STUDY GUIDE FOR PART 2: LIGHT II

Interference of Light Waves

1. Superposition of waves (Fourier series)		
2. Young's double slit	$n\lambda = d\sin(\theta_n)$ [for MAXIMUM]	S-22,23
3. Diffraction grating	[same as above only sharper]	S-24,25
4. Thin films	[constructive or destructive interference]	S-26,27
5. Michelson interferometer		S-28,29

SUPPLEMENTARY HOMEWORK PROBLEMS (S-):

22. Laser light of wavelength 632 nm is directed through a double slit with slit separation of 0.1 mm. What is the distance between adjacent maxima on a screen 4 meters away?

23. Laser light of unknown wavelength is directed through a double slit with slit separation of 0.2 mm. If the distance between adjacent maxima is 9.66 mm on a screen 4 meters away, what is the wavelength of light?

24. If a certain light is shown through a diffraction grating that has 13,400 lines per inch, what will be the angle that the first maximum of each of the following makes with the initial beam of light: (a) red light of wavelength 630 nm? (b) yellow light of wavelength 560 nm? (c) blue light of 450 nm wavelength.

25. If a certain light is shown through a diffraction grating that has 8,000 lines per inch and it is observed that the first maximum is at an angle of 15.3°, (a) what is the wavelength of the light? (b) what color is it?

26. A film of oil with an index of refraction of 1.60 floats on water (n = 1.33). One part of it preferentially reflects yellow light. (a) Assuming near normal incidence, how thick is the oil? (b) If the oil had an index of refraction of 1.16, would your answer change (if so, what would it be)? (c) If the reflected color gradually changes to blue, is the oil film getting thinner or thicker?

27. An anti-reflection coating on a lens is of a material of index of refraction 1.75 and the glass of the lens has an index of refraction of 1.50. How thick should the coating be if it is designed to minimize the reflection of yellow light at near normal incidence?

28. A Michelson interferometer is to be used to measure the expansion of a bar as it is heated. If blue light of wavelength 450 nm is used and 29.3 fringes are counted, what is the expansion of the bar?

29. A Michelson interferometer is to be used to measure the index of refraction of a certain gas at a certain pressure. A tube of inside length 5 cm with transparent ends is placed in one arm of the interferometer. Light of wavelength 632 nm (in vacuum) is used. Initially the tube has vacuum inside it (no gas). As the gas is slowly let into the tube, 84 fringes (bright to dark back to bright) are counted. What is the index of refraction of this gas at the final pressure? (HINT: how many wavelengths of light fit in the 5 cm of the tube initially? how many wavelengths of light fit into the tube after 84 fringe shifts? by what fraction did the wavelengths decrease?)

ANSWERS TO SUPPLEMENTARY PROBLEMS:

22) 2.53 cm.

23) 483 nm.

24) a) 19.4°; b) 17.2°; c) 13.7°

25) a) 838 nm; b) infrared.

26) a) 86 nm, or any ODD multiple of 86 nm; b) yes, 237 nm or ANY multiple of 237 nm; c) thinner.

27) 157 nm or ANY multiple of 157 nm.

28) 6.59 mm.

29) 1.00053\

Diffraction and Polarization

A. Diffraction

1. single slit diffraction $n\lambda = w\sin(\theta_n)$ n>0, for MINIMUM S-30,31
2. interference and diffraction
3. circular opening diffraction $1.22\, n\lambda = D\sin(\theta_n)$ n >0, for MIN
4. resolving power $\theta_{limit} = \theta_1$ in above circular diffraction S-32
5. x-ray diffraction $n\lambda = 2\, d\sin(\theta_n)$ for MAXIMUM

B. Polarization S-33

1. by reflection: Brewster angle: $\tan(\theta_B) = n_{mat}/n_{med}$
2. by selective absorption
3. by double refraction
4. by scattering

C. Optical instruments

1. single lens S-34,35,36

   a) the eye

   b) the camera [Amt of light $\propto$ A$\bullet$ t]

2. the telescope S-37

3. the microscope S-38,39

4. the spectrometer

SUPPLEMENTARY HOMEWORK PROBLEMS (S-):

30. A laser light of wavelength 633 nm shines through a crack and the resulting diffraction pattern on a screen 2 meters away shows the central maximum to have a width of 1.2 cm. How wide is the crack?

31. A low frequency (50 Hz) sound wave (v = 350 m/s in air) is incident on a door of width one meter. (a) What is the angle for the first minimum as the sound spreads out due to the diffraction effects of the door? (b) What if the frequency is 500 Hz?

32. What is the minimum angle that can be resolved (i.e., the resolving power) of an instrument that has a circular opening for the incoming light of diameter 4 mm? (Assume yellow light - 550 nm wavelength).

33. Sunlight reflects off the calm (flat) surface of a pond. (a) Can polarized sunglasses help cut out the reflected glare? (b) Will the polarized sunglasses cut out more, the same or less glare at 3 pm (assume angle of sun with water is 42°) than at noon (angle of sun is 12°)?

34. A lens of focal length 5 mm and diameter 2 mm is used as a magnifying glass to look at an object 0.1 mm in length. If the lens is placed near the eye and the object under investigation is placed so that its image is at an easy viewing distance (25 cm behind the lens) (a) how near the lens should the object be placed? (b) What is the effective magnification? (c) What is the image size? (d) What angle does the image make at the eye? (e) What is the smallest angle (according to the Rayleigh Criterion) that this magnifying glass can resolve?

35. What is the minimum angle (according to the Rayleigh Criterion) that a person with good eyesight can resolve? (Estimate the diameter of the opening to the eye [pupil] and use the middle of the visible spectrum for the wavelength of the light.)

36. A camera with a 55 mm focal length lens takes a picture of an object two meters long using an f-stop of 8 and time exposure of 1/30 sec. (a) If the film is 24 mm x 36 mm in size, and the image of the two meter long object is to fill up the long side of the film (36 mm side), how far away should the object be from the camera? (b) How far should the lens be from the film? (c) What is the diameter of the opening to the lens for this f-stop? (d) How close can two points of light on the subject be to be resolvable on the film assuming the film itself does not limit this and lenses are as perfect as possible? (e) If an f-stop of 1.4 is used, how close can the two points of light on the object be to be resolvable on the film? (f) What time

exposure should be used to obtain the same amount of light for the film? (g) What is the distance between the image of the dots of part -e- on the film? \

37. A telescope with an objective lens of focal length 125 cm and diameter 5 inches (12.7 cm) is used to look at Jupiter. (a) What focal length lens should be used for the eyepiece if a magnification of 200 is desired? (b) What angle does Jupiter make with the eye at Jupiter's nearest approach? (Diameter is 144,000 km, distance to Jupiter is 6.25×10^8 km.) *[HINT: what is the definition of an angle measured in radians?]* (c) What is the smallest angle this telescope can theoretically resolve? (d) What % of Jupiter's size is this angle? (e) What distance does this correspond to on Jupiter's surface? (f) What angle does this become when magnified by the telescope?

38. A microscope consists of an objective lens of focal length 2 cm and diameter 2 cm, and an eyepiece of focal length 4 cm positioned at a distance of 18 cm above the objective lens. (a) Where should the sample be placed if the image is to appear at the easy viewing distance (25 cm)? (b) What magnification does the microscope give?

39. Assuming ideal optical systems, (a) what resolving limit (i.e., size of the smallest detail able to be resolved) is there on a microscope? (b) What would be the maximum useful magnification of this ideal microscope?

ANSWERS TO SUPPLEMENTARY PROBLEMS:

30) 0.211 mm.

31) a) no minimum; b) 44.4°.

32) 1.68×10^{-4} rad = 0.0096° = 34.6 sec of angle.

33) a) yes; b) more.

34) a) 4.90 mm; b) 51 X; c) 5.1 mm; d) 0.0204 rad = 1.17°; e) .00033 rad = .019°.
(such a magnifying glass would be very hard to use!)

35) for a pupil diameter of 4 mm, $\theta_{limit} \approx 0096° \approx$ ½ arc-minute.

36) a) 3.111 m; b) 55.99 mm; c) 6.875 mm; d) 0.30 mm; e) 0.053 mm.
f) 1/1000 sec; g) 954 nm or » 1mm.

37) a) 6.3 mm; b) 2.3×10^{-4} rad = 0.013° = 47.5 sec of angle;
c) 5.29×10^{-6} rad = 1.1 sec of angle; d) 2.3%; e) 3300 km; f) 218 sec = 2 min 38 sec.

38) a) 2.32 cm from objective lens; b) 45X.

39) a) approximately the wavelength of light or ≈ 1 μm; b) ≈ 500X.