1. Why does slip occur in close-packed directions?

2. Why does slip occur on highest-density planes?

3. What are the Miller indices of the close-packed direction in a FCC crystal?

4. In a cube of edge length *a*, what is the length of the face diagonal?

5. What is the analytical relationship between the edge length and atomic radius for a FCC unit cell?

6. How many atoms per unit cell in a FCC crystal?

7. Calculate the volume per atom in a unit cell for FCC iron (r = 0.124 nm). Report the value in cm^3/atom/unit cell.

8. How can a thermoplastic be converted into a thermoset (one word)?

9. What type of solid solution is expected to form when C is added to Fe (one word)?

10. A synthetic biomaterial is prepared to replace a biological membrane that selectively removes certain metabolites from the body. If the concentrations on both sides of a 0.1-cm-thick membrane are typically maintained at 0 and 8×10^{20} molecules/cm^3, and the diffusion coefficient of the metabolite through the membrane is 10^{-12} m^2/s, what is the flux of metabolites through the membrane?

11. How long does it take for a random-coil (i.e., roughly spherical in shape) protein in solution to diffuse a distance equivalent to its diameter (d = 20 nm) if its diffusion coefficient is 2 x 10^{-12} m^2/s?

12. What is the concentration of vacancies in copper at room temperature (25 °C) if the activation energy for formation of vacancies is 83 kJ/mol?

13. What is the ratio of iron to carbon atoms in steel that contains 0.4 wt% carbon?

14. If the infinite-temperature self-diffusion coefficient for polyethylene in the melt is 1.2 x 10^{-11} m^2/s and the activation energy is 28 kJ/mol, what is the self-diffusion coefficient at 200 °C?

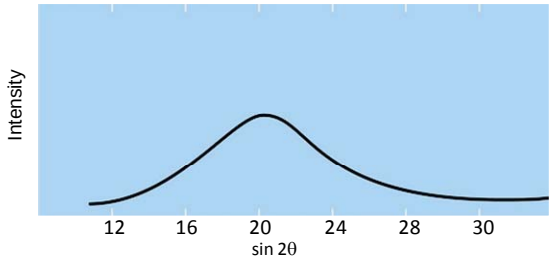
15. A polymer of average chain length 3 μm exhibits a self-diffusion coefficient of 10^{-18} m^2/s. What is the self-diffusion coefficient of the same polymer of average chain length 1 μm at the same temperature?

16. How long does it take to reach a carbon concentration of 0.2% at a depth of 0.01 cm beneath the surface of an iron bar when carburizing at 1000 °C? The initial concentration of the carbon in the bar is 0.1% and the surface concentration is maintained at 0.4%. The diffusion coefficient of carbon in iron at this temperature is 2.98 x 10^{-11} m^2/s.

17. Which of the following materials exhibit mechanical properties that are anisotropic?
(a) single crystal of FCC copper
(b) bone
(c) wood
(d) steel
(e) all of the above

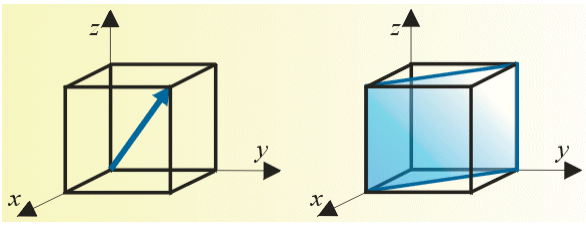
18. What is the density of FCC copper (r_{Cu} = 0.128 nm)?

19. For the amorphous material represented by the x-ray diffractogram shown below, what is the average inter-atomic spacing in Å? The wavelength of the radiation is 1.54 Å.



20. Sketch a schematic plot of specific volume versus temperature for a semicrystalline polymer. Clearly label axes and any thermal transition(s).

21. What are the Miller indices for the direction shown in the schematic below?



22. What are the Miller indices for the plane shown in the schematic above?

23. What is the flux of copper atoms into an aluminum slab if the concentration at the surface is 0.19 atomic % and the concentration 1.2 mm below the surface is 0.18 atomic % (D = 4 x 10^{-14} m^2/s and density of FCC aluminum is 2.70 g/cm^3)?

24. How long does it take a dye molecule to penetrate to the center of polymer fiber with a cylindrical cross-section (diameter = 25 μm) if the dye diffusion coefficient at this temperature is 10^{-13} m^2/s?

25. What is the viscosity of molasses at 100 °C if it is 50 Poise at 25 °C and the activation energy is 30 kJ/mol?

Bonus Problems:

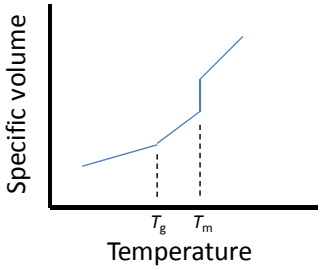
26. A ceramic cylinder, 10-mm in diameter and 1-m long, is axially loaded with a force of 2000 N. Assuming the material is linear elastic with a modulus of 380 GPa, what is the elongation in μm?

27. What is the relaxation time of a polymer fiber that is stretched 25% and held if the initial tensile stress is 30 kPa and the stress after 10 minutes is 20 kPa?

$2d \sin\theta = n\lambda$
$N_v = N_T \exp(-Q_{fv}/RT)$, $\eta = \eta_o \exp(Q/RT)$, $D = D_o \exp(-Q/RT)$, $Rate = C\exp(-Q/RT)$,
$D \sim 1/L^2$, $J = -D(dC/dx)$, $C(x,t) - C_o/(C_s - C_o) = 1 - \text{erf}(x/2\sqrt{Dt})$, $C(x,t) = (\beta/2\sqrt{\pi Dt})\exp(-x^2/4Dt)$,
$x_{\text{eff}} = \gamma\sqrt{Dt}$
$\sigma(t) = \sigma_o exp(-t/\tau)$, $\sigma = F/A_0$, $\varepsilon = (l - l_o)/l_o$, $E = \sigma/\varepsilon$,
R = 8.314 J/K mol, g = 9.8 m/s^2, N_{Av} = 6.02 x 10^{23}, C = 12 g/mol, Fe = 55.8 g/mol, Cu = 63.5 g/mol, Al = 27 g/mol

z	erf(z)	z	erf(z)	z	erf(z)
0	0	0.35	0.379	0.70	0.678
0.05	0.056	0.40	0.428	0.75	0.711
0.10	0.113	0.45	0.476	0.80	0.742
0.15	0.168	0.50	0.521	0.85	0.771
0.20	0.223	0.55	0.563	0.90	0.797
0.25	0.276	0.60	0.604	1.00	0.843
0.30	0.329	0.65	0.642	1.05	0.862

1. minimum distance for atoms to move between lattice points
2. least friction
3. ‹1 1 0›
4. a√2
5. a = 4r/√2
6. 4
7. 1.08 x 10^{-23} cm^3/atom/unit cell
8. crosslink
9. interstitial
10. 8 x 10^{13} molecules/cm^2s
11. 2.2 x 10^{-5} s = 22 μs
12. 2.8 x 10^{-15}
13. 53
14. 9.7 x 10^{-15} m^2/s
15. 9 x 10^{-18} m^2/s
16. 171 s = 2.85 min
17. a,b,c
18. 8.9 g/cm^3
19. 4.4 Å



20.
21. [1 1 1]
22. (1 1 0)
23. 8.5 x 10^9 atoms/cm^2s
24. 391 s = 6.5 min
25. 4.4 Poise

Bonus:
26. 67 μm
27. 1480 s