University of Technology

Department of Laser & Opto-electronic Engineering

Final Examination 2011-2012

Subject: Semiconductor Devices

Division: Laser Eng.

Examiner: Asis.Prof.Dr.Mohammed A.Mahdi

Class: 3rd year

Time: 3 hours

Date: 7 / 6 /2012

Answer five questions only

Q1/ Let **T=300K**. Determine the probability that an energy level **3KT** above the Fermi energy is occupied by an electron. **(20 mark)**

Q2/ Prove that:

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

Where : **D**: diffusion constant.

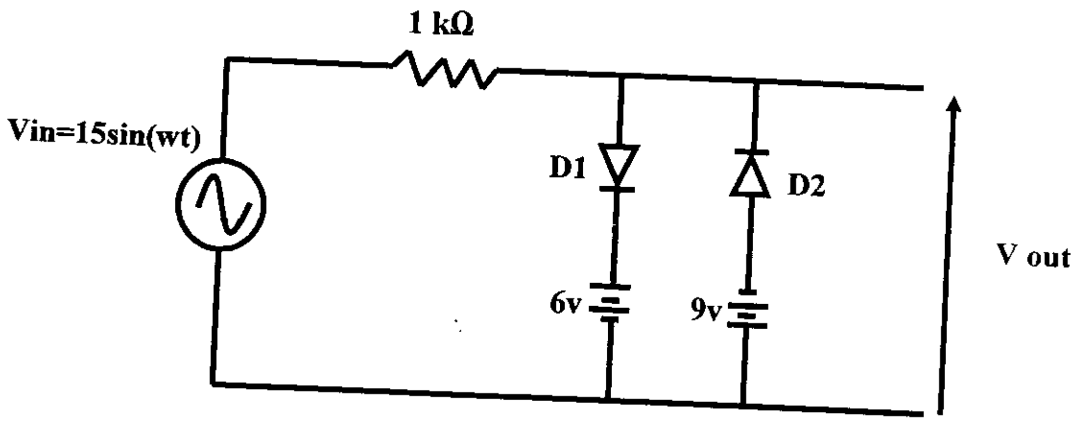
k: Boltzmann constant.

T: temperature.

q: charge of electron.

(20 mark)

Q3/ Draw the output voltage waveform were D1 & D2 are ideal:



(20 mark)

Q4/ A copper wire **19m** long and cross sectional area of **0.5 mm²** has resistance equal **0.34 Ω**. Calculate the conductivity for copper. The mobility of electrons and number of collision of the electrons in one second. Given that free electron concentration is **8.5×10²⁸ electron/m³**.

(20 mark)

Q5/ / Prove that

$$V_B = V_T \ln\left(\frac{N_D N_A}{n_i^2}\right)$$

Where: V_B: potential barrier.

V_T: Volt-equivalent of temperature.

N_D: Donor electrons concentration.

N_A: Acceptor holes concentration.

n_i: intrinsic electron concentration.

(20 mark)

أقلب الصفحة

Q6/ The atomic weight of Ge is **72.6 gm/mol** and density is **5.32 gm/cm^3**. Find:

1- The resistivity of intrinsic Ge at **300K**.

2- If a donor type of impurity is added with doping level of **10^{-8}** find the new resistivity of the sample. Knowing that the intrinsic **concentration= 2.5×10^{13} cm^{-3}**, **Mobility of hole= 1800 cm^2/v.s**, and the **mobility of electron= 3800 cm^2/v.s.** **(20 mark)**

Good luck

أ. د. محمد صالح موسى

أقلب الصفحة

اجوبة اسئلة اشباه موصلات نموذج (2)
ثالث \ ليزر

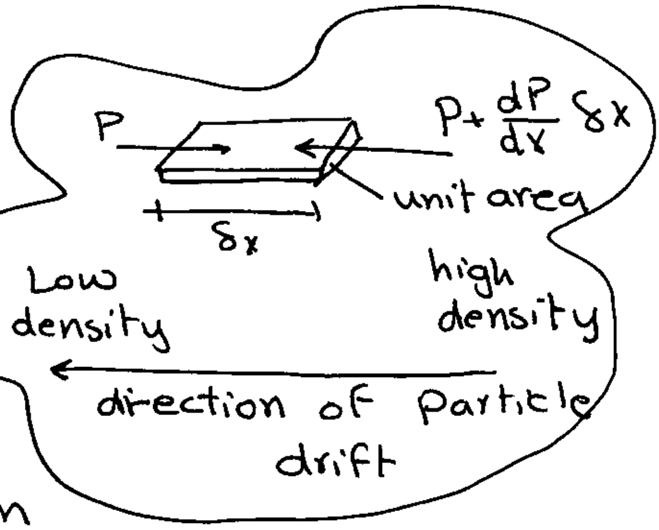
Q1/

$$F_f(E) = \frac{1}{1 + e^{\frac{E-E_f}{KT}}}$$

$$= \frac{1}{1 + \exp\left(\frac{3KT}{KT}\right)}$$

$$= \frac{1}{1+20.9} = 0.047 = 4.7\%$$

Q2/ a current will exist in a material because of v_D imposed on all current carriers by an external electrical field.



current also exist without an external field if there is an unequal concentration of charge carriers with in a material. Let us first consider an example of this in a gas of neutral Particales, a molecular gas contain filled with gas in which the Pressure is greater to the right than to the left. Suppose the Pressure gradient exists in the x-direction only. imagine a volume of molecules of length δx and unit cross-sectional area.

The force on left-hand force of the cylinder is P and the right-hand face $P + (dP/dx)\delta x$, where P is the pressure. Thus the overall force on the cylinder is

$$-\left(\frac{dP}{dx}\right)\delta x$$ to the right. If there are N moleculs per unit volume, than the total number in the cylinder is $N\delta x$. The average force per moleculs is therefore.

$$\frac{-\frac{dP}{dx}\cancel{\delta x}}{N\cancel{\delta x}} = \frac{-\frac{dP}{dx}}{N}$$ this force also results in

adrift velocity v_D. The argument now closely parallels the one used for calculating mobility except that the above force replaces the electric field force $-eE$. if τ is mean ~~f~~free time between collision.

the v_D equal = $$v_D = \frac{-\tau}{2mN} \cdot \frac{dP}{dx} \quad \text{—— (1)}$$

Now for any gas having N molecules per unit volume at temprature T, Kinetic theory gives:-

$$\boxed{P = NKT}$$ K: Boltzman constant

$$dP = KT\,dN$$

Subsiturced it in (1)

$$v_D = -\frac{\tau KT}{2mN}\frac{dN}{dx} \quad \text{—— (2)}$$

the constant is called the diffusion constant D

$$D = \frac{\tau KT}{2m}$$

and $v_D = \frac{-D}{N}\frac{dN}{dx}$ there is arelation between the mobility of gas of charged particles and the diffusion constant of such agas $D = \frac{\tau KT}{2m}$ and $\mu = \frac{q\tau}{2m}$

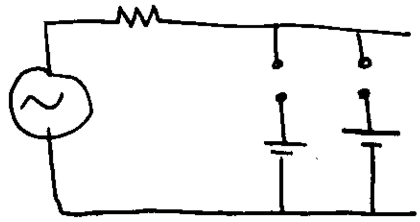
Q 3:1

$V_{in} - V_{D_1} - 6 = 0$

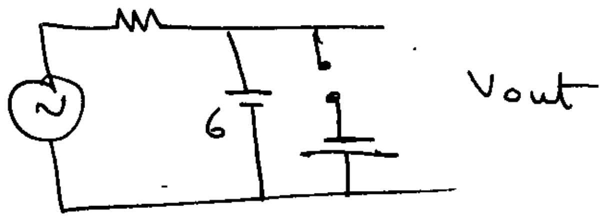
$V_{in} + V_{D_1} + 9 = 0$

$V_{D_1} = V_{in} - 6$

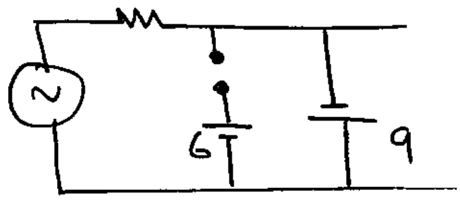
$V_{in} = V_{out}$

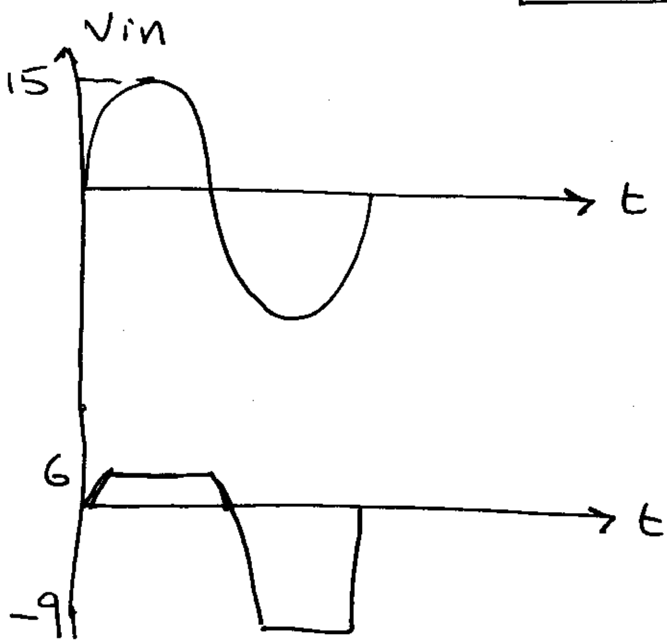


* $V_{out} = 6V$



* $V_{out} = -9$





Q4/

$L = 19\ m$

$A = 0.5\ mm^2$

$R = 0.34\ \Omega$

$\sigma = ?$

$$\rho = R\,\frac{A}{L}$$

$$= 0.34\,\frac{0.5 * 10^{-6}}{19} = 8.94\ n(\Omega.m)$$

$$\sigma = 0.112 * 10^{9}\ (\Omega.m)^{-1}$$

$$\mu_e = \frac{\sigma}{Ne} = \frac{0.112 * 10^{9}}{(8.5 * 10^{28})(1.6 * 10^{-19})}$$

$$\mu_e = 8.2 * 10^{-3}\ m^2/V.s$$

No. of collision of electron in one seconds $= \dfrac{1}{\tau} = \dfrac{e}{2\mu_e m}$

$$= \frac{1.6 * 10^{-19}}{2(4.33 * 10^{-3})(9.1 * 10^{-31})}$$

$$= 4 * 10^{13}$$

Q5/

$$n_n = n_p\, e^{V_B/V_T}$$

$$\frac{n_n}{n_p} = e^{V_B/V_T}$$

$$\ln\left(\frac{n_n}{n_p}\right) = \frac{V_B}{V_T}$$

$$n_p \cdot P_p = n_i^2$$

$$V_B = V_T \ln\left(\frac{n_n P_p}{n_i^2}\right)$$

$n_n = N_D + n_i$ and $P_p = N_A + P_i$

$N_A \gg P_i$ and $N_D \gg n_i$

$\therefore$ $n_n = N_D$ and $P_p \approx N_A$

$\therefore$ $V_B = V_T \ln \dfrac{N_A N_D}{n_i^2}$

Q6/

① $\sigma = n_i q (\mu_e + \mu_h)$

$= (2.5\times10^{13})(1.6\times10^{-19})(3800+1800)$

$\sigma = 0.0224\ (\Omega.cm)^{-1}$

$\sigma = 2.24\ (\Omega.m)^{-1}$

$\rho = \frac{1}{\sigma} = 0.446\ (\Omega.m)$

$n = \frac{\text{Avo.no.} * \text{density}}{\text{atomic weight}}$

$= \frac{6.02*10^{23} * 5.32}{72.6}$

$n = 4.4*10^{28}\ m^{-3}$

② $N_D = n \times 10^{-8}$

$= (4.4\times10^{28})10^{-8} = 4.4\times10^{20}$

$\sigma_n = q N_D \mu_n$

$= (1.6*10^{-19})(4.4*10^{20})(3800*10^{-4})$

$\sigma_n = 26.72\ (\Omega.m)^{-1}$

$\rho = 0.037\ (\Omega.m)$