EEE105 Tutorial Question Set 4
Solutions

1. This question is asking you to calculate the value of the constant C in the equation

$$n_i = CT^{3/2}\exp\left(-\frac{W_g}{2kT}\right)$$

You could look up k, but here I have used the rule of thumb that kT=1/40 eV at room temperature. (You should note that small differences in what you use in the exponent for thermal energy will have a large impact on the value you calculate. However, for the purposes of this question we are making an estimate so do not worry too much about this as long as you answer is in the right ballpark.)

$$\therefore C = \frac{n_i}{T^{3/2}}\exp\left(\frac{W_g}{2kT}\right) = \frac{1.5x10^{16}}{5196}\exp\left(\frac{1.1}{2x0.025}\right) = 2.9x10^{12}x3.6x10^{9} = 1x10^{22}$$

The question then asks you to apply this value for Ge and C(diamond) to find the intrinsic carrier concentrations. For Ge:

$$n_i = 1x10^{22}x5196.\exp\left(-\frac{0.66}{2x0.025}\right) = 9.6x10^{19}m^{-3}$$

Similarly for C(diamond): n_i=4x10^{-27} m^{-3}

2. The electron current density in a material is given by:

$$J = nqv$$
$$v = \mu_e E$$
$$\therefore J_e = nq\mu_e E$$

However, in this intrinsic material there are *both electrons and holes* and (since it is intrinsic) the concentration of electrons and holes is the same (i.e. n=p)

Both the electrons and holes contribute to the current so we need to modify the equation for current density:

$$J = qE(\mu_e n + \mu_h p)$$
$$J = n_i qE(\mu_e + \mu_h)$$
$$\therefore J = 2.5x10^{19}x1.6x10^{-19}x500x(0.39+0.19) = 1160A/m^2$$

Note: This question illustrates a key problem. In semiconductors there are two types of carrier (electrons and holes) and we need to think about which of these will make a significant contribution to the conductivity. In undoped (intrinsic) material n=p so we need to consider both, but in doped (extrinsic) material usually either n>>p or p>>n so we only need to consider the contribution of one carrier. We will see this in a question in a later self assessment sheet.