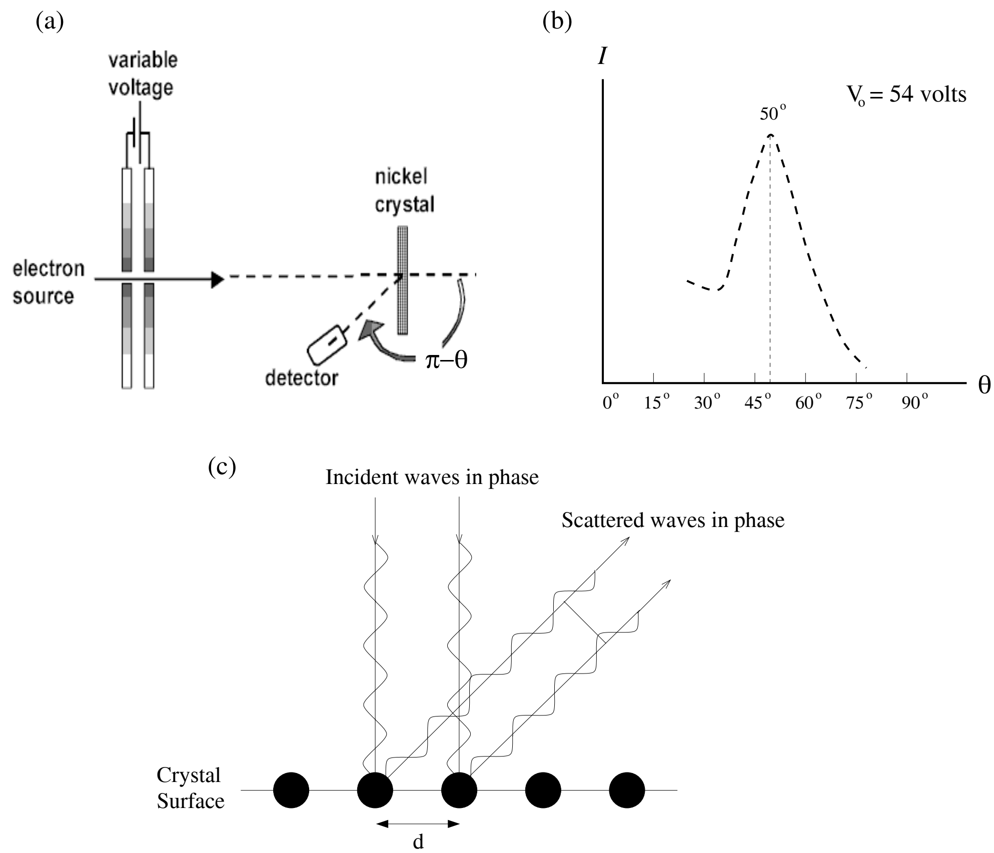
Tuesday 11th March 2008

Quantum Physics Classwork 3
Electron Diffraction

This classwork gives you the opportunity to understand the definitive experiment of Davisson and Germer, which established that the electron had wave properties. It also gives you more experience with the electron-volt unit of energy and revises some relativity.



The Davisson-Germer experiment is shown in (a) above. Electrons are emitted from a heated filament, accelerated through a potential difference V_0 volts, and directed at a crystal of nickel. When V_0 is 54 volts, a peak in the signal I measured by the detector is observed when the angle $\theta = 50^o$, as in (b).

1. Find an expression for the path difference between waves scattered from adjacent atoms in (c), and hence show that the condition for constructive interference is:

$$d \sin\theta = n\lambda \ ,$$

   where n is an integer.

2. If the spacing of the atoms in the nickel crystal was measured (by X-ray diffraction) to be 0.215 nm and the signal at 50^o is assumed to be the $n = 1$ peak, what does the result in (1) suggest for the electron wavelength?

3. If $V_0 = 54$ volts, what is the kinetic energy of the electrons after acceleration, in eV?

4. What is the speed of electrons that have fallen through a potential difference of 54 volts, assuming that non-relativistic formulae apply? Is this assumption valid? You could also decide if non-relativistic formulae apply, without calculating the speed, given the information that the rest mass of the electron is 0.511 MeV/c^2. How?

5. Show that de Broglie's relationship predicts that the wavelength of an electron accelerated through V_0 volts is given by:

$$\lambda = \frac{h}{\sqrt{2m_e e V_0}} \ .$$

6. Determine the electron wavelength predicted by de Broglie at $V_0 = 54$ volts and compare with your result in (2).

7. The Americans Davisson and Germer shared the 1937 Nobel Prize with G.P. Thomson. The latter used a much higher energy electron beam of 600 eV and produced his diffraction patterns by transmission through films rather than reflection. By considering how the electron wavelength depends on V_0, calculate the wavelength used by G.P. Thompson.

8. G.P. Thomson was the son of J.J. Thomson, the discoverer of the electron. The father got the Nobel Prize for showing that the electron was a particle, and the son for showing that it was a wave! What was G.P. Thomson's other claim to fame?