1. The dislocation of Burgers vector $[\bar{1}01]a/2$ moves along the $(1\bar{1}1)$ plane of an fcc crystal and interacts with a parallel dislocation on the $(11\bar{1})$ plane having Burgers vector $[1\bar{1}0]a/2$. The interaction forms a Cottrell-Lomer dislocation. Determine the three partial dislocations making up the Cottrell-Lomer dislocations. Which of these three dislocations is the stair rod dislocation? (10%)

2. Show by means of qualitative sketches the essential difference between X-ray diffraction patterns that would be produced by
   (a) a mechanical mixture of 50% copper powder with 50% nickel powder,
   (b) an alloy of 50% copper and 50% nickel. (Hint: Both Ni and Cu are fcc metals and the atomic radius of Cu is slighter larger than that of Ni.) (10%)

3. For interstitial diffusion in a body-centered cubic lattice,
   (a) Prove that α, in the diffusion equation $D = \alpha a^2/\tau$, equals 1/24, where a and τ are respectively the lattice constant of the solvent and the mean time of stay of a solute atom in an interstitial site. (5%)
   (b) For the torsion pendulum with a vanadium wire containing nitrogen, discuss how the pendulum period and temperature affect the specific damping capacity of this vanadium wire. (5%)

4. Consider the problem of increasing the chemical homogeneity of a solid solution of zinc in copper.
   (a) Can inhomogeneity be completed removed by diffusion in a practical time? Why? (5%)
   (b) Would cold-working a cast alloy before a high-temperature increase or decrease the rate of homogenization? Why? (5%)

5. If a hypereutectoid steel is slowly cooled from the austenite region, the primary cementite crystals form a continuous layer in the austenite grain boundaries.
   (a) How this cementite network affects the mechanical properties of this steel? Why? (5%)
   (b) What heat treatment would be most effective in removing this cementite network? (5%)

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6. Discuss and explain in detail how cooling rate affects (a) the degree of segregation and (b) the scale of the microstructural features of an Al-7% (in weight) Si alloy ingot. (Hint: The Al-Si phase diagram consists of one eutectic reaction and two terminal solid solutions. The eutectic composition contains about 12.6 % Si.) (10%)

7. Discuss the dependence of the yield strength on temperature and strain rate for the materials that deform primarily by
   (a) slip. (5%)
   (b) twinning. (5%)

8. Briefly discuss the various energies associated with a martensitic transformation. Why different materials undergone a complete temperature-induced martensitic transformation cycle might have hysteresis loops of quite different sizes? (10%)

9. A component is made of steel for which $K_C = 54\mathrm{MNm}^{-3/2}$. Non-destructive testing by ultrasonic methods shows that the component contains cracks of up to 2a = 0.2 mm in length. The crack-growth rate under cyclic loading is given by $\frac{da}{dN} = A(\Delta K)^4$, where $A = 4\mathrm{x}10^{-14}(\mathrm{MNm}^{-2})^{-4}\mathrm{m}^{-1}$. The component is subjected to an alternating stress of range $\Delta\sigma = 180\mathrm{MNm}^{-2}$ about a mean stress of $\frac{\Delta\sigma}{2}$. Given that $\Delta K = \Delta\sigma\sqrt{\pi a}$, calculate the number of cycles to failure. (10%)

10. Why dynamic recovery occurs most strongly in metals of high stacking-fault energies, but not in those of very low stacking-fault energies? How temperature affects the tensile strength and elongation of the fcc metals of high stacking-fault energies? Explain why. (10%)

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