Data Provided: None

EEE105

The University of Sheffield

DEPARTMENT OF ELECTRONIC AND ELECTRICAL ENGINEERING

Autumn Semester 2002-2003 (2 hours)

Electronic Devices

Answer **THREE** questions. **No marks will be awarded for solutions to a fourth question.** Solutions will be considered in the order that they are presented in the answer book. Trial answers will be ignored if they are clearly crossed out. **The numbers given after each section of a question indicate the relative weighting of that section.**

You may require the following:

$q=1.6\text{x}10^{-19}$C
Permittivity of free space $\varepsilon_0 = 8.85\text{x}10^{-12}$ F/m
Boltzmann's constant $k=1.38\text{x}10^{-23}$ J/K
Plank's constant $h=6.6\text{x}10^{-34}$ Js
speed of light $c=3\text{x}10^{8}$ m/s

Poisson's Equation $\dfrac{d^2V}{dx^2} = -\dfrac{\rho}{\varepsilon}$

$$E = -\frac{dV}{dx}$$

$$d_j = \left(2\varepsilon_0\varepsilon_r V_j / qN_d\right)^{0.5}$$

$$J = qD\frac{dn}{dx}$$

$$J_0 = \frac{qL_e n_p}{\tau_e} + \frac{qL_h p_n}{\tau_h}$$

$$J = J_0\left[\exp\left(\frac{qV}{kT}\right) - 1\right]$$

$$D = \frac{kT}{q}\mu$$

$$\beta = \frac{\alpha_B}{1-\alpha_B}$$

$$\alpha_B = \gamma_E \alpha$$

Energy of a photon $=hc/\lambda$

$$\partial p = \partial p_0 \exp\left(\frac{-x}{L_h}\right)$$

$$L = \sqrt{D\tau}$$

$$R = \rho \, L/A$$

For silicon: Relative permittivity $\varepsilon_r = 12$
Built in voltage =0.7V
electron mobility=0.07m^2/Vs
hole mobility=0.045m^2/Vs

	Ge	Si	GaAs	InSb
n_i (m^{-3})	2.4×10^{19}	1.45×10^{16}	1.8×10^{12}	2.1×10^{22}

1a. Describe the change in conductivity you would expect in intrinsic Si as the temperature is raised from 0 kelvin to room temperature. Explain carefully your reasoning for expecting this change. **(5)**

b. Calculate the expected conductivity of intrinsic Si at room temperature. **(3)**

c. The Si sample is doped with a density of 10^{21} m^{-3} boron atoms. Calculate the conductivity of the sample and the fractional contribution from both electrons and holes. **(5)**

d. A thin slab of intrinsic Si is uniformly irradiated with visible light, causing a 10^6 increase in the generation of electron-hole pairs. Briefly explain the increase and calculate the conductivity of the illuminated material. **(7)**

2a. For a p^+-n junction given that, under zero bias,

$$P_{(p)} = P_n \exp\left(\frac{qV_o}{kT}\right)$$

prove that under forward bias

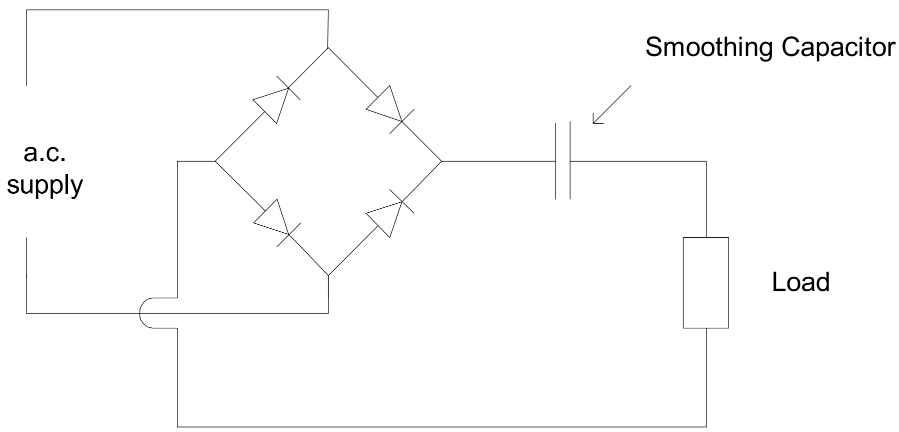
$$I = \left[\frac{qAL_h p_n}{\tau_h}\right]\left[\exp\left(\frac{qV}{kT}\right) - 1\right]$$

Where the symbols have their usual meaning. State any assumptions you make. **(8)**

b. Briefly explain how a p-n junction diode can be used as a rectifier, describing the behaviour of the device during each part of the current cycle. **(6)**

c. The following circuit uses 4 identical diodes, where for each $I_0=1\times10^{-12}$A. The input a.c. voltage measured on a multimeter was 5V and the instantaneous maximum current through the diodes was found to be 100mA using an oscilloscope.

Estimate the d.c. voltage across the load, stating any assumptions you make.



(6)

3a. Apply Poisson's equation for an n^+-p junction to show that the width of the depletion region can be given by

$$d = \left(\frac{2\varepsilon_0\varepsilon_r V_o}{qN_a}\right)^{1/2}$$

Where the symbols have their usual meaning. State any assumptions you make. **(8)**

b. A silicon n-p-n Bipolar Junction Transistor (BJT) is doped as follows:

Emitter	:	5×10^{25}m^{-3} Arsenic
Base	:	2×10^{24}m-^{3} Boron
Collector	:	1×10^{23}m-^{3} Arsenic

Modifying the equation derived in part **(a)** as appropriate for each case, calculate the depletion region thicknesses for both junctions under the following bias conditions: V_{BE} = 0.8V, V_{CE} = 10V and assuming V_o = 0.8V. State any assumptions you make. **(5)**

c. For the base-collector junction in the BJT in **(b)** calculate the thickness of the depletion region on the p-type side of the junction. **(3)**

d. Explain what will happen to the effective base region thickness if V_{CE} is increased to 20V, for example, and describe how you would expect this to change the performance of the device. **(4)**

4a. Using diagrams as appropriate describe the physical structure of an n-channel JFET and describe in detail how it could be used as a transistor, with reference to its output characteristic. **(9)**

b. For such a device plot the so-called 'transfer characteristic' and hence explain what is meant by the transconductance of the device. **(5)**

c. For the single JFET amplifier shown, a sinusoidal input signal of 10mV (peak – to – peak) is applied. If the transconductance is 120mS then calculate the voltage gain of the circuit, assuming V_d = 7.5V at the quiescent point. **(6)**