PROBLEMS

7-1 Two mutually coherent beams having parallel electric fields are described by

$$E_1 = 3\cos\left(ks_1 - \omega t + \frac{\pi}{5}\right)$$

$$E_2 = 4\cos\left(ks_2 - \omega t + \frac{\pi}{6}\right)$$

with amplitudes in kV/m. The beams interfere at a point P where the phase difference due to path is $\pi/3$ (the first beam having the longer path). At the point of superposition, calculate (a) the irradiances I_1 and I_2 of the individual beams; (b) the irradiance I_{12} due to their interference; (c) the net irradiance; (d) the fringe visibility.

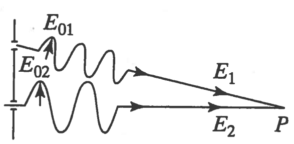

Figure 7-23 Problem 7-1.

7-2 Two harmonic light waves with amplitudes of 1.6 and 2.8 interfere at some point P on a screen. What visibility results there if (a) their electric field vectors are parallel and (b) if they are perpendicular?

7-3 The ratio of the amplitudes of two beams forming an interference fringe pattern is 2/1. What is the visibility? What ratio of amplitudes produces a visibility of 0.5?

7-4 **a.** Show that if one beam of a two-beam interference setup has an irradiance of N times that of the other beam, the fringe visibility is given by

$$V = \frac{2\sqrt{N}}{N + 1}$$

b. Determine the beam irradiance ratios for visibilities of 0.96, 0.9, 0.8, and 0.5.

7-5 A mercury source of light is positioned behind a glass filter, which allows transmission of the 546.1-nm green light from the source. The light is allowed to pass through a narrow, horizontal slit positioned 1 mm above a flat mirror surface. Describe both qualitatively and quantitatively what appears on a screen 1 m away from the slit.

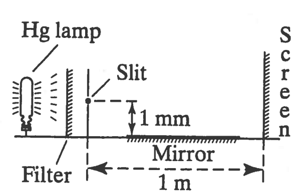

Figure 7-24 Problem 7-5.

7-6 Two slits are illuminated by light that consists of two wavelengths. One wavelength is known to be 436 nm. On a screen, the fourth minimum of the 436-nm light coincides with the third maximum of the other light. What is the wavelength of the other light?

7-7 In a Young's experiment, narrow double slits 0.2 mm apart diffract monochromatic light onto a screen 1.5 m away. The distance between the fifth minima on either side of the zeroth-order maximum is measured to be 34.73 mm. Determine the wavelength of the light.

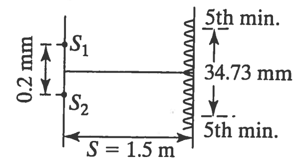

Figure 7-25 Problem 7-7.

7-8 A quasi-monochromatic beam of light illuminates Young's double-slit setup, generating a fringe pattern having a 5.6-mm separation between consecutive dark bands. The distance between the plane containing the apertures and the plane of observation is 7 m, and the two slits are separated by 1.0 mm. Sketch the experimental arrangement. Why is an initial single slit necessary? What is the wavelength of the light?

7-9 In an interference experiment of the Young type, the distance between slits is 0.5 mm, and the wavelength of the light is 600 nm.

a. If it is desired to have a fringe spacing of 1 mm at the screen, what is the proper screen distance?

b. If a thin plate of glass ($n = 1.50$) of thickness 100 microns is placed over one of the slits, what is the lateral fringe displacement at the screen?

c. What path difference corresponds to a shift in the fringe pattern from a peak maximum to the (same) peak half-maximum?

7-10 White light (400 to 700 nm) is used to illuminate a double slit with a spacing of 1.25 mm. An interference pattern falls on a screen 1.5 m away. A pinhole in the screen allows some light to enter a spectrograph of high resolution. If the pinhole in the screen is 3 mm from the central white fringe, where would one expect dark lines to show up in the spectrum of the pinhole source?

7-11 Sodium light (589.3 nm) from a narrow slit illuminates a Fresnel biprism made of glass of index 1.50. The biprism is twice as far from a screen on which fringes are observed as it is from the slit. The fringes are observed to be separated by 0.03 cm. What is the biprism angle α?

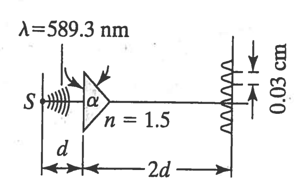

Figure 7-26 Problem 7-11.

7-12 The small angle θ between two plane, adjacent reflecting surfaces is determined by examining the interference fringes produced in a Fresnel mirror experiment. A source slit is parallel to the intersection between the mirrors and 50 cm away. The screen is 1 m from the same intersection, measured along the normal to the screen. When illuminated with sodium light (589.3 nm), fringes appear on the screen with a spacing of 0.5 mm. What is the angle θ?

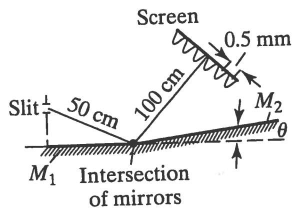

Figure 7-27 Problem 7-12.

7-13 The prism angle of a very thin prism is measured by observing interference fringes as in the Fresnel biprism technique. The distances from slit to prism and from prism to eye are in the ratio of 1:4. Twenty dark fringes are found to span a distance of 0.5 cm when green mercury light is used. If the refractive index of the prism is 1.50, determine the prism angle.

7-14 Light of continuously variable wavelength illuminates normally a thin oil (index of 1.30) film on a glass surface. Extinction of the reflected light is observed to occur at wavelengths of 525 and 675 nm in the visible spectrum. Determine the thickness of the oil film and the orders of the interference.

7-15 A thin film of MgF_2 ($n = 1.38$) is deposited on glass so that it is antireflecting at a wavelength of 580 nm under normal incidence. What wavelength is minimally reflected when the light is incident instead at 45°?

7-16 A nonreflecting, single layer of a lens coating is to be deposited on a lens of refractive index $n = 1.78$. Determine the refractive index of a coating material and the thickness required to produce zero reflection for light of wavelength 550 nm.

7-17 Remember that the energy of a light beam is proportional to the square of its amplitude.

a. Determine the percentage of light energy reflected in air from a single surface separating a material of index 1.40 for light of $\lambda = 500$ nm.

b. When deposited on glass of index 1.60, how thick should a film of this material be in order to reduce the reflected energy by destructive interference?

c. What is then the effective percent reflection from the film layer?

7-18 A soap film is formed using a rectangular wire frame and held in a vertical plane. When illuminated normally by laser light at 632.8 nm, one sees a series of localized interference fringes that measure 15 per cm. Explain their formation.

7-19 A beam of white light (a continuous spectrum from 400 to 700 nm, let us say) is incident at an angle of 45° on two parallel glass plates separated by an air film 0.001 cm thick. The reflected light is admitted into a prism spectroscope. How many dark "lines" are seen across the entire spectrum?

7-20 Two microscope slides are placed together but held apart at one end by a thin piece of tin foil. Under sodium light (589 nm) normally incident on the air film formed between the slides, one observes exactly 40 bright fringes from the edges in contact to the edge of the tin foil. Determine the thickness of the foil.

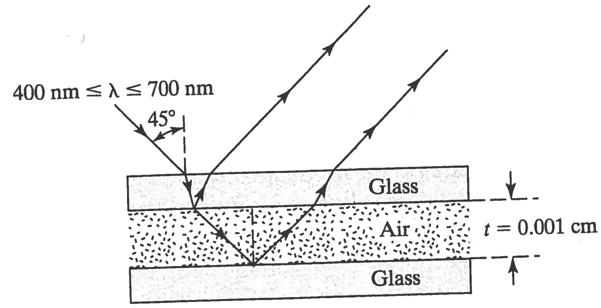

Figure 7-28 Problem 7-19.

7-21 Plane plates of glass are in contact along one side and held apart by a wire 0.05 mm in diameter, parallel to the edge in contact and 20 cm distant. Using filtered green mercury light ($\lambda = 546$ nm), directed normally on the air film between plates, interference fringes are seen. Calculate the separation of the dark fringes. How many dark fringes appear between the edge and the wire?

7-22 Show that the separation of the virtual sources I_1 and I_2 producing interference from a film of index n and uniform thickness t, when illuminated by a point source, is $2t/n$. Assume the film is in air and light is incident at near-normal incidence.

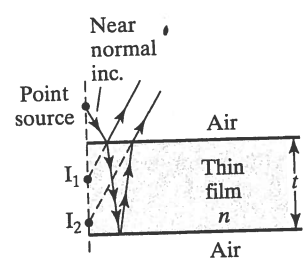

Figure 7-29 Problem 7-22.

7-23 Newton's rings are formed between a spherical lens surface and an optical flat. If the tenth bright ring of green light (546.1 nm) is 7.89 mm in diameter, what is the radius of curvature of the lens surface?

7-24 Newton's rings are viewed both with the space between lens and optical flat empty and filled with a liquid. Show that the ratio of the radii observed for a particular order fringe is very nearly the square root of the liquid's refractive index.

7-25 A Newton's ring apparatus is illuminated by light with two wavelength components. One of the wavelengths is 546 nm. If the eleventh bright ring of the 546-nm fringe system coincides with the tenth ring of the other, what is the second wavelength? What is the radius at which overlap takes place and the thickness of the air film there? The spherical surface has a radius of 1 m.

7-26 A fringe pattern, such as that in Figure 7-20, found using an interference microscope objective, is observed to have a regular spacing of 1 mm. At a certain point in the pattern, the fringes are observed to shift laterally by 3.4 mm. If the illumination is green light of 546.1 nm, what is the dimension of the "step" in the film that caused the shift?

7-27 A laser beam from a 1-mW He-Ne laser (632.8 nm) is directed onto a parallel film with an incident angle of 45°. Assume a beam diameter of 1 mm and a film index of 1.414. Determine (a) the amplitude of the E-vector of the incident beam; (b) the angle of refraction of the laser beam into the film; (c) the magnitudes of r' and tt', using the Stokes relations and a reflection coefficient, $r = 0.280$; (d) the independent amplitudes of the first three reflected beams and, by comparison with the incident beam, the percentage of radiant power density reflected in each; (e) the same information as in (d) for the first two transmitted beams; (f) the minimum thickness of film that would lead to total cancellation of the reflected beams when they are brought together at a point by a lens.

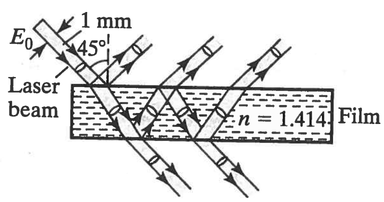

Figure 7-30 Problem 7-27.

7-28 a. Using Eq. (7-27) and the stokes relations, show that amplitudes of the first three reflected and first three transmitted beams from a parallel, nonabsorbing glass ($n = 1.52$) plate, when the incident beam is near normal and of unit amplitude, are given by

	(1)	(2)	(3)
reflected	0.206	0.198	0.0084
transmitted	0.957	0.041	0.0017

b. Show as a result that the first two reflected rays produce a visibility of 0.999, whereas the first two transmitted rays produce a visibility of only 0.085.