Problem Set 8
Due: see website for due date
Chapter 27: Interference and the Wave Nature of Light
Questions: 1, 2, 6, 8, 12
Problems: 3, 6, 7, 8, 9, 15, 16, 18, 19

Q27.1: The two loudspeakers in the drawing are producing identical sound waves. The waves spread out and overlap at the point P. What is the difference $\ell_2 - \ell_1$ in the two path lengths if point P is at the third sound intensity minimum from the central sound intensity maximum? Express this difference in terms of the wavelength $\lambda$ of the sound. (a) 0.5$\lambda$ (b) $\lambda$ (c) 1.5$\lambda$ (d) 3$\lambda$ (e) 2.5$\lambda$.

Q27.2: In a certain Young’s double-slit experiment, a diffraction pattern is formed on a distant screen, as the drawing shows. The angle that locates a given bright fringe is small, so that the approximation $\sin \theta \approx \theta$ is valid. Assuming that $\theta$ remains small, by what factor does it change if the wavelength $\lambda$ is doubled and the slit separation $d$ is doubled? (a) The angle does not change. (b) The angle increases by a factor of 2. (c) The angle increases by a factor of 4. (d) The angle decreases by a factor of 2. (e) The angle decreases by a factor of 4.

Q27.6: Light of wavelength 600 nm in vacuum is incident nearly perpendicularly on a thin film whose index of refraction is 1.5. The light travels from the top surface of the film to the bottom surface, reflects from the bottom surface, and returns to the top surface, as the drawing indicates. How far has the light traveled inside the film? Express your answer in terms of the wavelength $\lambda_{\text{film}}$ of the light within the film. (a) 2$\lambda_{\text{film}}$ (b) 3$\lambda_{\text{film}}$, (c) 4$\lambda_{\text{film}}$, (d) 6$\lambda_{\text{film}}$ (e) 12$\lambda_{\text{film}}$

Q27.8: Light is incident perpendicularly on four transparent films of different thickness. The thickness of each film is given in the drawings in terms of the wavelength $\lambda_{\text{film}}$ of the light within the film. The index of refraction of each film is 1.5, and each is surrounded by air. Which film (or films) will appear bright due to constructive interference when viewed from the top surface, upon which the light is incident? (a) 1, 2, 3, 4 (b) 2, 3 (c) 3 (d) 3, 4 (e) 4.

Q27.12: Light passes through a single slit. If the width of the slit is reduced, what happens to the width of the central bright fringe? (a) The width of the central bright fringe does not change, because it depends only on the wavelength of the light and not on the width of the slit. (b) The central bright fringe becomes wider, because the angle that locates the first dark fringe on either side of the central bright fringe becomes smaller. (c) The central bright fringe becomes narrower, because the angle that locates the first dark fringe on either side of the central bright fringe becomes larger. (d) The central bright fringe becomes wider, because the angle that locates the first dark fringe on either side of the central bright fringe becomes smaller. (e) The central bright fringe becomes narrower, because the angle that locates the first dark fringe on either side of the central bright fringe becomes larger.
P27.3: Two in-phase sources of waves are separated by a distance of 4.00 m. These sources produce identical waves that have a wavelength of 5.00 m. On the line between them, there are two places at which the same type of interference occurs. (a) Is it constructive or destructive interference, and (b) where are the places located? 
Answer: destructive, 3.25 m, 0.75 m

P27.6: Two parallel slits are illuminated by light composed of two wavelengths. One wavelength is $\lambda_A = 645$ nm. The other wavelength is $\lambda_B$ and is unknown. On a viewing screen, the light with wavelength $\lambda_A = 645$ nm produces its third-order bright fringe at the same place where the light with wavelength $\lambda_B$ produces its fourth dark fringe. The fringes are counted relative to the central or zeroth-order bright fringe. What is the unknown wavelength? 
Answer: 553 nm

P27.7: In a setup like that in Figure 27.7, a wavelength of 625 nm is used in a Young’s double-slit experiment. The separation between the slits is $d = 1.4 \times 10^{-5}$ m. The total width of the screen is 0.20 m. In one version of the setup, the separation between the double slit and the screen is $L_A = 0.35$ m, whereas in another version it is $L_B = 0.50$ m. On one side of the central bright fringe, how many bright fringes lie on the screen in the two versions of the setup? Do not include the central bright fringe in your counting. 
Answer: 6; 4

P27.8: At most, how many bright fringes can be formed on either side of the central bright fringe when light of wavelength 625 nm falls on a double slit whose slit separation is 3.76 $\mu$m? 
Answer: 6

P27.9: In a Young’s double-slit experiment the separation $y$ between the second-order bright fringe and the central bright fringe on a flat screen is 0.0180 m when the light has a wavelength of 425 nm. Assume that the angles that locate the fringes on the screen are small enough so that $\sin \theta \approx \tan \theta$. Find the separation $y$ when the light has a wavelength of 585 nm. 
Answer: 24.8 mm

P27.15: A transparent film ($n = 1.43$) is deposited on a glass plate ($n = 1.52$) to form a nonreflecting coating. The film has a thickness that is 107 nm. What is the longest possible wavelength (in vacuum) of light for which this film has been designed? 
Answer: 612 nm

P27.16: A tank of gasoline ($n = 1.40$) is open to the air ($n = 1.00$). A thin film of liquid floats on the gasoline and has a refractive index that is between 1.00 and 1.40. Light that has a wavelength of 625 nm (in vacuum) shines perpendicularly down through the air onto this film, and in this light the film looks bright due to constructive interference. The thickness of the film is 242 nm and is the minimum nonzero thickness for which constructive interference can occur. What is the refractive index of the film? 
Answer: 1.29

P27.18: A film of oil lies on wet pavement. The refractive index of the oil exceeds that of the water. The film has the minimum nonzero thickness such that it appears dark due to destructive interference when viewed in red light (wavelength = 640.0 nm in vacuum). Assuming that the visible spectrum extends from 380 to 750 nm, for which visible wavelength(s) in vacuum will the film appear bright due to constructive interference? 
Answer: 427 nm

P27.19: Orange light ($\lambda_{\text{vacuum}} = 611$ nm) shines on a soap film ($n = 1.33$) that has air on either side of it. The light strikes the film perpendicularly. What is the minimum thickness of the film for which constructive interference causes it to look bright in reflected light? 
Answer: 115 nm