1. An iron-carbon steal containing 0.5 percent carbon has a microstructure consisting of 85 percent pearlite and 15 percent ferrite.
   (a) Are these the amounts of the constituents that one would expect to find in the steel if it had been slowly cooled from the austenite region?
   (b) In a slowly cooled microstructure, pearlite normally has a 7 to 1 ratio of the widths of the ferrite and cementite lamellae. What would this ratio be in the present case?

   (10%)

2. Determine the mean time of stay of an oxygen atom in an interstitial site in niobium at 300 k. The lattice parameter, a, for niobium is equal to 0.3301 nm. The diffusion equation for oxygen in niobium is

   $$D = 7.31 \times 10^{-7} e^{-110{,}000/RT}$$

   $R = 8.314$ J/k mole *(10%)*

3. The dendrite arm spacing (DAS) is dependent on the cooling rate, ε, by an equation of the form $DAS = k\varepsilon^{-n}$. Suppose for Al-4.9%Cu, DAS was measured as 100 and 10 μm at the cooling rates 0.1 and 60 k/s respectively.
   (a) Determine k and n for the alloy.
   (b) What cooling rate is necessary to reduce the arm spacing to 1.0 μm?
   (c) Melt spinning and powder atomization are two techniques which are commonly used to achieve rapid cooling rates. Briefly describe what these techniques are.

   (10%)

4. Sketch stress strain curves and indicate the various work hardening stages for single crystals of the following:
   (a) FCC crystal at low temperature (no cross slip)
   (b) FCC crystal at high temperature (cross slip may occur)
   (c) BCC crystal
   (d) HCP crystal oriented for basal slip.
   Explain the mechanisms of the various work hardening stages.
   (20%)

5. There are several important methods to increase the strength of HSLA steels. Discuss these methods with the proper mechanisms in detail. What are the characteristics of the dual phase steel? What would you suggest a heat treatment to get the dual phase structure?
   (20%)

6. Consider the Bragg equation with respect to first order reflection from {100} plane of a bcc metal by how much of a wavelength do the reflected pathlengths differ for two adjacent parallel (100) planes, if the interplanar spacing, d, is taken as, a, instead of , a/2? Does this explain why the {100} plane is not a reflecting bcc plane? Explain. *(10%)*

7. (a) Draw a diagram to show the energy barrier associated with the growth of a precipitate during a solid state phase change in a polymorphic pure metal.
   (b) Based on the thermodynamic and kinetic considerations, derive the growth equation

$$v = \lambda \nu e^{-\Delta g_a / kT} \left(1 - e^{-\Delta g^{Fe} / kT}\right)$$

where Δg_a : the energy barrier between α & β

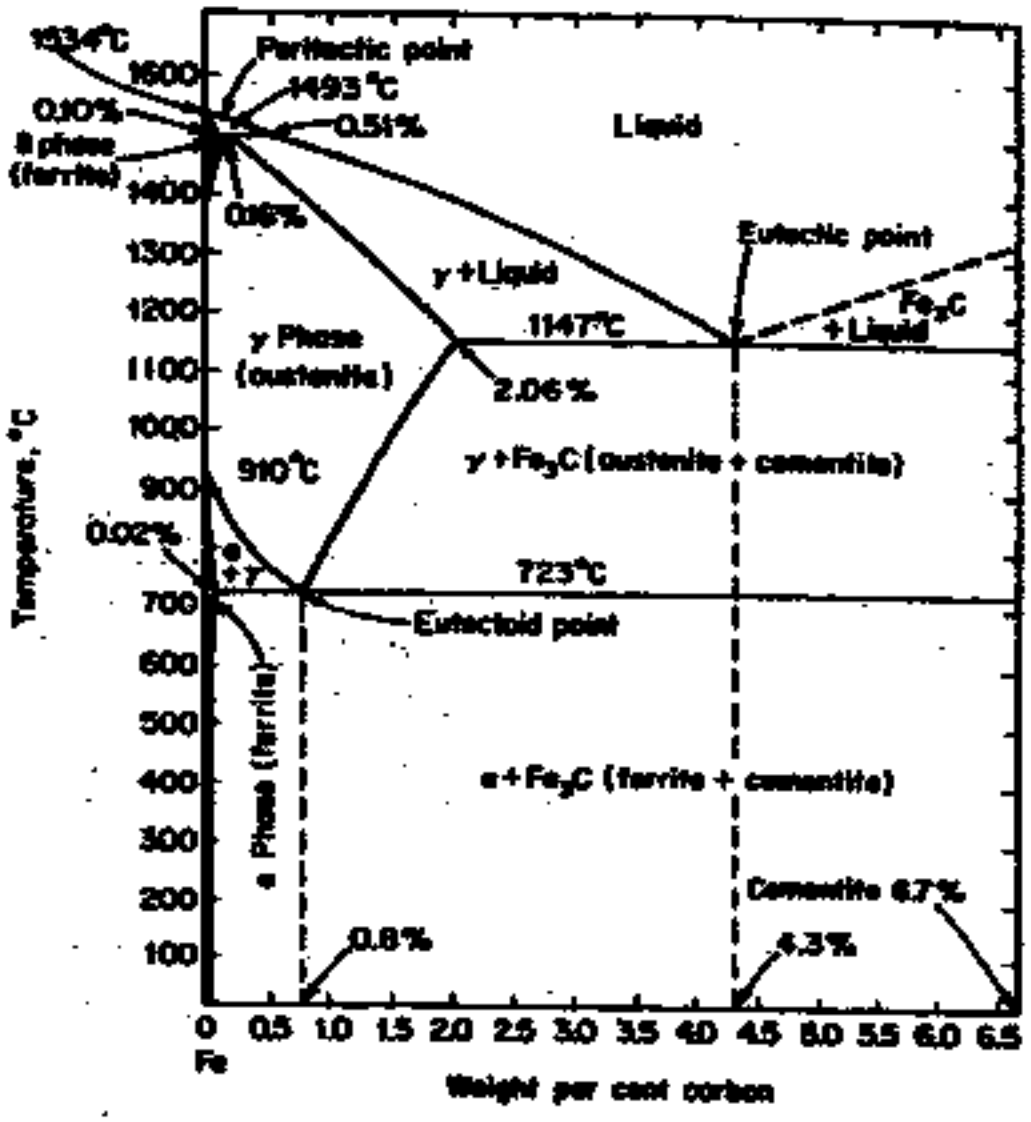
$\Delta g^{\beta\alpha}$: the difference in free energy of α & β

ν : an atom vibration frequency

λ : the atom average jump distance.

(c) Find the simplified equation of the growth velocity with the condition of a small supercooling and a larger supercooling.
(d) Draw a diagram to show the variation of growth velocity with temperature for the growth of a precipitate.

(20%)



The metastable system $Fe\text{-}Fe_3C$.