SOLUTION TO PROBLEM SHEET 3

3) $I = I_0 [\exp(eV/kT) - 1]$

when V is large and negative ; $|I| = I_0 = 2 \times 10^{-7}$ A.

$I = 2\times10^{-7} [\exp(1.6\times10^{-19} \cdot 0.1)/(1.38\times10^{-23} \cdot 293) - 1]$

$= 2\times10^{-7} [52.3 - 1]$

$I = \underline{10.2\ \mu A \text{ at } 20°C}$ #.

4) $I = I_0[\exp(eV/kT) - 1]$ and $I_0 = 30\mu A$

To obtain dynamic resistance;

$r = \frac{dV}{dI} = \left[\frac{dI}{dV}\right]^{-1} = \left[\frac{I_0 e}{kT} \exp(eV/kT)\right]^{-1}$

$= \left[\frac{30\mu \cdot e}{1.38\times10^{-23} \cdot 398} \exp(e \cdot 0.2/1.38\times10^{-23} \cdot 398)\right]^{-1}$ ... in forward direction

$= [(8.74\times10^{-4})(339)]^{-1}$

$= \underline{3.4\ \Omega}$ #.

in reverse direction

$= \left[\left(\frac{30\mu \cdot e}{1.38\times10^{-23} \cdot 398}\right) \exp\left(e \cdot -0.2/1.38\times10^{-23} \cdot 398\right)\right]^{-1}$

$= [(8.74\times10^{-4})(2.95\times10^{-3})]^{-1}$

$= \underline{388\ k\Omega}$ #.

5) $I_o = 1\ \mu A$

(i) when $I = 1mA$

$\Rightarrow \quad 1\times10^{-3} = 1\times10^{-6}\left[\exp\left(eV/kT\right) - 1\right]$

$$1000 = \exp\left(eV/kT\right) - 1$$

$$\ln 1001 = eV/kT$$

$$V = \frac{(\ln 1001)(kT)}{e}$$

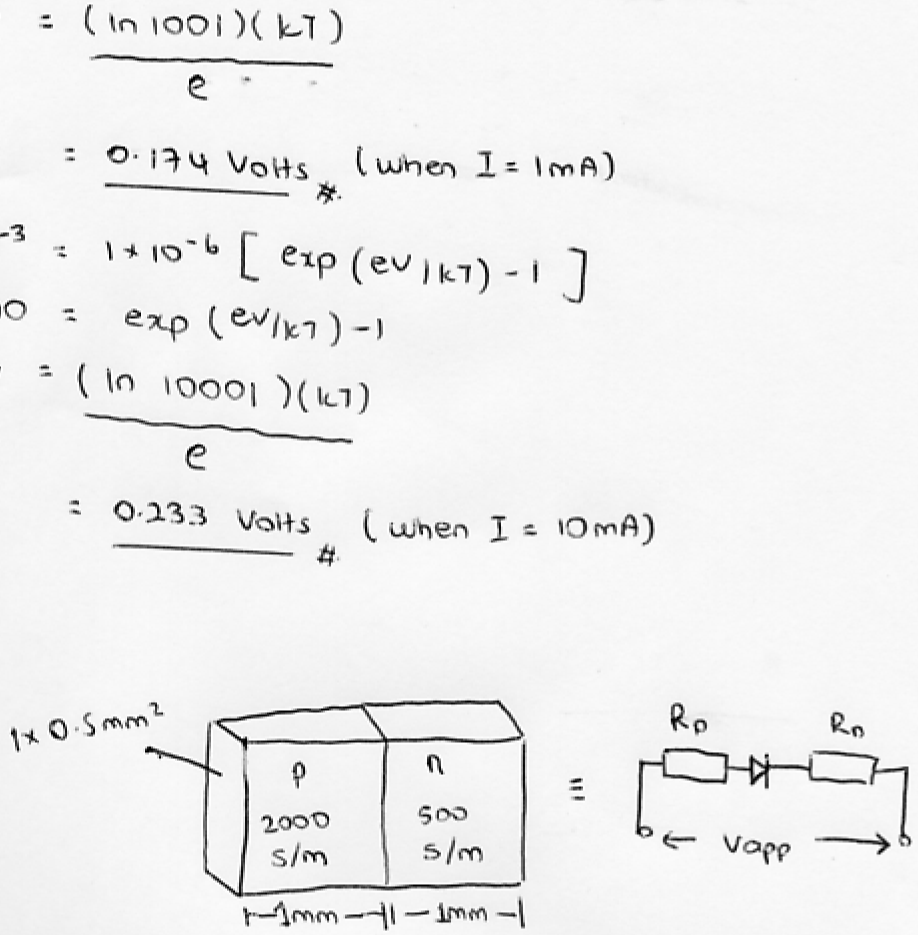
$$= \underline{0.174 \text{ Volts}}_{*} \quad (\text{when } I = 1mA)$$

(ii) $10\times10^{-3} = 1\times10^{-6}\left[\exp\left(eV/kT\right) - 1\right]$

$$10000 = \exp\left(eV/kT\right) - 1$$

$$V = \frac{(\ln 10001)(kT)}{e}$$

$$= \underline{0.233 \text{ Volts}}_{\#} \quad (\text{when } I = 10mA)$$



$$R_p = \frac{L}{\sigma A} = \frac{10^{-3}}{2000\times1\times0.5\times10^{-6}} = 1\Omega$$

$$R_n = \frac{L}{\sigma A} = \frac{10^{-3}}{500\times1\times0.5\times10^{-6}} = 4\Omega$$

$\left.\right\} = 5\Omega$ (total R_D)

$\therefore \quad V_{app}\ (a) = 0.174 + (5)(1\times10^{-3}) = \underline{0.18 \text{ Volts}}_{\#}$

$\quad\;\; V_{app}\ (b) = 0.233 + (5)(1\times10^{-2}) = \underline{0.283 \text{ Volts}}_{\#}$

* The difference between applied voltage and internal junction voltage is only significant at high currents

6) $I_{o\text{-}si} = 10^{-8}$ A

$I_{o\text{-}ge} = 10^{-6}$ A

I = 100 mA in both cases

$\therefore \quad I = I_{o\text{-}si}\left(\exp\left(eV_{si}/kT\right) - 1\right)$

$100 \times 10^{-3} = 1 \times 10^{-8}\left(\exp\left(eV_{si}/kT\right) - 1\right)$

$10 \times 10^{6} = \exp\left(eV_{si}/kT\right) - 1$

$$V_{si} = \frac{(\ln 10 \times 10^{6})\, kT}{e}$$

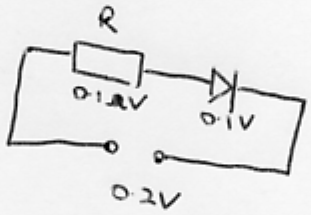
$V_{si} = \underline{407 \text{ mV}}$ #

Similar technique for Vge gives $V_{ge} = \underline{290 \text{ mV}}$ #

ii) An additional bulk resistance of 1Ω will increase the voltage drop;

$V_{drop} = IR = (100\text{mA})(1)$

$= \underline{100 \text{ mV}}$ #

7) 

$I_o = 3\,\mu A$

$V = 0.1$ V

$V_{diode} = 0.1$ V

$\therefore \quad I = I_o\left[\exp\left(eV/kT\right) - 1\right]$

$$R = \frac{V}{3 \times 10^{-6}\left(\exp\left(e \cdot 0.1/kT\right) - 1\right)}$$

$$= \frac{0.1}{1.54 \times 10^{-4}}$$

$= \underline{637\ \Omega}$ #

8) $I = I_0 \left(\exp(eV_1/kT) - 1 \right)$

$2I = I_0 \left(\exp(eV_2/kT) - 1 \right)$

$2 = \exp\left(\frac{e}{kT} (V_2 - V_1) \right)$

$\frac{kT}{e} \ln 2 = V_2 - V_1 = 175 \text{ mV}$

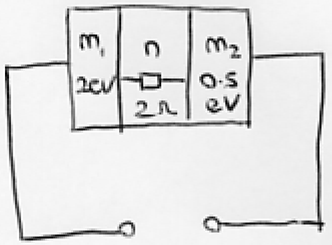
Since $V_1 = 0.25\text{ V}$; $\underline{V_2 = 0.2675\text{ V}}$. #

$I_0 = \dfrac{I}{\exp(eV_1/kT) - 1}$; $\left(I = 10\text{mA}, V_1 = 0.25\text{V} \right)$

$= \underline{0.5\ \mu A}$. #

9) $r \approx \dfrac{kT}{eI}$. To double the slope resistance, requires I halving.
(based on Q4) From Q8, this requires 17.5mV less applied voltage,
So $V = 0.250 - 0.0175 = \underline{0.233V}$ #.

10)



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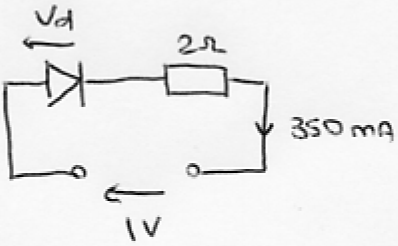

$V_D = 1 - (0.35)(2) = 0.30V$

$I = I_0 \left(\exp(eV/kT) - 1 \right)$

$I_0 = \dfrac{0.35}{\exp(e0.3/kT) - 1}$

$= \underline{2.15\ \mu A}$ #.

(In reverse direction, 2Ω will be insignificant)