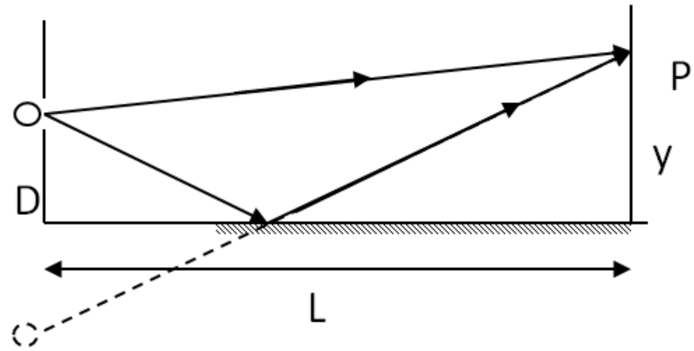
5.5 PROBLEMS

Problem 5.5.1. Two radio antennas are 1 km apart. They broadcast 4 MHz signals in phase. A car travels on a road parallel to the line joining the two antennas. The road is 20 km away from the antennas, i.e. the length of a line perpendicular to both the line joining the antennas and the road is 20 km. When the car moves on the road at a constant speed the net signal increases and decreases periodically. State why one would observe such variation in the intensity and determine five successive places on the road the strongest signals will be found and four successive places where the weakest signals will be found.

Problem 5.5.2. Two radio antennas are 10 km apart. They broadcast 8 MHz signals in phase. A car travels with speed 50 km/h on a road 200-km away parallel to the line joining the two antennas. The driver finds that the reception become strongest and fades periodically. Find the time interval between two successive strongest signals. Ans: 54 sec.

Problem 5.5.3. When you place a plastic tape over one of the slits of a double-slit experiment you find that the constructive and destructive interferences occur at different places than before. How much would the $m = 1$ constructive interference for a green light of wavelength 530 nm in air move on the screen of a Young's double-slit experiment that is one meter away with the slits 5 μm apart if one of the slits is covered with a plastic tape of refractive index 1.5 and thickness 2 μm? Ans: 11.7°.

Problem 5.5.4. A Lloyd's mirror is a set up that allows a double-slit experiment with only one source by placing a mirror between the slit and the screen as shown. The image of the slit serves as the second slit. (a) Find the conditions for constructive and destructive interferences on the screen if the screen is a distance L away and the slit is a distance D above the mirror. (b) If $L = 2$ m , $D = 2$ cm and wavelength of light used is the yellow sodium D line of wavelength 589 nm, find two places on the screen you will find bright spots and two places where there will be dark spots. Use the simplification that comes with the approximation that $D << L$.

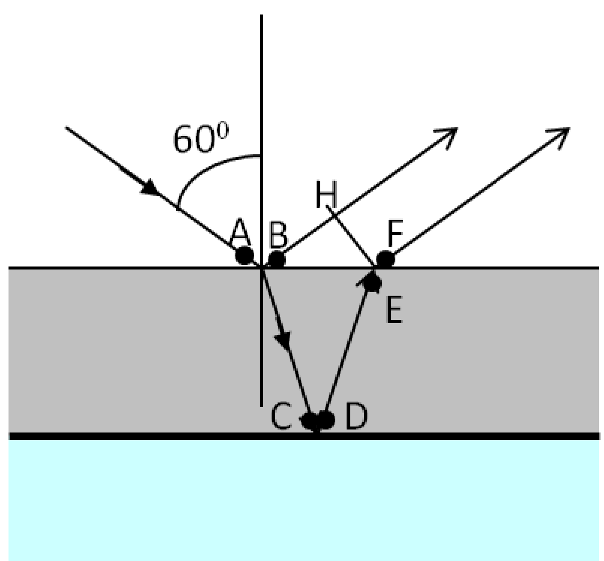


Problem 5.5.5. A radio transmitter atop a 100-m tall tower near a large lake emits a monochromatic electromagnetic wave of frequency 110 MHz. An airplane flying at 3000 meters away from tower finds the signal to vary in intensity with a period of 3 minutes. How fast is the plane flying with respect to the ground?

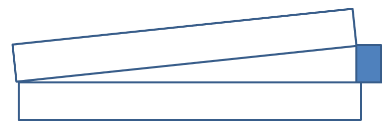
Problem 5.5.6. There is a oil film of uniform thickness of 150 nm floating on water. A ray of light of wavelength 550 nm is incident at 60 degrees on the film from air nearly perpendicularly to the film.

(a) Determine the phase difference between the following points shown in the figure. (i) A and B, (ii) C and D, (iii) E and F (iv) H and A, (v) H and B, (vi) H and C, (vii) H and D, (viii) H and E and (ix) H and F. Note that points near the interface are immediately on either side of the interface and the line FH is perpendicular to the line BH. Use $n(\text{oil}) = 1.2$ and $n(\text{water}) = 4/3$.

(b) As you vary the angle of incidence, or equivalently look at different angles, you will find constructive and destructive interferences. Determine two angles at which you would find constructive interference.



Problem 5.5.7. A wedge of air is made by inserting a 100 μm thick plate at one end of two glass plates each of width 25 cm.



Find the horizontal distance between two successive constructive interference if a light of frequency 530 nm is shown on it vertically.
Ans: 0.66 mm.

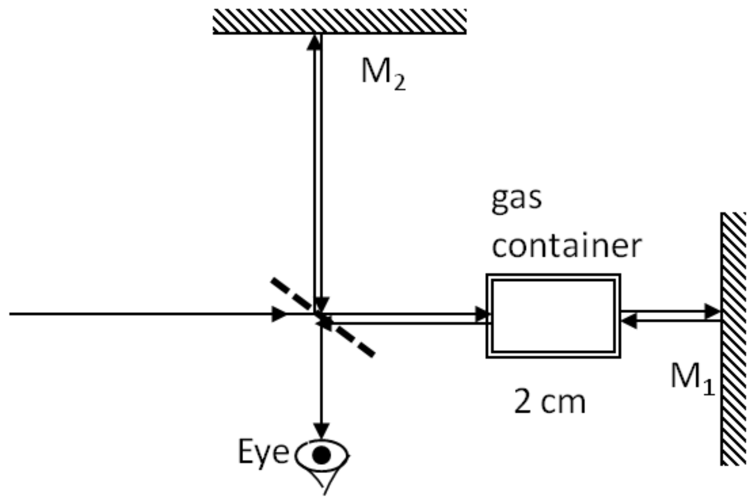
Problem 5.5.8. Two optically flat glass of length 25 cm are used to form a wedge of air by placing a narrow wire of thickness 100 micrometer between them at one end. A monochromatic light of wavelength 550 nm is incident normally on the top glass plate. Find the horizontal distance an observer from above will need to move to find successive constructive interference patterns near the center of the plate. Choose a particular x where there is a constructive interference and find the next x at which there is another constructive interference. Use $n(\text{air}) = 1$ and $n(\text{glass}) = 1.55$.

Problem 5.5.9. Two optically flat glass of length 25 cm are used to form a wedge of air by placing a narrow wire of thickness 100 μm between them at one end. The wedge is then filled with a transparent fluid of refractive index 1.8. A monochromatic light of wavelength 550 nm is incident normally on the top glass plate. Find the horizontal distance an observer from above will need to move to find successive constructive interference patterns near the center of the plate. Use $n(\text{glass}) = 1.55$.

Problem 5.5.10. A He-Ne laser emitting light at 632.8 nm goes through a concave lens which acts a beam expander before being incident nearly normally on a wedge of air made between a two glass plates of length 10 cm. The wedge has an angle of incline of 2 degrees. (a) How many bright fringes are observed from above? (b) How many bright fringes will be observed if the wedge is filled with water? (n = 1.5 for glass, n = 1.33 for water, and n = 1 for air.)

Problem 5.5.11. Light of wavelength 632.8 nm from a He-Ne laser is incident on two narrow slits separated by 0.5 mm. The intensity of the $m = 0$ constructive interference is maximum at the center and decreases to zero at the $m = \pm 1$ destructive interference. Find the direction in which the intensity of the $m = 0$ peak is half of the maximum in the middle.

Problem 5.5.12. In one arm of a Michelson's interferometer a glass container with attachments for evacuating the inside and putting gases in it is placed. The space inside the container is 2 cm wide. Initially the container is empty. As gas is slowly filled in the container it is observed that dark fringes move past a reference line in the field of observation. By the time the container is filled to the desired density 122 fringes are counted to have moved past the reference line when the wavelength of the light used is 632.8 nm. What is the refractive index of the gas at the last stage?



Problem 5.5.13. A plano-convex lens is made so that the curved shape is not spherical, but instead is given by

$$z = \frac{(x^2 + y^2)^2}{625 \text{ cm}^3},$$

where x, y and z are in cm. Newton's rings are observed when light is reflected off the top surface. Find the radius of the second bright ring for two different wavelengths: (a) 450 nm and (b) 650 nm. Do not count the center spot as a ring.