2014 Spring CS 210002 Circuits and Electronics Midterm I

Class: ____________________

ID: ____________________

Name: ____________________

Part One: Calculation (82%)

$E_g = 1.1$ eV for Si, $B = 5.23 \times 10^{15}$ cm^{-3} K$^{-3/2}$ for Si, $k = 86 \times 10^{-6}$eVK^{-1},

$u_n = 1350 cm^2V^{-1}S^{-1}$, $u_p = 480 cm^2V^{-1}S^{-1}$, $ni(T) = BT^{\frac{3}{2}}e^{(-Eg/2kT)}$

1. (11%) The impurity concentration in silicon at $T = 320$ K is $Na = 1 \times 10^{18}$ cm^{-3}. (a)(4%) Determine the electron concentration. (b)(2%) Is the material n-type or p-type? (c)(2%) What might the impurity be? (d)(3%) What is the resistivity ρ of this material?

2. (10%) Prove that the current density in a semiconductor can be expressed as $J = J_n + J_p = qnu_nE + qpu_pE$ where q is charge, n is electron concentration, p is hole concentration, u_n is the electron mobility, u_p is the hole mobility, and E is electrical field.

3. (6%) Prove that the Vp $= 2^{\frac{1}{2}}$ Vrms for a sine wave V= Vp×sinθ where Vp is peak value and Vrms is the root-mean-square value of signal V.

4. (8%) Given a diode circuit as shown in Fig. 1. Assume the $I_s = 4 \times 10^{-14} A$, n=2, and $T = 320$ K. Using the iteration method to determine the diode voltage V_D and diode current I_D.

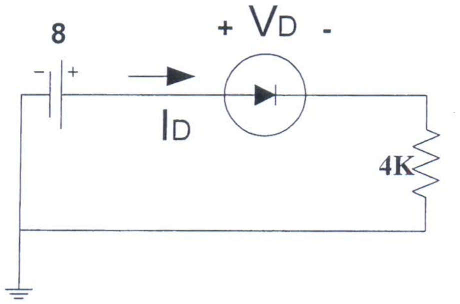

Fig. 1

5. (6%) (a) At what reverse bias voltage does the reverse-bias current in a silicon pn junction diode reach 80 percent of its saturation value? (b) What is the ratio of the current for a forward-bias voltage of 0.4V to the current for reverse-bias voltage of 0.4V? ($T = 300\,\text{K}$, n =1)

6. (5%) Using the superposition theorem, solve for the current I in Fig. 2.

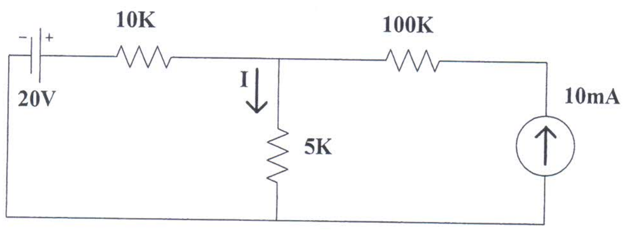

Fig. 2

7. (6%, 4%) The circuit as shown in Fig. 3 is terminal equivalent to that as shown in Fig. 4 by seeing from the 15KΩ resistor according to Thevenin's theorem. (a) Determine the values of Vth, Rth, and I in Fig. 4, respectively. (b) Determine the values of I in Fig. 4 if the 15KΩ resistor is replaced with a 9KΩ resistor.

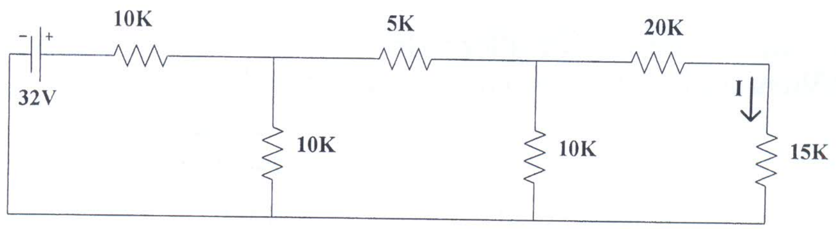

Fig. 3

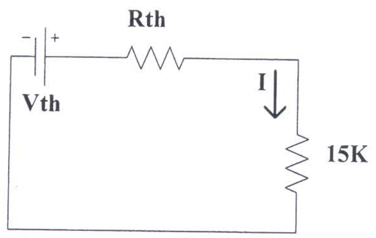

Fig. 4

8. (6%) Assume the parameters of the diode in Fig. 5 are V_γ =0.7v and r_f =0 (constant-voltage drop model), find the V_D and I_D.

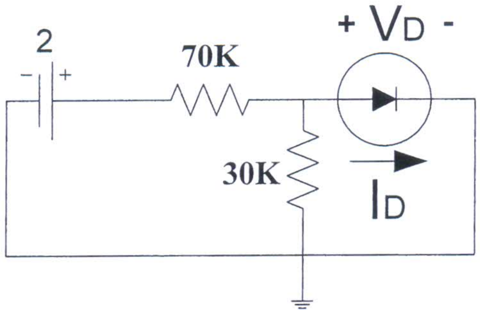

Fig. 5

9. (4%, 3%) (a) In the circuit shown in Fig. 6, find the diode voltage V_D and the supply voltage V such that the current is I = 0.80 mA. Assume the reversed-saturation current is $I_s = 2\times10^{-12}A$ and n=2, $T = 300\,K$. (b) From the results of part (a), determine the power dissipated in the diode.

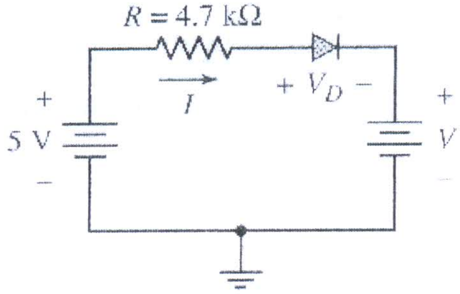

Fig. 6

10. (7%) Find the equivalent resistance between terminals a and b in Fig. 7.

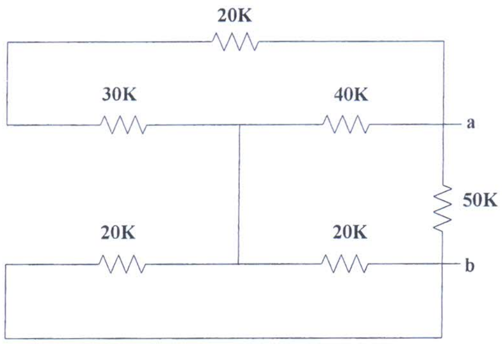

Fig. 7

11. (6%) Use the mesh analysis method to solve for the current in Fig. 8. List the equations only.

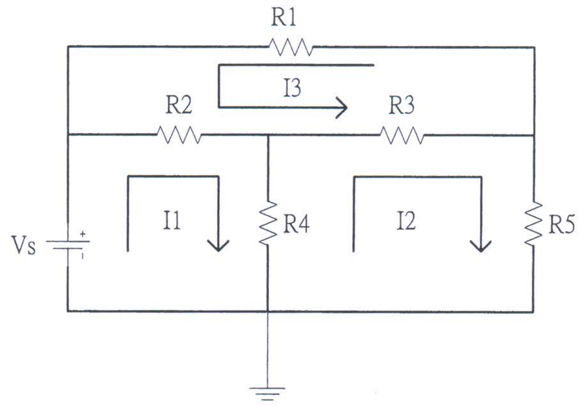

Fig. 8

Part Two: Brief Answer (18%)

1. (3%) Describe the difference between donor and acceptor impurities.

2. (3%) Explain why the iteration method is useful in solving the current and voltage of a diode circuit.

3. (3%) Why is the breakdown voltage of a diode positive-temperature-coefficient under the mechanism of the avalanche breakdown?

4. (3%) What is the purpose of doping impurity into a semiconductor?

5. (3%) What is the key difference among conductor, semiconductor, and insulator?

6. (3%) What is the difference between drift current and diffusion current in a semiconductor from the mechanism viewpoint?