Seat Number

King Mongkut's University of Technology Thonburi
Midterm Examination
Semester 1 -- Academic Year 2016

Subject: EIE 210 Electronic Devices and Circuit Design I

For: Electrical Communication and Electronic Engineering, 2nd Yr (Inter. Program)

Exam Date: Wednesday September 21, 2016 **Time:** 13.00-16.00 pm.

Instructions:-

1. This exam consists of 5 problems with a total of 8 pages, including the cover.
2. This exam is closed books.
3. You are **not** allowed to use any written A4 note for this exam.
4. Answer each problem on the exam itself.
5. A calculator compiling with the university rule is allowed.
6. A dictionary is **not** allowed.
7. **Do not** bring any exam papers and answer sheets outside the exam room.
8. Open Minds … No Cheating! GOOD LUCK!!!

Remarks:-

- **Raise your hand when you finish the exam to ask for a permission to leave the exam room.**
- **Students who fail to follow the exam instruction might eventually result in a failure of the class or may receive the highest punishment with university rules.**
- **Carefully read the entire exam before you start to solve problems. Before jumping into the mathematics, think about what the question is asking. Investing a few minutes of thought may allow you to avoid twenty minutes of needless calculation!**

Exam No.	1	2	3	4	5	6	7	8	TOTAL
Full Score	10	10	20	30	10				80
Graded Score									

Name ________________________________ **Student ID** ________________

This examination is designed by
Asst. Prof. Kamon Jirasereeamornkul. Ph.D, & Prof. Niel S. Kurt. Ph.D.; Tel: 9067.

This examination has been approved by the committees of the ENE department.

(Assoc. Prof. Rardchawadee Silapunt, Ph.D.)
Head of Electronic and Telecommunication Engineering Department

1. A pn-junction silicon diode (T = 350 K) is doped with the following concentrations: $N_A = 2.5\text{x}10^{16}$ cm^{-3}, $N_D = 4.5\text{x}10^{13}$ cm^{-3}. Calculate the intrinsic carrier density n_i of silicon and the junction built-in voltage V_0 (10 marks).

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2. Analyze and draw the output of the clipper in Figure 1. Assume that the diode is an ideal one (10 marks).

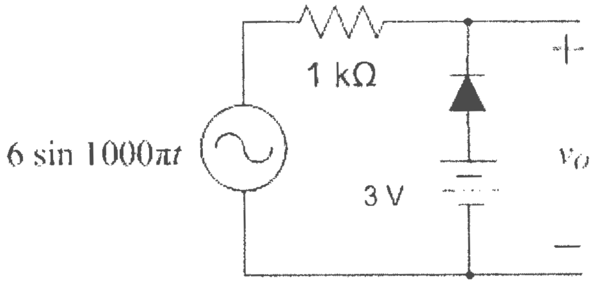

Fig. 1

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3. Consider the circuit in Figure 2. Sketch the waveform of output voltage v_O and current i_O compare with secondary voltage v_s. Also, determine the peak values of i_O and the reverse voltage at D_1. (20 marks)

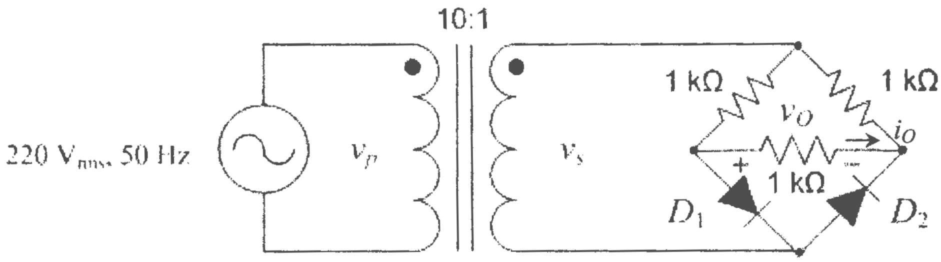
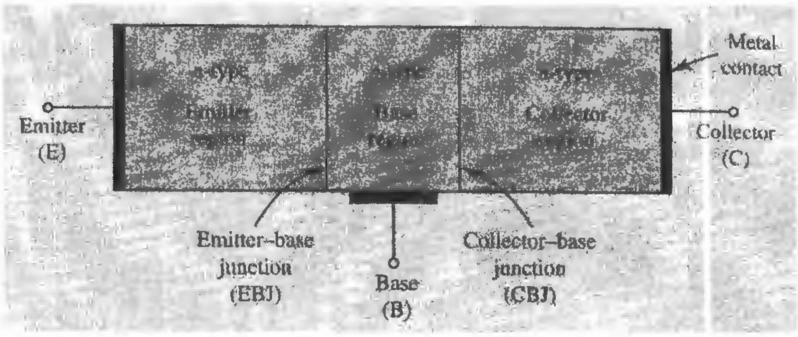


Fig. 2

4. A zener diode whose nominal voltage is 7.2 V at 20 mA is used in the design of a shunt regulator fed from a 24-V supply. The knee current I_{ZK} is specified to be 5 mA. The load current varies over a range of 0 mA to 200 mA.
   4.1) Draw a sketch of the circuit (input voltage, zener diode, shunt resistor R_S, and load R_L) (10 marks).
   4.2) Find a suitable value for the shunt resistor R_S (10 marks).
   4.3) Calculate the maximum power dissipation of the zener diode and of the shunt resistor R_S (10 marks)?

5. Bipolar junction transistor in npn-format and in active mode: Check the answers for the following questions (10 marks):



The emitter-base junction is in forward bias	☐ yes	☐ no	
The collector-base junction is in forward bias	☐ yes	☐ no	
The collector current depends on the collector-base voltage	☐ yes	☐ no	
The collector current depends on the emitter-base voltage	☐ yes	☐ no	
The common-emitter current gain β is in the range of	☐ 0.1 - 10	☐ 50 - 200	☐ 10^5 - 10^7

Summary of given formulars

Table 1.3 Summary of Important Semiconductor Equations

Quantity	Relationship	Values of Constants and Parameters (for Intrinsic Si at $T = 300$ K)
Carrier concentration in intrinsic silicon ($\mathrm{cm^{-3}}$)	$n_i = BT^{3/2}e^{-E_g/2kT}$	$B = 7.3 \times 10^{15}\ \mathrm{cm^{-3}K^{-3/2}}$ $E_g = 1.12$ eV $k = 8.62 \times 10^{-5}$ eV/K $n_i = 1.5 \times 10^{10}/\mathrm{cm^3}$
Diffusion current density ($\mathrm{A/cm^2}$)	$J_p = -qD_p \frac{dp}{dx}$ $J_n = qD_n \frac{dn}{dx}$	$q = 1.60 \times 10^{-19}$ coulomb $D_p = 12\ \mathrm{cm^2/s}$ $D_n = 34\ \mathrm{cm^2/s}$
Drift current density ($\mathrm{A/cm^2}$)	$J_{drift} = q(p\mu_p + n\mu_n)E$	$\mu_p = 480\ \mathrm{cm^2/V \cdot s}$ $\mu_n = 1350\ \mathrm{cm^2/V \cdot s}$
Resistivity ($\Omega \cdot$ cm)	$\rho = 1/[q(p\mu_p + n\mu_n)]$	μ_p and μ_n decrease with the increase in doping concentration
Relationship between mobility and diffusivity	$\frac{D_n}{\mu_n} = \frac{D_p}{\mu_p} = V_T$	$V_T = kT/q \simeq 25.9$ mV
Carrier concentration in n-type silicon ($\mathrm{cm^{-3}}$)	$n_{n0} \simeq N_D$ $p_{n0} = n_i^2/N_D$	
Carrier concentration in p-type silicon ($\mathrm{cm^{-3}}$)	$p_{p0} \simeq N_A$ $n_{p0} = n_i^2/N_A$	
Junction built-in voltage (V)	$V_0 = V_T \ln\left(\frac{N_A N_D}{n_i^2}\right)$	
Width of depletion region (cm)	$\frac{x_n}{x_p} = \frac{N_A}{N_D}$ $W = x_n + x_p$ $= \sqrt{\frac{2\epsilon_s}{q}\left(\frac{1}{N_A} + \frac{1}{N_D}\right)(V_0 + V_R)}$	$\epsilon_s = 11.7\epsilon_0$ $\epsilon_0 = 8.854 \times 10^{-14}$ F/cm

Table 1.3 *continued*

Quantity	Relationship	Values of Constants and Parameters (for Intrinsic Si at $T = 300$ K)
Charge stored in depletion layer (coulomb)	$Q_J = q\dfrac{N_A N_D}{N_A + N_D} AW$	
Forward current (A)	$I = I_p + I_n$ $I_p = Aqn_i^2 \dfrac{D_p}{L_p N_D}\left(e^{V/V_T} - 1\right)$ $I_n = Aqn_i^2 \dfrac{D_n}{L_n N_A}\left(e^{V/V_T} - 1\right)$	
Saturation current (A)	$I_S = Aqn_i^2\left(\dfrac{D_p}{L_p N_D} + \dfrac{D_n}{L_n N_A}\right)$	
I–V relationship	$I = I_S\left(e^{V/V_T} - 1\right)$	
Minority-carrier lifetime (s)	$\tau_p = L_p^2/D_p \qquad \tau_n = L_n^2/D_n$	$L_p, L_n = 1\ \mu\text{m}$ to $100\ \mu\text{m}$ $\tau_p, \tau_n = 1$ ns to 10^4 ns
Minority-carrier charge storage (coulomb)	$Q_p = \tau_p I_p \qquad Q_n = \tau_n I_n$ $Q = Q_p + Q_n = \tau_T I$	
Depletion capacitance (F)	$C_{j0} = A\sqrt{\left(\dfrac{\epsilon_s q}{2}\right)\left(\dfrac{N_A N_D}{N_A + N_D}\right)\dfrac{1}{V_0}}$ $C_j = C_{j0} \Big/ \left(1 + \dfrac{V_R}{V_0}\right)^m$	$m = \dfrac{1}{3}$ to $\dfrac{1}{2}$
Diffusion capacitance (F)	$C_d = \left(\dfrac{\tau_T}{V_T}\right) I$	