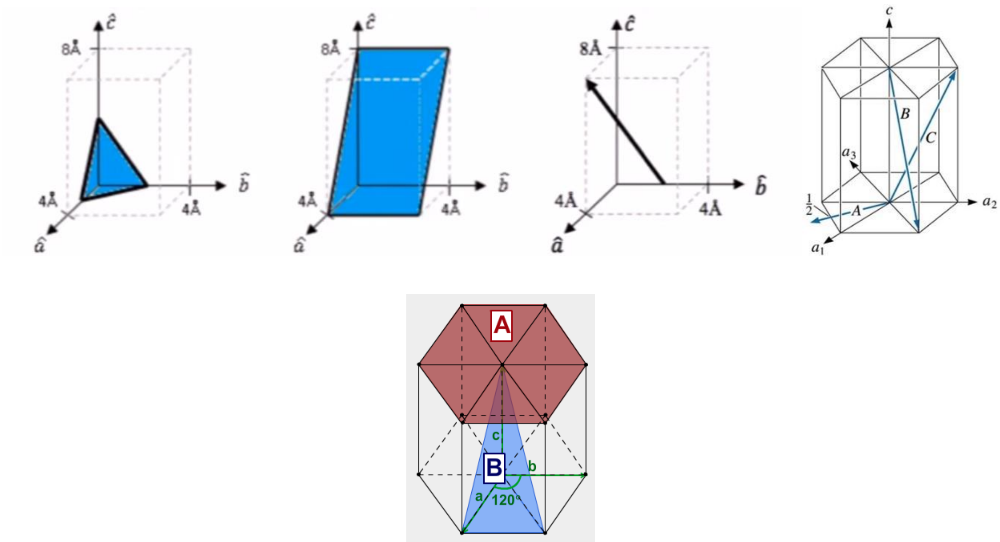
Materials Science and Engineering

1. Draw the following directions and planes: (a) $[1\bar{2}3]$, (b) {110}, (c) $(\bar{3}02)$, (d) $1/2[1\bar{1}00]$ and (e) $(\bar{3}121)$.

2. Determine the Miller or Miller-Bravais indices of the following figures.



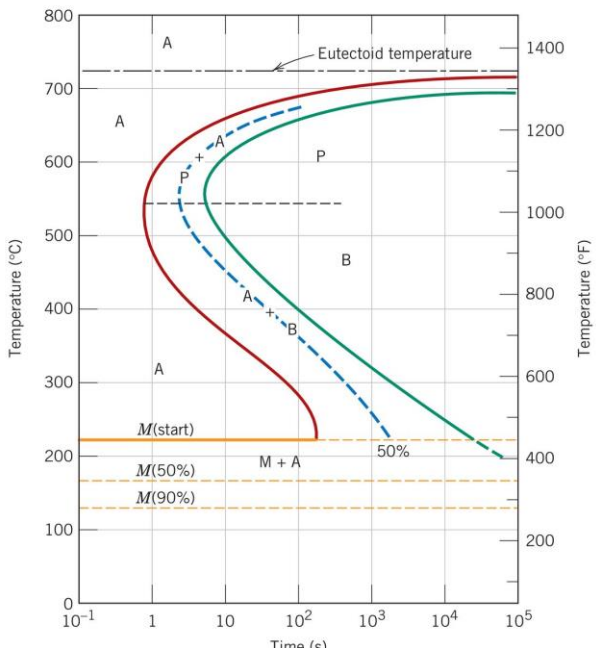
3. Please determine whether the following planes diffract incident x-ray for the simple cubic, body-centered cubic, face-centered cubic: (120), (214), (451), (323), (422), (204), $(\bar{1}03)$, (200), $(6\bar{1}4)$, (010), (934) and (206)

4. A tensile strength is to be applied along the long axis of a cylindrical brass rod that has a diameter of 10 mm (0.4 in). Determine the magnitude of the load required to produce a 2.5×10^{-3} mm (10^{-4} in) change in diameter if the deformation is entirely elastic. (ν=0.34 and E=97 GPa).

5. Please determine and draw the crystal structure of LiF and calculate its density given r_{Li}=0.133 nm, r_F=0.064 nm, A_{Li}=6.94, and A_F=19.

6. Using the isothermal transformation diagram for an iron-carbon alloy of eutectoid composition below, specify the nature of the final microstructure (in terms of

microconstituents present and approximate percentages of each) of a small specimen that has been subjected to the following time-temperature treatment. In each case assume that the specimen begins at 760 °C (1033 K) and that it has been held at this temperature long enough to have achieved a complete and homogeneous austenitic structure.



a. Cool rapidly to 700 °C (973 K), hold for 10^4 s, then quench to room temperature.

b. Reheat the specimen in part (a) to 700 °C for 20 h.

c. Rapidly cool to 600 °C (873 K), hold for 4 s, rapidly cool to 448 °C (721 K), hold for 10 s, then quench to room temperature.

d. Cool rapidly to 398 °C (671 K), hold for 2 s, then quench to room temperature.

e. Cool rapidly to 398 °C (671 K), hold for 20 s, then quench to room temperature.

f. Cool rapidly to 398 °C (671 K), hold for 200 s, then quench to room temperature.

g. Cool rapidly to 575 °C (848 K), hold for 20 s, rapidly cool to 350 °C (623 K), hold for 100 s, then quench to room temperature.

h. Cool rapidly to 250 °C (523 K), hold for 100 s, then quench to room temperature in water. Reheat to 315 °C (588 K) for 1 h and slowly cool to room temperature.

7. Please derive the condition of necking in the true stress-true strain diagram.

8. Write down the electron configuration of a new material with atomic number of 114 and determine which group does it belong.

9. Please write down the following three materials in the order of melting points and explain why. (a) silver, (b) CH_4, (c) MgF_2, (d) ice and (e) $C_{10}H_{22}$.

10. Memorize the 7 crystal system and 14 Bravais lattice points.

11. (a) Rewrite the expression for the total free energy change for nucleation for the case of a cubic nucleus of edge length a (instead of a sphere of radius r). Now differentiate

this expression with respect to a and solve for both the critical cube edge length, a*, and ΔG*.

(b) Is ΔG* greater for a cube or a sphere? Why?

12. (a) For the solidification of nickel, calculate the critical radius r* and the activation free energy ΔG* if nucleation is homogeneous. Values for the latent heat of fusion and surface free energy are -2.53×10^9 J/m^3 and 0.255 J/m^2, respectively. Use the supercooling value found in a textbook.

    (b) Now calculate the number of atoms found in a nucleus of critical size. Assume a lattice parameter of 0.360 nm for solid nickel at its melting temperature.

13. Is it possible to have a copper–silver alloy of composition 20wt% Ag–80wt% Cu that, at equilibrium, consists of α and liquid phases having mass fractions $W_\alpha = 0.80$ and $W_L = 0.20$? If so, what will be the approximate temperature of the alloy? If such an alloy is not possible, explain why.

14. Consider a metal single crystal oriented such that the normal to the slip plane and the slip direction are at angles of 60° and 35°, respectively, with the tensile axis. If the critical resolved shear stress is 6.2 MPa, will an applied stress of 12 MPa cause the single crystal to yield? If not, what stress will be necessary?

15. Consider a single crystal of some hypothetical metal that has the FCC crystal structure and is oriented such that a tensile stress is applied along a [112] direction. If slip occurs on a (111) plane and in a [011] direction, and the crystal yields at a stress of 5.12 MPa compute the critical resolved shear stress. compute the critical resolved shear stress.

16. Compute the volume percent of graphite, V_{Gr}, in a 2.5 wt% C cast iron, assuming that all the carbon exists as the graphite phase. Assume densities of 7.9 and 2.3 g/cm^3 for ferrite and graphite, respectively.

17. (a) Compute the electrical conductivity of a cylindrical silicon specimen 7.0 mm diameter and 57 mm in length in which a current of 0.25 A passes in an axial direction. A voltage of 24 V is measured across two probes that are separated by 45 mm.

    (b) Compute the resistance over the entire 57 mm of the specimen.

18.(a) Calculate the number of free electrons per cubic meter for silver, assuming that there are 1.3 free electrons per silver atom. The electrical conductivity and density for Ag are 6.8×10^{7} $(\Omega\cdot m)^{-1}$ and 10.5 g/cm^3, respectively.

(b) Now compute the electron mobility for Ag.

19. For some hypothetical metal, the equilibrium number of vacancies at 900°C is 2.3×10^{25} m^{-3}. If the density and atomic weight of this metal are 7.40 g/cm^3 and 85.5 g/mol, respectively, calculate the fraction of vacancies for this metal at 900°C.

20.Calculate the energy for vacancy formation in nickel (Ni), given that the equilibrium number of vacancies at 850°C (1123 K) is 4.7×10^{22} m^{-3}. The atomic weight and density (at 850°C) for Ni are, respectively, 58.69 g/mol and 8.80 g/cm^3.

21. (a) Briefly define Burgers vector for a dislocation.

(b) Explain how to distinguish edge, screw and mixed dislocation by their difference in dislocation line and Burgers vector.

22. (a) What is glass transition temperature in polymers?

(b) Suggest one experimental method to determine the glass transition temperature of a polymer, for example polystyrene. Briefly explain how the instrument works.

23. (a) Describe the formation of depletion layer in a p-n junction.

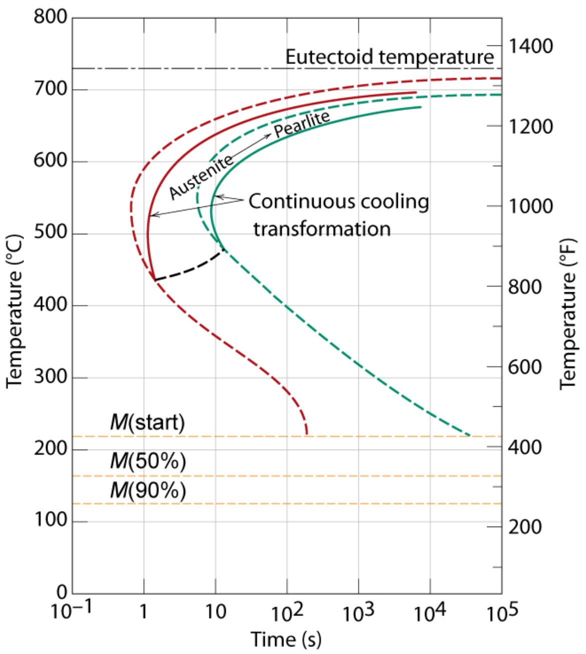
(b) What is the difference in I-V relationship of a p-n junction compared to an ohmic material under electric conduction?

24. (a) What is a 0D material? Draw its density of state (DoS) diagram.

(b) Why the color of quantum dots (e.g. Gold) appear differently compared to their 3D bulk form?

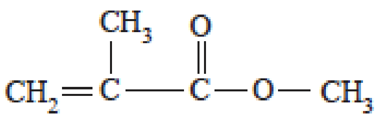
25. (a) Below is a typical Continuous Cooling Transformation (CCT) Diagram of a steel. Draw a quenching (i.e. rapid cooling and hardening) curve on the CCT that the steel will result in fully martensitic structure.

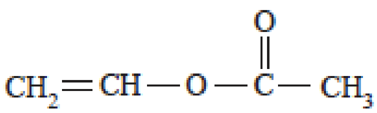
(b) Rank the following quenching medium according to their cooling rate: water, oil, still air.



26. (a) For each of the monomer below, write down their structural formulae after polymerization. (b) Name the polymers.

$CH_2{=}CH{-}COOH$

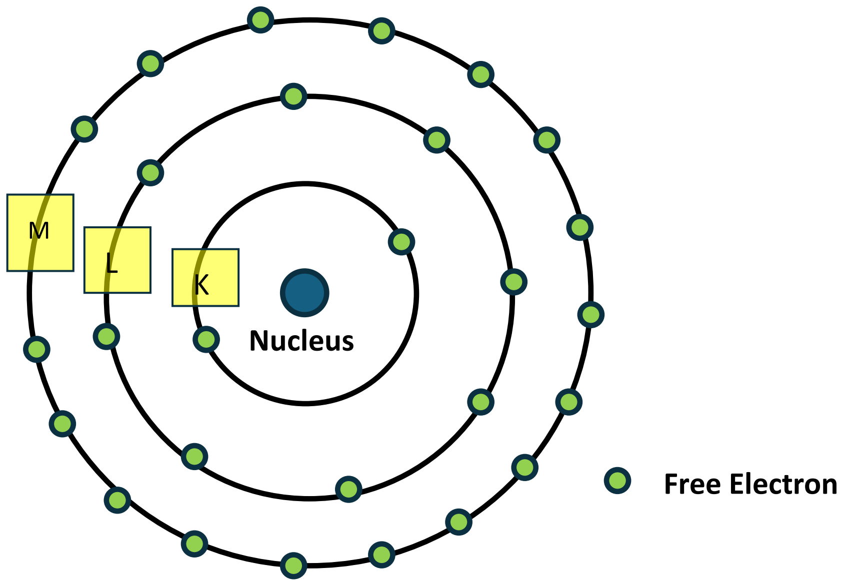




$CH_2{=}CH{-}CH_3$

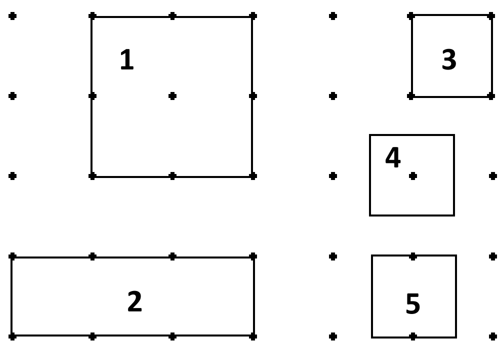
$CH_2{=}CH{-}CN$

27. (a) Explain the formation of X-ray by using the following atomic model.
(b) according to your answer, how can you generate an X-ray source for a diffractometer?



28. Explain the relationship of mean free path and pressure in a vacuum chamber. Why does the operation of X-ray photoelectron spectroscopy (XPS) requires ultra-high vacuum environment?

29. Which of the following are primitive cells? Justify your answer by the definition of a primitive cell.



30. TiO2 is a well-known smart material. Suggest one of its application and the working mechanism behind.