EECS 170A
Professor Burke Section B
Homework #2 Solutions and Grading Criteria

1) A thin metal resistor as shown in the figure below has a resistance of 1MΩ. It is 1mm long, 10 μm wide, and 1 μm thick.

a) Calculate the resistivity (ρ), in units of Ω-m. **(10 pts total)**

2 pts $A = Wt$
2 pts $= (10\mu m \times 1\mu m)(1m^2/10^{12}\ \mu m^2) = 1\times10^{-11} m^2$
2 pts $\rho = RA/l$
2 pts $= [(10^6\ \Omega)(1\times10^{-11} m^2)]/[(1mm)(1m/1000mm)]$
2 pts $= 1\times10^{-2}\ \Omega\text{-}m$

b) Now express the resistivity in units of μΩ-cm, a more common unit **(10 pts total)**

2 pts $1\ \Omega = 10^6\ \mu\Omega$
2 pts $1\ m = 10^2\ cm$
4 pts $\rho = (10^{-2}\ \Omega\text{-}m)(10^6\ \mu\Omega/\Omega)(10^2 cm/m)$
2 pts $= 1\times10^6\ \mu\Omega\text{-}cm$

2) For Si at 300K, do the following: (Use cm^{-3} as your units.)

a) $N_D = 10^{20}cm^{-3}$; $N_A \ll N_D$. Calculate the equilibrium electron concentration (n) and hole concentration (p). **(15 pts total)**

Since $N_A \ll N_D$ *and* $n_i \ll N_D$:
6 pts $n = N_D = 10^{20}cm^{-3}$
6 pts $p = n_i^2/n$
3 pts $= (10^{10}cm^{-3})^2/10^{20}cm^{-3} = 1cm^{-3}$

b) $N_D = 10^{10}cm^{-3}$; $N_A \ll N_D$. Calculate the equilibrium electron concentration (n) and hole concentration (p). **(15 pts total)**

Since $N_A \ll N_D$, $N_A \approx 0$:
4 pts $n = \frac{N_D - N_A}{2} + [(\frac{N_D - N_A}{2})^2 + n_i^2]^{1/2}$
4 pts $= \frac{10^{10}cm^{-3}}{2} + [(\frac{10^{10}cm^{-3}}{2})^2 + (10^{10}cm^{-3})^2]^{1/2} = 1.62\times10^{10}cm^{-3}$
4 pts $p = n_i^2/n$
3 pts $= (10^{10}cm^{-3})^2/(1.62\times10^{10}cm^{-3}) = 6.18\times10^9 cm^{-3}$

c) $N_A = 10^{20}cm^{-3}$; $N_D \ll N_A$. Calculate the equilibrium electron concentration (n) and hole concentration (p). **(15 pts total)**

Since $N_D \ll N_A$ *and* $n_i \ll N_A$:
6 pts $p = N_A = 10^{20}cm^{-3}$
6 pts $n = n_i^2/p$
3 pts $= (10^{10}cm^{-3})^2/10^{20}cm^{-3} = 1cm^{-3}$

d) $N_A = 10^{10}cm^{-3}$; $N_D \ll N_A$. Calculate the equilibrium electron concentration (n) and hole concentration (p). **(15 pts total)**

Since $N_D \ll N_A$, $N_D \approx 0$:
4 pts $p = \frac{N_A - N_D}{2} + [(\frac{N_A - N_D}{2})^2 + n_i^2]^{1/2}$
4 pts $= \frac{10^{10}cm^{-3}}{2} + [(\frac{10^{10}cm^{-3}}{2})^2 + (10^{10}cm^{-3})^2]^{1/2} = 1.62\times10^{10}cm^{-3}$
4 pts $n = n_i^2/p$
3 pts $= (10^{10}cm^{-3})^2/(1.62\times10^{10}cm^{-3}) = 6.18\times10^9 cm^{-3}$

3) For the silicon sample at T = 300K shown below, given $N_A = 10^{17}\ cm^{-3}$, $N_D \ll N_A$,

a) Find the resistivity ρ of the Si to within 10%. For units, use Ω-cm. **(10 pts total)**

10 pts *Off the graph:* $\rho = .189\ \Omega\text{-}cm$
Allowed values are (.170-.208 Ω-cm)
Full credit also received if resistivity is calculated from the equation.

b) Calculate the resistance R_{AB} in units Ω, for the following geometry: **(10 pts total)**

2 pts $A = Wt$
2 pts $= (1mm \times 250\mu m)(1cm/10mm)(1cm/10^4\ \mu m) = 2.5\times10^{-3}\ cm^2$
4 pts $R = \rho l/A = (.189\ \Omega\text{-}cm)(1cm)/(2.5\times10^{-3}\ cm^2)$
2 pts $= 75.6\ \Omega$
Range of R excepted is: 68-83.2 Ω due to errors from graph readings.