Level 3 Condensed Matter Physics- Part II

Examples Class 1

(1) *Crystal and photon momenta*

(i) Using Bloch's theorem state the form of the electron wavefunction in a periodic crystal potential.

(ii) Using the quantum mechanical operator for momentum show that the Bloch wavevector **k** does <u>not</u> represent the electron momentum (it is in fact the crystal momentum, i.e. electron + lattice)

(iii) Calculate the momentum of a 500 nm wavelength photon.
Calculate the crystal momentum $\hbar\mathbf{k}$ corresponding to the first Brillouin zone of a linear chain of atoms with atom spacing a = 5 Å.
Comment on the magnitude of photon vs crystal momenta.

(2) *Band gap in semiconductors*

(i) Draw separate energy (E)- wavenumber (k) diagrams for a direct and indirect band gap semiconductor. Clearly label the conduction, valence bands and band gap in each diagram.

(ii) The band gap (E_g) in eV of a CdS_xTe_{1-x} alloy is given by:

$$E_g(x) = 1.54 - 0.90x + 1.84x^2$$

Determine the composition range over which the alloy is transparent to light of 700 nm wavelength.

(iii) The energy-wavenumber dispersion relations for the conduction band minimum (E_c) and valence band maximum (E_v) for a particular semiconductor are:

$$E_c(k) = k^2 - 2.0k + 4.3$$

$$E_v(k) = -3.0k^2 + 2.0$$

Where the wavenumber k is in units of m^{-1} and the resulting energy is expressed in units of eV. Calculate the magnitude of the semiconductor band gap and deduce if it is a direct or indirect band gap.