PH-107 (2017)
Tutorial Sheet 4

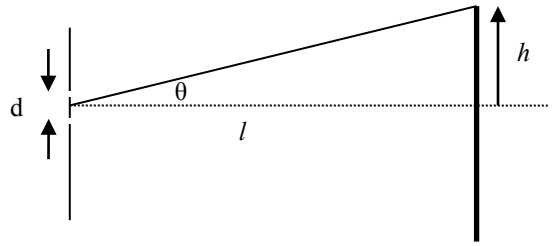
* Problems to be done in tutorial.

A. Electron interference, Diffraction, Young's double slit experiment, Davison-Germer experiment :

P32. The thermal kinetic energy of a hydrogen atom is roughly equal to kT , where k = 1.38×10^{-23} J/K, and T is the absolute temperature. The radius of the atom is roughly equal to the radius of the n=1 Bohr orbit, r_1 = 0:53 10^{-10} m. For what temperature will the deBroglie wavelength of the hydrogen atom be equal to its diameter? Take the mass of the atom to be that of the proton, 1.66 10^{-27} kg.

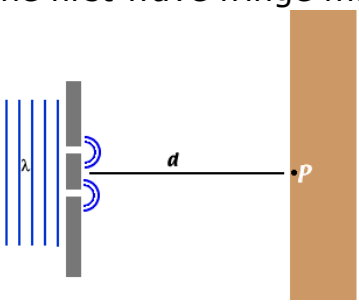
P33*. Consider two plane waves one with wave vector, $\mathbf{k_1} = (2\pi/\lambda)(\mathbf{x + y + z})$, and the other with wave vector, $\mathbf{k_2} = (2\pi/\lambda)\mathbf{z}$. Take λ = 500 nm. Calculate the resultant wave due to the interference of these two waves. Calculate the intensity ? Analyze the interference pattern in the xy-plane i.e. the condition for maxima and minima ?

P34. In a double slit interference experiment (see figure below), the distance between the slits is 0.0005m and the screen is 2 meters from the slits. Yellow light from a sodium lamp is used and it has a wavelength of 5.89×10^{-7} m. Show that the distance between the first and second fringes on the screen is 0.00233 m. (Fringe is another word for bright spot).



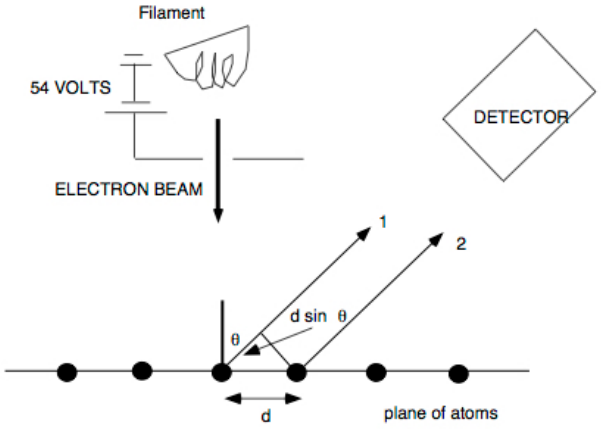
P_0

P35*. Water waves of wavelength 5.44 meters are incident upon a breakwater with two narrow openings separated by a distance 247 meters (see figure below). To the nearest thousandth of a degree what is angle corresponding to the first wave fringe maximum?



P36*. A Young's double slit experiment is performed (see figure of question P33). Answer the following questions.
(a) Plot the intensity pattern at the observing plane, Po. Label x and y-axis clearly.
(b) Light passes through two slits separated by a distance d=0.8mm, and the observing plane is 1.6m away from the two slits. If the distance between the two consecutive maxima is 5mm, what is the wavelength of the light?
(c) When one of the slits is covered by a film of transparent material, the zeroth order is seen to shift by 2.2 fringes. If the refractive index of the transparent material is 1.4, how thick is the film?
(d) The two slits are illuminated by light containing two wavelengths, 450nm and 600nm. What is the least order at which a maximum of one wavelength will fall exactly on a minimum of the other?

P37*. In the Davisson-Germer experiment, 54 eV electrons were diffracted from a nickel crystal. Consider the case when the electron beam impinges normal to the nickel crystal surface. See the figure below



A plot of the intensity of the diffracted electrons as a function of the angle from the normal to the surface shows the first peak at $\theta=50^0$)
(a) Calculate the spacing between the atoms on the nickel surface from the peak in the intensity distribution
(b) The electron beam energy is now changed to 100 eV. Find the angle from the surface normal where the maximum intensity is expected. Is there a second angle at which the intensity is again a maximum? If there is, what is this second angle?
c) If a beam of He atoms is used instead of electrons, what is the energy of the He atoms required to yield a maximum at the same angle as for the electrons?

B. Wave packet and Fourier Theory:

P38*. 6. A wave packet is of the form

$f(x) = e^{-\alpha|x|}$ (for $-\infty \le x \le \infty$) where α is a positive constant.

(a) Plot $f(x)$ versus x.

(b) At what values of x does $f(x)$ attain half of its maximum value ?

(c) Calculate the Fourier transform of $f(x)$, i.e. $g(k) = \int_{-\infty}^{+\infty} f(x)e^{ikx}dx$?

(d) Plot $g(k)$ versus k.

(e) Find the values of k at which $g(k)$ attains half of its maximum value

(f) From the values obtained in parts (b) and (e), find the value of the product $\Delta x.\Delta k$

$$\left[Given: \int_0^{\infty} e^{-(\alpha - ik)x}dx = \frac{1}{\alpha - ik} \right]$$