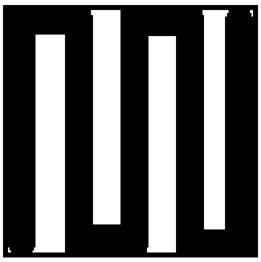
EEE105 Tutorial Question Set 3
Solutions

1. This question is designed to hint at the way you would fabricate a resistor in an integrated circuit technology. You would deposit a thin film of metal onto the chip surface and pattern in into a long strip to get a resistance between the ends.

First we need to work out the geometry that will give you the highest resistance. Unfortunately, for realistic values of resistance, a very long, thin resistor is difficult to incorporate into the layout of a chip. So to make a more convenient shape, we "fold" the resistor so that it takes a shape a bit like a snake wriggling across the chip area.

In this case the metal track cannot be less than 10 μm wide and the separation between "folds" cannot be less than 10 μm (defined by the question), so the best geometry looks like this.



90 micron square

So now we know the geometry, and the resistivity was given in the question, therefore we can work out the resistance.

If you haven't yet tried the next bit have a go without reading any more of this solution.

We know that resistance is related to geometry by

$$R = \rho \frac{l}{A}$$

In this case it is not immediately clear what we should use for length since the resistor folds, but a reasonable approximation might be 490 μm (if you chose a slightly different length, don't worry provided you can justify it. In practice the current tends to crowd towards the inside of the corners, so a nearer approximation might be 450 μm).

The area is the cross-sectional area of the track. It should be 10 μm wide (as narrow as possible to get the resistance up) and the question tells us that it is 0.01 μm thick. So

R=3.15x10^{-6} Ωm x 490x10^{-6} m / 0.01x10^{-6} m x 10x10^{-6} m =15.4 kΩ

Note that questions that get you to work out resistance from the geometry and conductivity make nice exam questions (although usually I'll complicate it in some devious way). So make sure that you are fully happy with this technique.

2. We know the electric field and want to know drift velocity. But these are proportional to each other with mobility as the coefficient of proportionality. So first we need to calculate mobility. The conductivity and the carrier concentration are known, so the mobility can be easily found from:

$$\sigma = nq\mu$$

$$\therefore \mu = \frac{\sigma}{nq} = \frac{6.7x10^{-7}}{10^{29}x1.6x10^{-19}} = 4.2x10^{-3} m^2 / Vs$$

Note that it will be often necessary to manipulate this equation. Later we will look at using this equation when there is more than one type of carrier (both electrons and holes).

Returning to this question, we get drift velocity by

$$v = \mu E = 4.2x10^{-3} x10^2 = 0.42 m / s$$

To get the mean time between collisions we need to remember the physical origin of mobility and

$$\mu = \frac{q\tau}{m^*}$$

$$\therefore \tau = \frac{4.2x10^{-3} x9.1x10^{-31}}{1.6x10^{-19}} = 2.38x10^{-14} s$$

Note: I don't actually know if these are the correct values for silver, but at least the time between scattering events is very small as one would expect.