Assignment 4 (Quantum Mechanics)

1. Find packing fraction of SC, BCC and FCC unit cell.
2. What is the de Broglie wavelength (in Å) of an electron at 100 eV? What is the wavelength for electrons at 12 keV which is typical of electron microscopes? Comparing this to visible light, comment on the advantages of electron microscopes.
3. An electron is described by a plane-wave wave function $\Psi(x,t) == \mathbf{Ae^{i(10x+3Y-\ 4t)}}$.Calculate the expectation value of a function defined as $(4p_x^2 + 2p_z^3 + 7E/m)$, where m is the mass of the electron p_x and p_z are the x and z components of momentum and E is energy. (Give values in terms of the Planck constant.)
4. A particle is trapped in the ground state (lowest energy level) of a potential well of width L. To understand how the particle is localized, a common measure is the standard deviation Δx defined by $\Delta x = SQRT(<x^2> - <x>^2)$, where $<x^2>$ and $<x>^2$ are the expectation values of x^2 and x, respectively. Find the uncertainty Δx in the position of the particle in terms of length L and estimate the minimum uncertainty in the momentum of the particle, using the Heisenberg uncertainty principle in terms of L and the Planck's constant h.
5. Labels the Planes illustrated in figure P1-3.

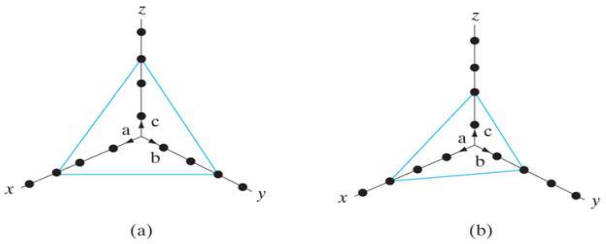
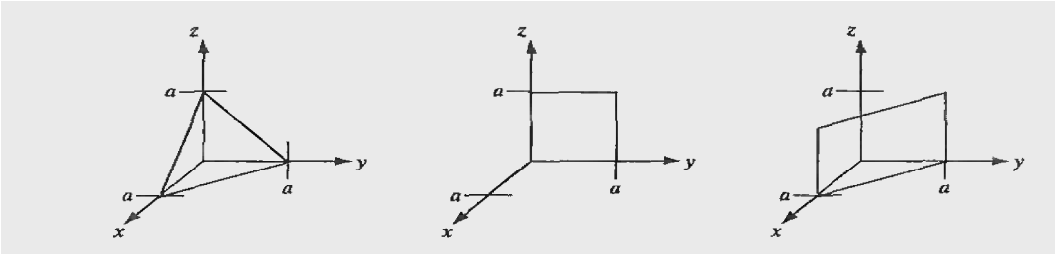
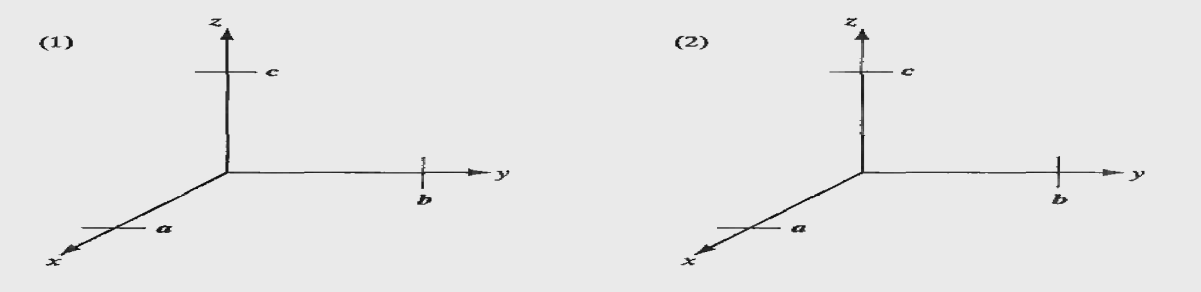


Figure 1.17.1 P1-3

6. A crystal with a simple cubic lattice and a monoatomic basis has an atomic radius of 2.5 Å and an atomic weight of 5.42. Calculate its density assuming that the atoms touch each other.
7. Find the number of atoms/cm^2 on the (100) surface of a Si wafer.
8. The ionic radii of Na^+ (atomic weight 23) and Cl^- (atomic weight 35.5) are 1.0 and 1.8 Å, respectively. Treating the ions as hard spheres, calculate the density of NaCl. Compare this with the measured density of 2.17 g/cm^3 .
9. Find the angle between [111] and [100] directions in a cubic lattice.
10. (a) Label the following planes using the correct notation for a cubic lattice of unit cell edge length a (shown within the unit cell).
    (b) Write out all of the equivalent <100> directions using the correct notation.



(c) On the two following sets of axes, (1) sketch the [011] direction and (2) a (111) plane (for a cubic system with primitive vectors **a**, **b**, and **c**).



11. Determine the total number of energy states in the GaAs between E_c and E_c+kT at T=300 K. For GaAs $m_n^* = 0.067\ m_o$, $m_p^* = 0.48\ m_o$.
12. Find the ratio of the effective density of states in the conduction band at E_c+kT to the effective density of states in the valence band at E_v-kT.