SI100B – Electrical Engineering, 2023 Spring

Homework #1

Notes:

1. The submission deadline is **2023-04-16 23:59:59**. No late submissions will be accepted.
2. You must work on this homework individually. Any plagiarism will result in a zero grade for this assignment.
3. You can either type your answers in a word document or handwrite them and scan them as a pdf file.
4. The simulation files that support your analysis should be named according to the problems. You can zip them together with your solutions into a single file.

Problem 1. Circuit analysis (45 points)

For this problem, you need to apply the circuit principles you have learned to analyze the voltage and current in the circuit.

1) Based on the circuit shown in Fig. 1-1, write down the KVL and KCL equations. **(15 points)**

2) Using the equations you wrote, find the resistor currents i_1, i_2, i_3, i_4, and the voltage drops across the resistors v_1, v_2, v_3, v_4. Given: $V_s = 20V$, $I_s = 1A$, $R_1 = R_2 = 2\Omega$, $R_3 = R_4 = 4\Omega$. **(15 points)**

3) Use a simulation software (MATLAB, Multisim, or any other software you prefer) to verify your results. **(15 points)**

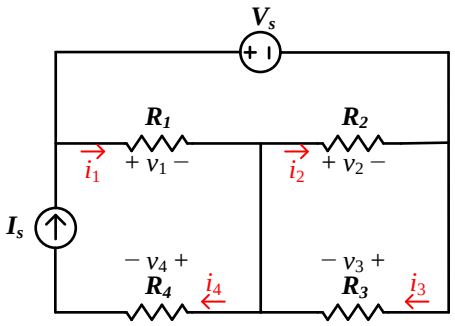

Fig. 1-1

(Hint: You should show all the equations you used to solve the circuit. Zip the simulation file and the answer into a single file.)

Problem 2. Diode Circuits (30 points)

You need to design an LED lamp circuit using a LED, a voltage source ($V_s = 6V$) and some resistors. The LED has a maximum current rating of $I_{max} = 20mA$. To prevent the LED from burning out, you need to add a current limiting resistor R_s. See Fig. 2-1 for the circuit diagram. Fig. 2-2 and Fig. 2-3 show the **RELATIVE LUMINOUS INTENSITY-FORWARD CURRENT** and **FORWARD CURRENT-FORWARD VOLTAGE** characteristics of the LED, respectively.

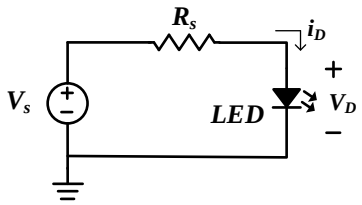

Fig. 2-1

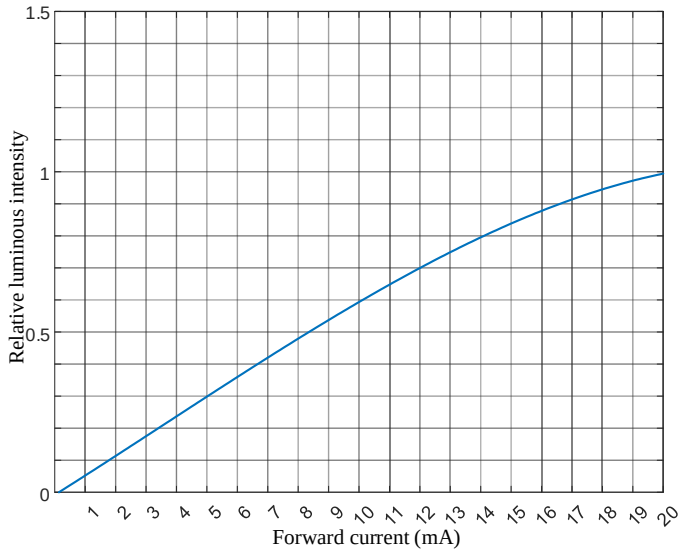

Fig. 2-2 Relative luminous intensity-current

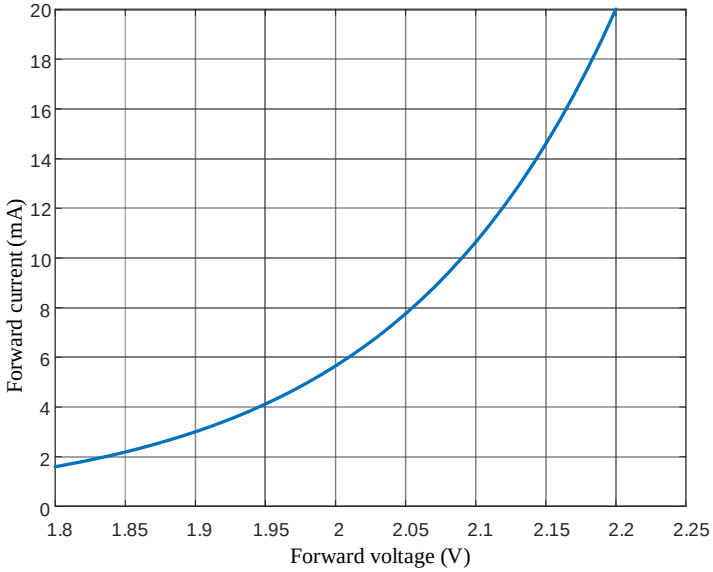

Fig. 2-3 I-V characteristic

1) To make the LED operate at a relative luminous intensity of 0.6, find the forward voltage and the value of R_s. **(15 points)**
(Hint: You only need to calculate the approximate value.)

2) If $R_s = 400\Omega$, what are the voltage drop, forward current, and relative luminous intensity of the LED in this case? **(15 points)**
(Hint: You can use the load-line analysis method from the reference book EEPA Chapter 9.2 to help you determine the diode operating point.)

Problem 3. CMOS (25 points)

You have learned how to make two-input CMOS NAND and NOR gates in class. In this problem, you need to design a two-input CMOS AND gate.

1) Draw the circuit diagram of a two-input CMOS AND gate. **(5 points)**

2) Show a truth table for the AND gate. **(5 points)**

3) Draw the equivalent circuits of the AND gate for: **a.** A high and B high; **b.** A high and B low; **c.** A low and B low. **(15 points)**

(Hint: You can refer to Figure 11.34 from the reference book EEPA Chapter 11.7.)

Bonus problem (10 points)

You can earn some bonus points for this homework (up to a total score of 100) if you answer the following questions reasonably. You can search the Internet for more information if you are interested in these topics.

1) Actually, we can use the Shockley diode equation to describe the relationship between current and voltage for diodes

$$i = I_s(e^{qv/nkT} - 1)$$

Where i is the current through the diode, I_s is the reverse saturation current ($I_s = 1.5 \times 10^{-9}$ A), e is the natural logarithm base, q is the charge on an electron ($q = 1.602 \times 10^{-19}$ C), v is diode voltage, n is the ideality factor (n=4 for this case), k is Boltzmann's constant ($k = 1.380 \times 10^{-23}$ J/K), T is the temperature in kelvin (T=300K).

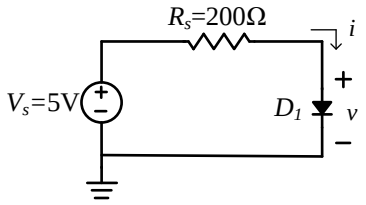

Fig. 4-1

Use this equation to find the diode current and voltage in Fig. 4-1. **(10 points)**

(Hint: You should use mathematical tools like MATLAB to solve the equations. If you do so, please include your codes in your submission.)