Question 1

(a) Compute the electrical conductivity of a 5.1 mm diameter cylindrical silicon specimen 51 mm 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.

(b) Compute the resistance over the entire 51 mm of the specimen.

<u>Solution</u>

(a) We use Equations 18.3 and 18.4 for the conductivity, as

$$\sigma = \frac{1}{\rho} = \frac{Il}{VA} = \frac{Il}{V\pi\left(\frac{d}{2}\right)^2}$$

And, incorporating values for the several parameters provided in the problem statement, leads to

$$\sigma = \frac{(0.1A)(38 \times 10^{-3}m)}{(12.5)\pi\left(\frac{5.1 \times 10^{-3}m}{2}\right)^2} = 14.9\ (\Omega - m)^{-1}$$

(b) The resistance, R, may be computed using Equations 18.2 and 18.4, as

$$R = \frac{\rho l}{A} = \frac{l}{\sigma A} = \frac{l}{\sigma\pi\left(\frac{d}{2}\right)^2}$$

$$R = \frac{51 \times 10^{-3}m}{(14.9\ (\Omega - m)^{-1})\pi\left(\frac{5.1 \times 10^{-3}m}{2}\right)^2} = 168\ \Omega$$

Question 2

Pure Germanium to which 5×10^{22} m^{-3} Sb atoms have been added is an extrinsic semiconductor at room temperature, and virtually all the Sb atoms may be thought of as being ionized (i.e., one charge carrier exists for each Sb atom). (a) Is this material n-type or p-type? (b) Calculate the electrical conductivity of this material, assuming electron and hole mobilities of 0.1 and 0.05 m^2/V-s, respectively.

<u>Solution</u>

(a) This germanium material to which has been added 5×10^{22} m^{-3} Sb atoms is n-type since Sb is a donor in Ge. (Antimony is from group VA of the periodic table--Ge is from group IVA.)

(b) Since this material is n-type extrinsic, Equation 18.16 is valid. Furthermore, each Sb will donate a single electron, or the electron concentration is equal to the Sb concentration since all of the Sb atoms are ionized at room temperature; that is $n=5\times 10^{22}$ m^{-3} and as given in the problem statement, $\mu_e = 0.1$ m^2/V-s. Thus:

$$\sigma = n|e|\mu_e = (5 \times 10^{22} \mathrm{m}^{-3})(1.62 \times 10^{-19}\mathrm{C})(0.1\,\mathrm{m}^2/\mathrm{Vs}) = 800\ (\Omega.\mathrm{m})^{-1}$$

Question 3

A copper wire is stretched elastically with a stress of 70 MPa at 20°C. If the length is held constant, to what temperature must the wire be changed to reduce the stress to 35 MPa?

<u>Solution</u>

We want to heat the copper wire in order to reduce the stress level from 70 MPa to 35 MPa; in doing so, we reduce the stress in the wire by 70 MPa – 35 MPa = 35 MPa, which stress will be a compressive one (i.e., σ= –35 MPa). Solving for T_f from Equation 19.8 [and using values for E and α_l of 110 GPa (Table 6.1) and 17.0×10^{-6} (˚C)$^{-1}$ (Table 19.1), respectively] yields:

$$T_f = T_0 - \frac{\sigma}{E\alpha_l}$$

$$= 20°\mathrm{C} - \frac{-35\ \mathrm{MPa}}{(110 \times 10^3\ \mathrm{MPa})\left[17.0 \times 10^{-6}\ (°\mathrm{C})^{-1}\right]}$$

= 20˚C + 19˚C = 39°C

Question 4

Considering the thermal shock resistant parameter (TSR) equation (below), what measures may be taken to reduce the likelihood of thermal shock of a ceramic piece?

$$TSR \cong \frac{\sigma_f k}{E\alpha_l}$$

Solution

According to the TSR parameter equation, the thermal shock resistance of a ceramic piece may be enhanced by increasing the fracture strength and thermal conductivity, and by decreasing the elastic modulus and linear coefficient of thermal expansion. Of these parameters, σ_f and α_l are most amenable to alteration, usually be changing the composition and/or the microstructure.

Question 5

Zinc selenide (ZnSe) has a band gap of 2.58 eV. Over what range of wavelengths of visible light is it transparent?

Solution

Only photons having energies of 2.58 eV or greater are absorbed by valence-band-to-conduction-band electron transitions. Thus, photons having energies less than 2.58 eV are not absorbed; the minimum photon energy for visible light is 1.8 eV (Equation 21.16b), which corresponds to a wavelength of 0.7 µm. From Equation 21.3, the wavelength of a photon having an energy of 2.58 eV (i.e., the band-gap energy) is just

$$\lambda = \frac{hc}{E} = \frac{(4.13 \times 10^{-15} eV.s)(3 \times 10^{8} m/s)}{2.58\ eV} = 4.5 \times 10^{-7} m = 0.48 \mu m$$

Thus, pure ZnSe is transparent to visible light having wavelengths between 0.48 and 0.7 µm.