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Set: 01

Brac University

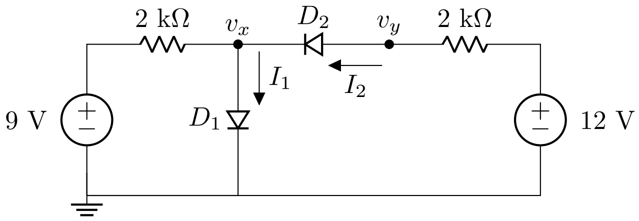
Semester: Spring 2023
Course No: CSE251
Course Title: Electronic Devices and Circuits
Section: 1 to 12

Midterm Exam
Full Marks: 30
Time: 1 hour 40 minutes
Date: March 4, 2023

Answer **any 3 questions**. All the questions carry equal marks.

Question 1 [CO1] **10**

Sherlock Holmes found a piece of paper from the pocket of one of Professor Moriarty's victim with the circuit shown below. One side of the paper is missing and the only other available information was that the **D1 diode is on**. Sherlock needs to know the values of v_x, v_y, I_1, and I_2 as it generates the passcode for the victim's locker, which can help him catch Moriarty. Sherlock knows nothing about diodes and asked for your help to solve the case.



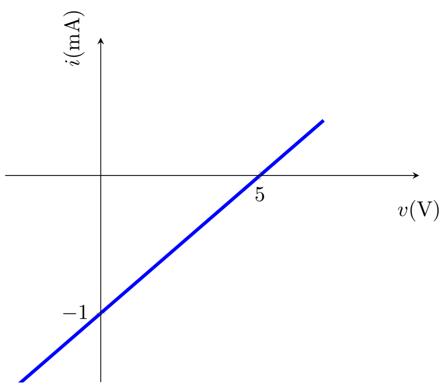
	v_x	I_1	I_2	v_y
Passcode $\Longrightarrow$	?	?	?	?

(a) **Show** the alternative representation of the given circuit. [1.5]

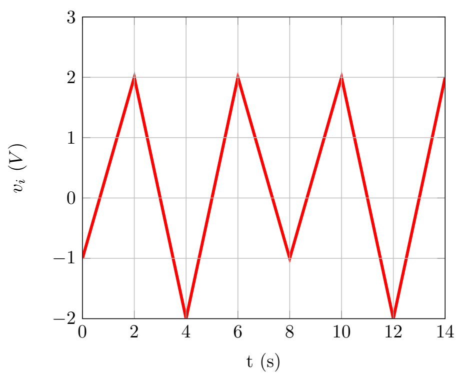
(b) **Analyze** the circuit to **calculate** the values of v_x, v_y, I_1 and I_2, and hence the passcode. You must **validate** your assumption. Use the constant voltage drop model with a forward voltage drop, $V_{D0} = 1$ V. [5+2]

(c) Passive sign convention states that a device is delivering power if $p = v \times I$ for the device is negative, and consuming power if p is positive. **Deduce** whether D_1 is consuming or delivering power. [1.5]

Question 2 [CO1, CO2] **10**



(i) IV Characteristics of the PCB model



(ii) Input of the FW rectifier

Part 1

Afia, an engineer at Intel, is tasked to model a two-terminal printed circuit board (PCB) with hundreds of linear circuit components. She plotted the current I of the PCB as a function of the input voltage V. To her utter surprise, she found the simple IV graph shown in Figure (i), which she immediately recognized as the IV of a ___**"x"**___ source in series with a ___**"y"**___.

(a) **Identify** the components **"x"** and **"y"**. [1]

(b) **Draw** the equivalent circuit and **calculate** the model parameters, i.e., values of the **"x"** source and **"y"**. [2]

(c) **[Bonus]** It's amazing that a circuit with hundreds of elements can be modeled using only two elements **"x"** and **"y"**. **What** is the name of the theorem that supports this? [0.5]

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Part 2

A voltage waveform $v_i = 10\sin(1000\pi t)$ V is fed into a full-wave (FW) rectifier with a load resistance $R = 10$ kΩ. A capacitor is also connected in parallel with the load to reduce the fluctuation of the output voltage. It produces a peak-to-peak ripple voltage which is **3%** of the peak output voltage. The diodes have a forward voltage drop of $V_{D_0} = 0.8$ V.

(d) **Deduce** the peak output voltage, V_p, and the peak-to-peak ripple voltage, $v_{r(p-p)}$. [2]

(e) **Calculate** the average (DC) value of the output voltage. [1]

(f) **Estimate** the value of the capacitor from the given data. [2]

Now the input voltage v_i is changed to the one shown in Figure (ii) and the **capacitor is removed**.

(g) **Show** the output waveform and **indicate** the voltage levels properly. [2]

Question 3 [CO3] **10**

Part 1

Farhan, CEO of Rajshahi WASA, is building a water level indicator for an overhead tank. For this, he placed three sensors at three different levels of the tank. The voltage outputs of the three sensors are denoted as V_1 (lowest level), V_2 (mid-level), and V_3 (highest level). Farhan decided that the indicator for the water level would be,

$$V_{\text{indicator}} = \frac{1}{k}(V_1 + V_2 + V_3)$$

(a) Assuming $k = 1$, **design** the circuit using op amps that will take V_1, V_2, and V_3 as *input* and will produce $V_{\text{indicator}}$ as *output.* [3]

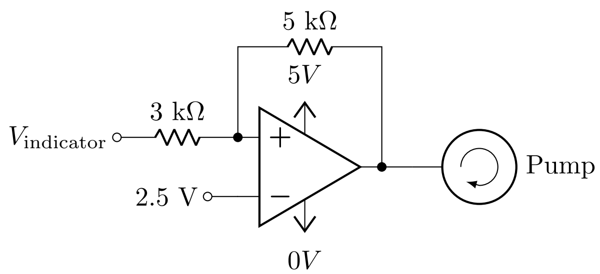
Upon further experimentation, Farhan realized that the maximum values of V_1, V_2, and V_3 are 5 V. Hence, the maximum value of $V_1 + V_2 + V_3$ can be 15 V. However, Farhan only has access to +5 V and −5 V as power supplies, meaning that the $V_{\text{indicator}}$ cannot be greater than +5 V or less than −5 V.

(b) **Choose** a value of k such that the maximum value of $V_{\text{indicator}}$ is within the given range. [1]

(c) **Design** the circuit in part (a) again using this new value of k. [2]

Part 2

Now Farhan wants to control a pump based on $V_{\text{indicator}}$. He observed that the voltage $V_{\text{indicator}}$ increases when the water level decreases, and vice-versa. He wants the pump to **turn on** when the water level is below a threshold, i.e., when $V_{\text{indicator}}$ is **greater than** V_{TU}, and **turn off** when the water level is above a threshold, i.e., $V_{\text{indicator}}$ is **less than** V_{TL}. Based on this, he built the following two-threshold comparator using op amp (Schmitt Trigger).



(d) **Calculate** the thresholds V_{TU} and V_{TL}. **Show** the voltage transfer characteristics of the comparator. [2 + 2]

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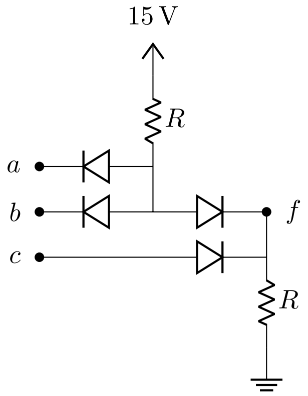
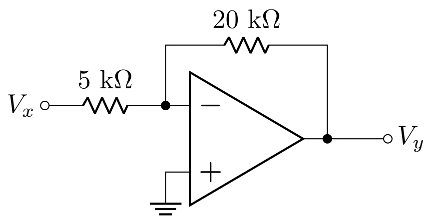
Question 4 [CO2, CO3] **10**



(i) Circuit for Question 4 (a)



(ii) Circuit for Questions 4 (c) and (d)

Part 1

(a) **Analyze** the circuit shown in Figure (i) to determine the logic expression of f as a function of boolean inputs a, b, and c. Here, assume all the diodes are ideal. [2]

Part 2

(b) **Design** a circuit using op amp that takes $V_i = 1 - 0.5\cos t$ as *input* and produces $V_o = 2\sin t$ as *output*. [4]

Now the output V_o of question 4(b) is used as the input to the circuit shown in Figure (ii), i.e., $V_x = V_o = 2\sin t$.

(c) **Deduce** an expression of V_y of the circuit shown in Figure (ii) as a function of V_x. [2]

(d) **Show** the waveform of V_y and **indicate** the voltage levels properly. [2]

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