Chapter 6 Supplemental Problems

Electrical Properties

1. What will be the resistance of a copper wire 0.08" in diameter and 100 ft. long if its resistivity is 1.7 microohm-cm?
2. A maximum resistance of 1 ohm is permitted in a copper wire 25 ft long. What is the smallest wire diameter which can be used?
3. What is the electrical conductivity of iron (a) at room temperature? (b) at 212 ˚F?
4. Silicon has a density of 2.40 g/cc. (a) What is the concentration of the silicon atoms per cubic centimeter? (b)
5. Phosphorus is added to the silicon to make it an n-type semiconductor with a conductivity of 1 mho/cm and an electron mobility of 1700 cm2/volt-sec. What is the concentration of the conduction electrons per cubic centimeter?
6. (a) How many silicon atoms are there for each conduction electron in the above problem? (b) The lattice constant for silicon is 5.42 D, and there are 8 atoms per unit cell. What is the volume associated with each conduction electron?
7. Germanium used for transistors has a resistivity of 2 ohm-cm and an electron "hole" concentration of 1.9 x 1015 holes/cc. (a) What is the mobility of the electron holes in the germanium? (b) What impurity element could be added to germanium to create electron holes?
8. Calculate the mobility of electrons in Cu. The resistivity of Cu is 1.72 x 10-8 ohm-m at 25˚C and its density is 8.9 g/cc. Assume each copper atom donates one valence electron to the conduction band.
9. Define a conductor, semi-conductor and insulator in terms of the energy band model.
10. What is the relation for conducting materials of the resistivity and temperature? Give a qualitative explanation for the three regions of temperature dependence in terms of the two contributions of resistivity.
11. Explain the factors affecting the electrical resistivity of metals.
12. (a) Compute the electrical conductivity of a 5.1-mm (0.2-in.) diameter cylindrical silicon specimen 51 mm (2 in.) long in which a current of 0.1 A passes in an axial direction. A voltage of 12.5 V is measured across two probes that are separated by 38 mm (1.5 in.). (b) Compute the resistance over the entire 51 mm (2 in.) of the specimen.
13. An aluminum wire 4 mm in diameter is to offer a resistance of no more than 2.5 Ω. Look up data for aluminum and compute the maximum wire length.
14. At room temperature the electrical conductivity and the electron mobility for copper are 6.0×10^7 $(\Omega\text{-m})^{-1}$ and 0.0030 m^2/V-s, respectively. (a) Compute the number of free electrons per cubic meter for copper at room temperature. (b) What is the number of free electrons per copper atom? Assume a density of 8.9 g/cm^3.

Answers for Electrical Properties

1. 0.16 ohm.
2. 0.016 in (0.04 cm).
3. (a) 10^5 mho/cm; (b) 6×10^4 mho/cm.
4. (a) 5.15×10^{22} atoms/cc; (b) 3.68×10^{15} carrier electrons/cc.
6. (a) 1.4×10^7 silicon atoms per conduction electron (also 1.4×10^7 silicon atom per phosphorus atom); (b) $(655\ \text{Å})^3$.
7. (a) 1600 cm^2/vol-sec; (b) Al, In, Ga.
8. 4.33×10^{-3} m^2/V-s
12. (a) 14.9 $(\Omega\text{-m})^{-1}$
13. 1195 m
14. (b) 1.48

Magnetic Properties

1. A coil of wire 0.20 m long and having 200 turns carries a current of 10 A. (a) What is the magnitude of the magnetic field strength *H*? (b) Compute the flux density *B* if the coil is in a vacuum. (c) Compute the flux density inside a bar of titanium that is positioned within the coil. (d) Compute the magnitude of the magnetization *M*.
2. The magnetic flux density within a bar of some material is 0.435 tesla at an *H* field of 3.44×10^5 A/m. Compute the following for this material: (a) the magnetic permeability, and (b) the magnetic susceptibility. (c) What type(s) of magnetism would you suggest as being displayed by this material? Why?
3. Compute (a) the saturation magnetization and (b) the saturation flux density for cobalt, which has a net magnetic moment per atom of 1.72 Bohr magnetons and a density of 8.90 g/cm^3.
4. The chemical formula for manganese ferrite may be written as $(MnFe_2O_4)_8$ because there are eight formula units per unit cell. If this material has a saturation magnetization of 5.6×10^5 A/m and a density of 5.00 g/cm^3, estimate the number of Bohr magnetons associated with each Mn^{2+} ion.
5. The following data are for a transformer steel:

H (A/m)	*B* (teslas)
0	0
10	0.03
400	1.28
20	0.07
600	1.36
50	0.23
800	1.39
100	0.70
1000	1.41
150	0.92
200	1.04

(a) Construct a graph of *B* versus *H*. (b) What are the values of the initial permeability and initial relative permeability? (c) What is the value of the maximum permeability? (d) At about what *H* field does this maximum permeability occur? (e) To what magnetic susceptibility does this maximum permeability correspond?

Answers

1. (a) 10,000 A-turns/m' (b) $B_0 = 1.257 \times 10^{-2}$ Tesla; (c) B ~ 1.257×10^{-2} Tesla; (d) $M = 1.81$ A/m
2. (a) $\mu \sim 1.26 \times 10^{-6}$ H/m; $\chi_m = 6 \times 10^{-3}$
3. (a) $M_s = 1.45 \times 10^6$ A/m
4. 4.6 Bohr magnetons/Mn^{2+} ion
5. (a) $\mu_i = 3.0 \times 10^{-3}$ H/m, $\mu_{ri} = 2400$; (b) $\mu(\text{max}) = \sim 9 \times 10^{-3}$ H/m

Optical Properties

1. Compute the velocity of light in calcium fluoride (CaF_2), which has a dielectric constant ϵ_r of 2.056 (at frequencies within the visible range) and a magnetic susceptibility of -1.43 10^{-5}.
2. The fraction of nonreflected radiation that is transmitted through a 10-mm thickness of a transparent material is 0.90. If the thickness is increased to 20 mm, what fraction of light will be transmitted?
3. The transmissivity T of a transparent material 20 mm thick to normally incident light is 0.85. If the index of refraction of this material is 1.6, compute the thickness of material that will yield a transmissivity of 0.75. All reflection losses should be considered.

Answers

1. $v = 2.09 \times 10^8$ m/s
2. $I_T/I_0 = 0.81$
3. $l = 67.3$ mm

Thermal Properties (Note: some of this is covered in previous chapters)

1. For aluminum, the heat capacity at constant volume C_v at 30 K is 0.81 J/mol-K, and the Debye temperature is 375 K. Estimate the specific heat (a) at 50 K and (b) at 425 K.
2. An aluminum wire 10 m (32.8 ft) long is cooled from 38 to 1°C. How much change in length will it experience?
3. To what temperature must a cylindrical rod of tungsten 10.000 mm in diameter and a plate of 316 stainless steel having a circular hole 9.988 mm in diameter have to be heated for the rod to just fit into the hole? Assume that the initial temperature is 25°C.

Answers

1. (a) C_v = 139 J/kg-K; (b) C_v = 925 J/kg-K
2. Δl = -9.2 mm
3. T_f = 129.5 °C