smaller i.e. half as wide?"; to illustrate that slit width and dark band separation vary inversely

(5) (Maybe) Give formulae for intensity:

diffraction is

$$I = I_{max}(sin(2\pi asin\theta/\lambda)/(2\pi asin\theta/\lambda))^2$$

interference is

$$I = I_{max}cos^2(\pi dsin\theta/\lambda)$$

both together gives

$$I = I_{max}cos^2(\pi dsin\theta/\lambda)(sin(2\pi asin\theta/\lambda)/(2\pi asin\theta/\lambda))^2$$

(6) Problem 38.51: Light from a helium-neon laser ($\lambda = 623.8$ nm) is incident on a single slit. What is the maximum width for which no diffraction minima are observed?

Resolution and Diffraction Gratings

Reading is 38.3,38.4; Problems 38.17, 38.57

(1) Introduction by instructor: how close can objects be and still be resolvable? Rayleigh's criterion: central maximum of one source on first minimum of other source; for slit $\theta_{min} = \lambda/a$; for circular aperture of diameter D, $\theta_{min} = 1.22\lambda/D$;

(2) Discussion (small groups): "Suppose we wanted to take a picture and actually see a planet around a nearby star. What things would we need to know to figure out how big a telescope we would need?" distance to star; distance of planet from star; wavelength of picture; (ignore relative brightness for now); typical values (for the non-astronomers!)

might be 10 pc = 3e17 m, 1 AU = 1.5e11 m, and 1 micron; minimum telescope diameter turns out to be only 2.4 m! Why we can't see planets right now is because the star is so much brighter than the planet that its diffraction pattern swamps the tiny signal from the planet.

(3) Presentation: CD as diffraction grating

(4) Follow-up/summary: if separation between lines in grating is d, then get bright maxima when $dsin\theta = m\lambda$; get sharp maxima and broad areas of darkness; d = 1/(number of lines/cm); resolving power $R = \lambda/\Delta\lambda$; if N lines illuminated, $R = mN$

(5) Problem: 38.57: Light of wavelength 500 nm is incident normally on a diffraction grating. If the third-order maximum of the diffraction pattern is observed at 32.0 degrees (a) what is the number of rulings per centimeter for the grating? (b) Determine the total number of primary maxima that can be observed in this situation.

Polarization

Reading is 38.6; Problems 38.41, 38.49

(1) Introduction: transverse wave; if E vector can lie anywhere in plane, it is unpolarized; if it always lies along one particular direction it is linearly polarized (plane polarized, or just polarized); suppose light passes through two polarizing sheets, transmission axes separated by angle θ; $I = I_o cos^2\theta$ where I_o is the intensity of the beam after it goes through the first sheet

(2) Demo and discussion: take two sheets of polarizer. Put them at 90 degrees to each other on overhead projector so no light gets through; take a third sheet and put it on top at 45 degrees; still no light, of course; move the third sheet to be IN BETWEEN the first two; light should come through; class discusses what is going on

(3) Presentation: polarization by reflection

(4) Followup/summary: 100% polarized at angle of incidence θ_p, where $n = tan\theta_p$ for light in air incident on surface; at other angles will be partially polarized; normal incidence, is unpolarized; flat surface gives you polarization in the horizontal direction; polarized sunglasses have a vertical transmission axis (why?)

(5) Presentation: polarization of sunlight in sky

(6) Followup/summary: 100% polarized when angle between sun and observer is 90 degrees (I think; ask Doug if this is right); intensity of scatter light $\sim 1/\lambda^4$ so more blue light scattered than red

(7) Problem 38.49: You want to rotate the plane of polarization of a polarized light beam by 45 degrees with a maximum intensity reduction of 10.0%. (a) How many sheets of perfect polarizers do you need to achieve your goal? (b) What is the angle between adjacent polarizers?

(8) Presentations: oil drops viewed through polarized glasses

Other discussion ideas not used this time

(1) Van Gogh museum: had to stand 7 m away from painting for it to look really good; what was typical size of brush strokes on the painting?

(2) From text, could use questions 3 (diffraction for AM vs FM radio signals; if not used as report topic), 5 (eye resolution), 7 (polarization of sunlight), 8 (sky on Earth vs Moon)

(No concept map available yet for this chapter.)

Suggested Presentation Topics

Diffraction between your fingers (Quick Lab p. 1216)

CD as diffraction grating (Quick Lab p. 1226)

Sheer curtains as diffraction gratings: estimation of thread spacing

Patterns in sheer curtain layers (could be done on overhead).

Corrugated metal as an acoustic diffraction grating.

Aluminum siding as an acoustic diffraction grating.

Polarization by reflection (Quick Lab p. 1233)

Variation of polarization of sunlight around the sky

Oil drips on wet pavement as seen through polaroid glasses.