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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

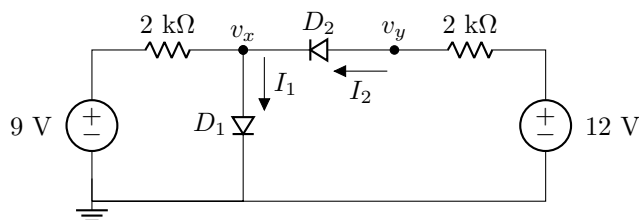
Date: March 4, 2023

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

### Question 1 [CO1]

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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.

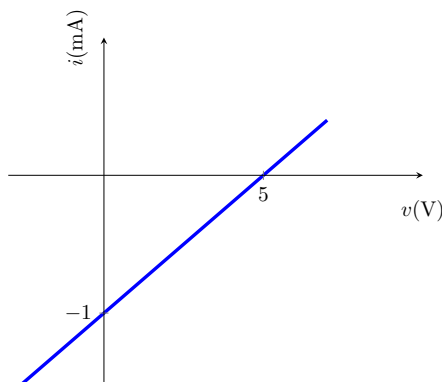


|       |       |       |       |
|-------|-------|-------|-------|
| $v_x$ | $I_1$ | $I_2$ | $v_y$ |
| ?     | ?     | ?     | ?     |

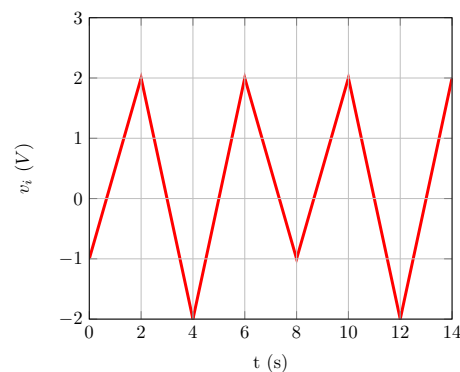
- Show the alternative representation of the given circuit. [1.5]
- Analyze the circuit to calculate the values of  $v_x$ ,  $v_y$ ,  $I_1$  and  $I_2$ , and hence the passcode. You must validate your assumption. Use the constant voltage drop model with a forward voltage drop,  $V_{D0} = 1$  V. [5+2]
- 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]

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(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”**.

- Identify the components **“x”** and **“y”**. [1]
- Draw the equivalent circuit and calculate the model parameters, i.e., values of the **“x”** source and **“y”**. [2]
- [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  $R = 10 \text{ k}\Omega$ . 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  $V_{D_0} = 0.8 \text{ V}$ .

- (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]

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#### 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,

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

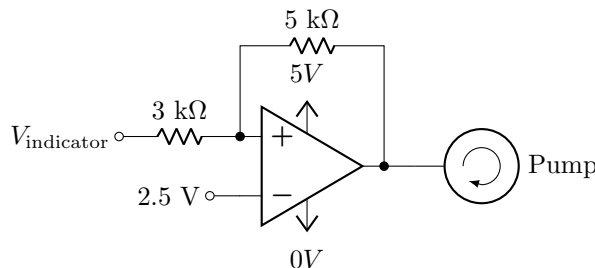
- (a) Assuming  $k = 1$ , **design** the circuit using op amps that will take  $V_1$ ,  $V_2$ , and  $V_3$  as *input* and will produce  $V_{\text{indicator}}$  as *output*. [3]

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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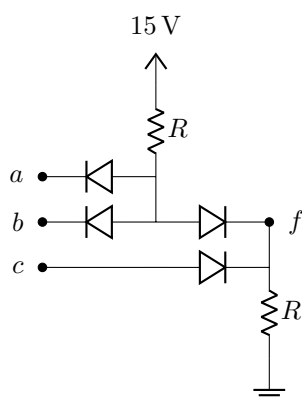
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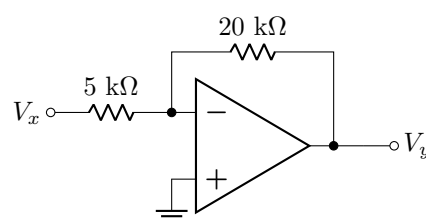
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## Question 4 [CO2, CO3]

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(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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