EEE105 Tutorial Question Set 9
Solutions

1. Most of the early sections of this question simply reuse techniques that you have practiced in earlier sheets. The only issue is to realise that they are relevant here. If this was an exam question I may ask you to determine the collector current [part (e)] expecting you to realise that you need to do parts (c) and (d) on the way.

(a) For the majority carrier concentrations, just use the standard equation for resistivity:

$$\rho = \frac{1}{nq\mu}$$

and apply to the emitter and the base. The resistivities and mobilities are given so you should easily find

p=2.08x10^{22} m^{-3}

n=1.6x10^{23} m^{-3}

Looking at these numbers, they are reasonable for majority carrier densities. To get the minority carrier concentrations just use $pn=n_i^2$. The intrinsic carrier concentration is given so:

n_p=1.08x10^{10} m^{-3}

p_n=1.4x10^{9} m^{-3}

As expected, these are much smaller than the majority carrier concentrations. This aspect should have been straightforward to you all.

(b) For this, you need to remember that the built in potential across a junction is given by

$$V_0 = \frac{kT}{q}\ln\left(\frac{n_n}{n_p}\right)$$

Putting in the values calculated in (a) gives **V_0 = 0.77 V**

You could try using the equation for the holes and prove that it gives the same result.

(c) To calculate the base emitter current, first calculate the current density. Remember that

$$J = J_0\left(e^{\frac{qV}{kT}} - 1\right)$$

You're told the applied voltage is 0.65 V and the saturation current density is 1 μAm^{-2}. You should get an answer around **1.52x10^{-3} A**

Remember that you are given 20ºC as the temperature (=293 K) so you should get an answer quite close to this, although rounding errors can make a small difference. If you used an assumption that the temperature is near enough room temperature and the thermal energy is 0.025eV) then in an exam you should state this and your answer may

be around **1.96x10^{-3} A**. *As you should remember the value obtained will be very sensitive to what you assumed for kT. In this case using 290 K and 300 K (or even 1/40 eV) should not be recommended as the question clearly states that T=20ºC!*
Also, if you are unsure what value of V to use consider how much current you expect to flow if the applied voltage is zero, then look at the equation again.

(d) For the next section you need to remember that the ratio of electron and hole currents across a junction can be considered to be controlled by the ratios of conductivity. **So the electron current is 20 times the hole current**. Of course this is what we want in a bipolar since we want most of the emitter current to be due to carriers injected from the emitter into the base.

(e) Note that if we neglect any recombination in the base, then all the electrons injected at the emitter will reach the collector. Written another way $I_C=I_e$

We know the emitter current (from part c) and the proportion of that due to electrons(from part d)

$$I_E = I_e + I_h = I_e\left(1+\frac{1}{20}\right) = \frac{21}{20}I_e$$

$$\therefore I_C = \frac{20}{21}I_E = 1.45mA$$

2. a) The first part of the exam question is bookwork: You should state that the main components to the base current are (1) recombination of electrons diffusing through the base (if an n-p-n device) and (2) hole injection from base to emitter.

(1) Can be described by the base transport factor: $\alpha = \dfrac{I_C}{I_e}$

(2) Can be described by the emitter injection efficiency: $\gamma_E = \dfrac{I_e}{I_e + I_h}$

where I_e is the emitter electron current and I_h is the emitter hole current.

(6 marks)

To get α close to 1 the base width should be kept small, much less than the minority carrier diffusion length.

To get γ_E close to 1 then doping in the base should be much less than the doping in the emitter.

(4 marks)

b) In the second part we are asked to calculate the common emitter current gain.

First let us get the ratio: $\dfrac{I_e}{I_h} = \dfrac{\sigma_E}{\sigma_B} = \dfrac{n\mu_e}{p\mu_h} = \dfrac{n}{p}\cdot\dfrac{\mu_e}{\mu_h} = 10\cdot 10 = 100$

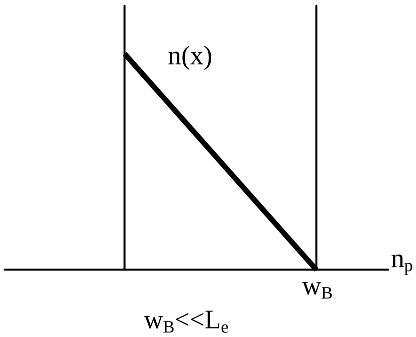
We can now get: $\gamma_E = \dfrac{I_e}{I_e + I_h} = \dfrac{1}{1+{I_h}/{I_e}} = 0.99$

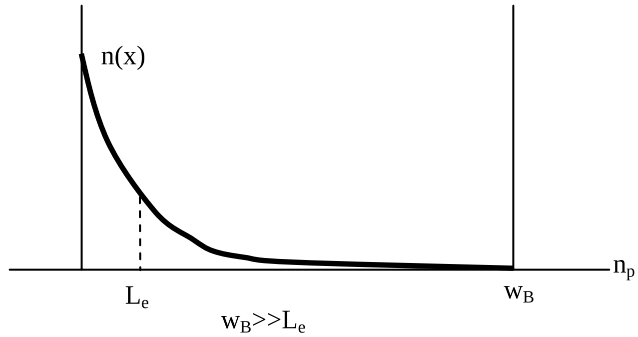
We are given $\alpha = \dfrac{I_C}{I_e} = 0.98$

And the common emitter current gain: $\beta = \dfrac{\gamma_E \alpha}{1 - \gamma_E \alpha} = \dfrac{0.97}{0.03} = 32.5$

(6 marks)

c) The final part of the question is again straight out of the notes. You should draw suitable figures along the lines of those below:





(4 marks)