PC2232 Physics for Electrical Engineers: Tutorial 3

Question 1: Tsunami!

On December 26, 2004, a violent magnitude 9.1 earthquake occurred off the coast of Sumatra. This quake triggered a huge tsunami (similar to a tidal wave) that killed more than 150,000 people. Scientists observing the wave on the open ocean measured the time between crests to be 1.0 hour and the speed of the wave to be 800 km/h. Computer models of the evolution of this enormous wave showed that it bent around the continents and spread to all the oceans of the earth. When the wave reached the gaps between continents, it diffracted between them as through a slit.

(a) What is the wavelength of this tsunami?

(b) The distance between the southern top of African and northern Antartica is about 4500 km, while the distance between the southern end of Australia and Antartica is about 3700 km. As an approximation, we can model this wave's behaviour by using Fraunhofer diffraction. Find the smallest angle away from the central maximum for which the waves would cancel after going through each of these gaps.

Question 2: Interference

Consider three very narrow slits with spacings of d and $\frac{3d}{2}$ as shown in the figure. The slits are irradiated from the left with a plane wave of monochromatic light with a wavelength $\lambda = \frac{2d}{5}$. You may assume that the screen is very far away from the slits.

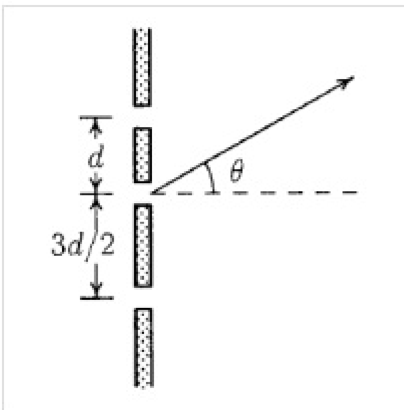

Figure 1:

(a) Derive the condition θ must satisfy such that it is the direction in which waves from *all three slits* interfere constructively, thus giving rise to principal maxima. What are the corresponding values of θ?

(b) Let the bottom slit be covered by a filter which introduces a half-cycle phase change. How many principal maxima will now be observed, and what are their corresponding values of θ?

(c) Now suppose the filter used in part (b) consists of a thin transparent film with an index of refraction $n = 1.33$, and it is now placed directly in front of the bottom slit. Calculate the minimum thickness of this film that would be needed to achieve the half-cycle phase change.

Question 3: Multiple slits

Laser light of wavelength 500.0 nm illuminates two identical slits, producing an interference pattern on a screen 90.0 cm from the slits. The bright bands are 1.00 cm apart, and the third bright bands on either side of the central maximum are missing in the pattern. Find the width and the separation of the two slits.

Question 4: Diffraction Grating

The wavelength range of the visible spectrum is approximately 400-700 nm. White light falls at normal incidence on a diffraction grating that has 350 slits/mm. Find the angular width of the visible spectrum in

(a) The first order and

(b) The third order.

Question 5: Intensity of Interference Pattern

Consider a two-slit interference experiment in which the two slits are of different widths. As measured on a distant screen, the amplitude of the wave from the first slit is E, while amplitude of the wave from the second slit is $2E$.

(a) Show that the intensity at any point of the interference pattern is

$$I = I_0 \left(\frac{5}{9} + \frac{4}{9} \cos\phi \right) \tag{1}$$

where ϕ is the phase difference between the two waves as measured at that particular point on the screen and I_0 is the maximum intensity in the pattern.

(b) Sketch a graph of I versus ϕ. What is the minimum value of the intensity, and for which values of ϕ does it occur?

Question 6: Beam splitter

Show that beam splitter will conserve power if

$$\begin{pmatrix} s_{11} & s_{12} \\ s_{21} & s_{22} \end{pmatrix} = \begin{pmatrix} \cos\phi & -\sin\phi \\ \sin\phi & \cos\phi \end{pmatrix}. \tag{2}$$