FSK324 Test 1
Solid State Physics

Time: 2 hours	**Total marks: [100]**

Section A: *Answer **all** questions in this section*

1. a.) Distinguish between a primitive and a non-primitive unit cell. [3]
   b.) Distinguish between a non-primitive and a non-Bravais lattice. [3]
   c.) Calculate the number of atoms in the HCP structure. [3]
2. State five operations that represent point symmetries on a crystal lattice. [5]
3. A crystal that has a n-fold rotation axis is invariant to a rotation of $2\pi/n$, $n \neq 0$. Show that $n = 1, 2, \ldots, 6$ only. [6]
4. Calculate the density of aluminium (FCC) if the lattice parameter is 0.404 nm and its atomic mass is 26.98. [6]
5. a.) Determine the energy of a photon, an electron and a neutron if the wavelength of each is 1.00Å. [6]
   b.) A beam of 150 eV electrons is incident on a powdered sample of nickel. Calculate the two smallest Bragg angles at which diffraction can occur if nickel is FCC with lattice parameter 3.25Å. [6]
   c.) What is a Brillouin zone? Describe how it is constructed. [6]
6. Starting from the Laue equation $\Delta\bar{k}=\bar{G}$, describe and illustrate as necessary how the Ewald construction is done. [6]

Section B: *Answer any five questions in this section*

7. Consider the hexagonal closed-packed (HCP) unit cell.
   a.) Show that the c/a ratio equals $\sqrt{8/3}$. [4]
   b.) Determine the packing fraction of the HCP structure. [6]
8. The total amplitude of the scattered wave in the direction $\overline{k'}$ for N cells is $F_{\overline{G}} = NS_{\overline{G}}$, where $S_{\overline{G}}$ is the structure factor defined as the integral [10]

$$S_{\overline{G}} = \int_{\text{cell}} n(\overline{r}) e^{-\overline{G}\cdot\overline{r}} dV$$

and $\Delta\overline{k} = \overline{G}$. The lattice vector $\overline{r} = 0$ at one corner. Show that the structure factor for hkl reflections is given by

$$S_{\overline{G}}(hkl) = \sum_{j}^{N} f_j e^{-2\pi i(hx_j + ky_j + lz_j)}.$$

9. The atomic form-factor for the j-th atom is defined as

$$f_j = \int n_j(\bar{\rho}) e^{-i\bar{G}\cdot\bar{\rho}_j}\, dV,$$

where $\bar{\rho}$=$\bar{r}$-$\bar{r}_j$. Show that for a spherical volume element centered at the origin, the form factor can instead be written as

$$f_j = 4\pi \int r^2 n_j(r) \frac{\sin Gr}{Gr}\, dr.$$

[10]

10. Derive the conditions necessary for diffraction in a FCC lattice if the structure factor is given by [10]

$$S_G = \sum_{j} f_j e^{(-i\overline{G}\cdot\overline{r}_j)}$$

11. The Bragg angle for a certain reflection of a powdered sample of copper is 47.75^o at 20^oC, and 46.60^o at 1000^oC. Determine the coefficient of linear expansion of copper. [10]

12. A study of aluminium ($a = 0.405\ nm$) is made using 50 keV radiation that is incident at 88^o with the (hkl) planes. What order reflections are present in the diffracted beam? *Ignore diffraction due to wavelengths greater than 0.2 nm, that are too weak to observe.* [10]

Useful constants

Planck's constant	$h = 6.626 \times 10^{-34}\ J.s$,	and $\hbar = h/2\pi$
Avogadro's constant	6.022×10^{23} mol^{-1}	
Electronic charge	$e = 1.6022 \times 10^{-19}$ C	
Electron mass	$m_e = 9.109 \times 10^{-31}$ kg	
Neutron mass	$m_n = 1.675 \times 10^{-27}$ kg	
Boltzmann's constant	$k_B = 1.38 \times 10^{-23}\ J/K$	