FSK324 Test 1
Solid State Physics

Time: 90 minutes	**Total marks: [70]**

Section A - The Crystalline State: *Answer any five questions in this section*

1. i.) Distinguish between amorphous, poly-crystalline and single crystal materials [3]
   ii.) What are line defects and vacancies? [3]
2. Using suitable diagrams, describe how Miller indices of crystal planes and crystal directions are determined [6]
3. Write down Bragg's law, defining all symbols used. [6]
4. Gold, which has an FCC structure, has density $\rho = 19.3\ g/cm^3$, and atomic number 197. Calculate
   i.) the distance between the (111) planes [3]
   ii.) the atomic radius of the gold atom, assuming that the spheres just touch each other. [3]
5. Show that for the HCP structure $c/a = \sqrt{8/3}$. [6]
6. For sodium, which transforms from BCC ($a = 0.423\ nm$) to HCP at 23K, calculate the parameter a in hexagonal phase for which $c/a = \sqrt{8/3}$. [6]

Section B - Diffraction & the Reciprocal lattice
Answer any five questions in this section

7. A crystal has n-fold rotation axis if it is invariant to a rotation of $2\pi/n$, $n \neq 0$. Show that $n = 1, 2, \ldots, 6$ only. [8]
8. Show that
   i.) the reciprocal lattice vector $\overrightarrow{G}_{hkl}$ is perpendicular ($\perp$) to the (hkl) plane. [4]
   ii.) the condition $\Delta\overrightarrow{k} = \overrightarrow{G}$ leads to Bragg's Law. [4]
9. Given that the structure factor is given by equation (1), derive the conditions necessary for diffraction in a BCC lattice. [8]

$$S_G = \sum_j f_j e^{(-i\overrightarrow{G}\cdot\overrightarrow{r}_j)} \tag{1}$$

10. 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. [8]

11. A beam of 150 eV electrons is incident on a sample of powdered nickel. If nickel has the FCC structure with $a = 3.25$Å, determine the two smallest angle at which diffraction can occur. [8]

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.* [8]

Some general information and data

Planck's constant	$h = 6.626 \times 10^{-34}\ J \cdot s$
	$\hbar = h/2\pi$
Avogadro's constant	$6.022 \times 10^{23}\ \text{mol}^{-1}$
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	$k_B = 1.38 \times 10^{-23}\ J/K$
Electron concentration	$N = Z_\nu \rho N_A / M$
Debye frequency	$\omega_D = \nu\left(6\pi^2 n\right)^{\frac{1}{3}}$
Debye temperature	$\theta_D = \hbar\omega_D / k_B$
Fermi energy	$\varepsilon = \frac{\hbar^2}{2m}\left(3\pi^2 n\right)^{\frac{2}{3}}$
A useful integral:	$\int_0^\infty \frac{x^3}{e^x - 1} dx = \frac{\pi^4}{15}$