BRAC University
Dept. of Computer Science and Engineering

Assessment: Assignment 3
Due: **11:59 PM 27 October 2023**
Full Marks: **65**

Semester:	Fall 2023
Course Code:	CSE251
Section:	**21**
Course Name:	Electronic Devices and Circuits

Name: ______________________________

Student ID: ______________________________

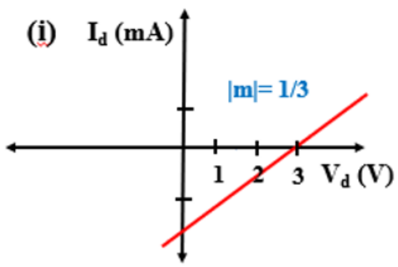
- ✓ Write down your student ID on the **top right corner of each of the pages**.
- ✓ Clearly write the solutions, along with the questions, on white paper with black ink (no need to use color pen, don't use pencils).
- ✓ Use **CamScanner**, or **Adobe Scan**, or **Microsoft Office Lens**, or any other software to scan the pages and make a **single PDF file**.
- ✓ After creating the PDF, make sure that **(a)** there are no pages missing, **(b)** all of the pages are legible, **(c)** your student ID on each page are visible.
- ✓ Please note, **collaboration ≠ copying**. You are allowed to discuss the questions and clear confusion you might have, but you have to write your solutions independently and be able to explain your answers during a random viva.
- ✓ **[Very Important]** Rename the PDF in the following format: **"A1_StudentID_FullNameWithoutSpace.pdf"**. For example, if my student ID is 12345678 and my name is Shadman Shahid, the filename should be **"A1_12345678_ShadmanShahid.pdf"**.
- ✓ **Submission Link: https://forms.gle/Ec4w1dmpmox9groVA**

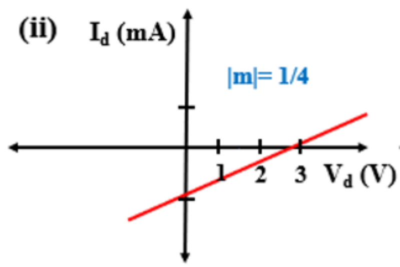
Question 1: 10 Marks

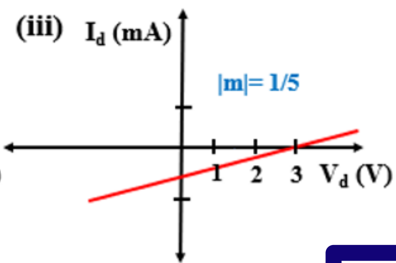
a) For the following sub-circuits, do the following: - Write down the equation representing this curve; - **Determine** the unknown parameters, - Label the I-V curve. [CO1] 5

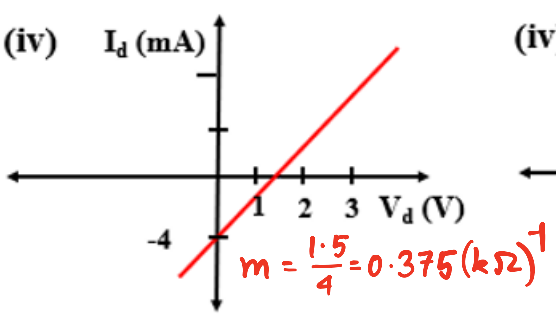
i. A $\mathbf{3\ V}$ voltage source
ii. A $\mathbf{5\ mA}$ current source in parallel with a $\mathbf{5\ k\Omega}$
iii. A $\mathbf{-10\ V}$ voltage source with $\mathbf{3\ \ k\Omega}$
iv. A short circuit
v. A current Source, $I_o = 5$ mA in parallel with a resistor. The slope of the curve is, $m = 5\ k\Omega^{-1}$

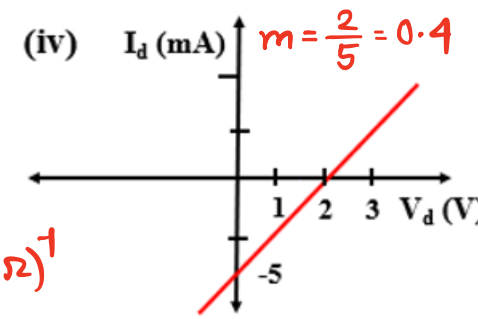
b) **Draw** the sub-circuit that will result in the following IV characteristics. [CO3] 5

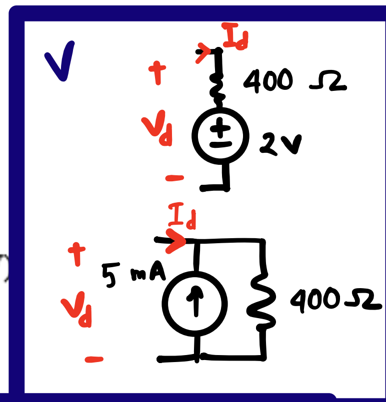




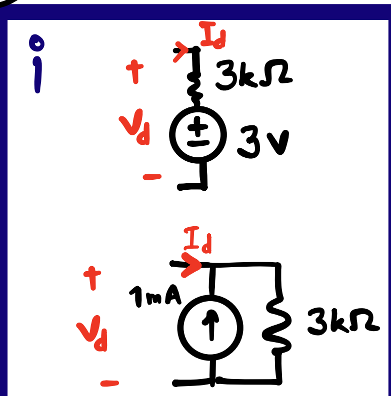


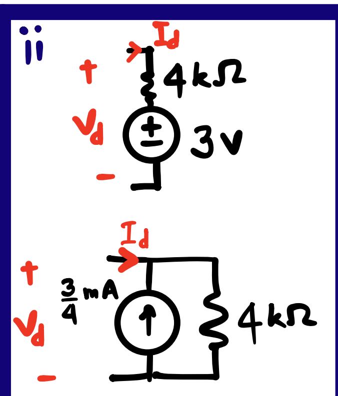


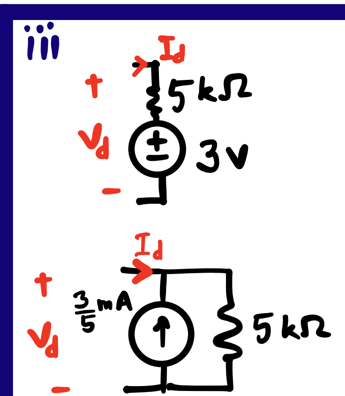


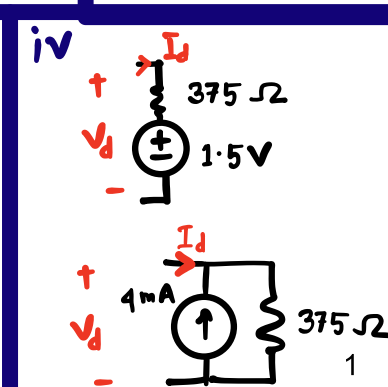


b



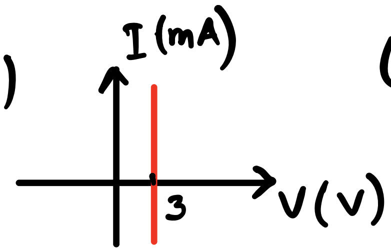






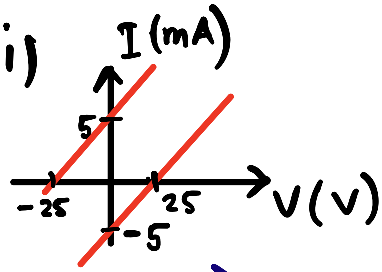
(a)

(i)



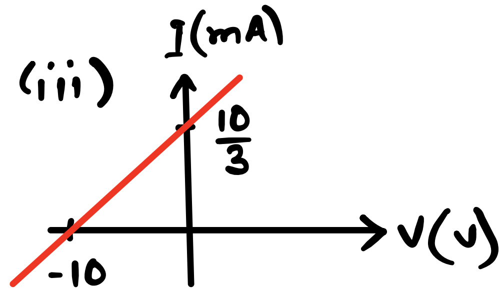
$(V = 3\,V)$

(ii)



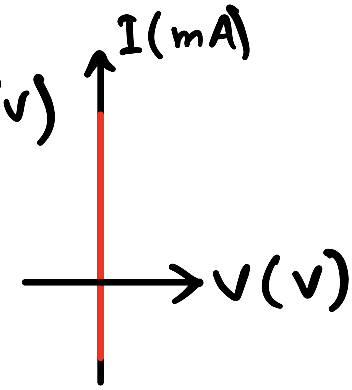
$\left(I = \frac{V}{5} \pm 5\right)$

(iii)



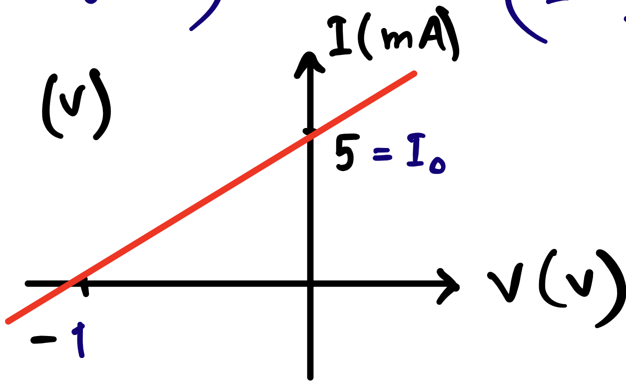
$\left(I = \frac{V}{3} + \frac{10}{3}\right)$

(iv)



$(V = 0)$

(v)



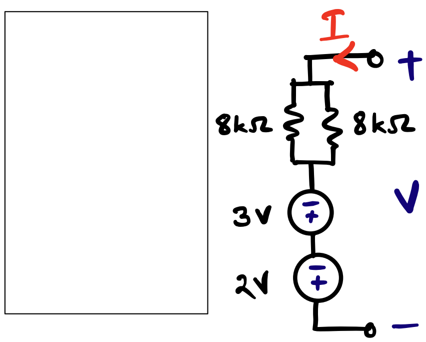
$(I = 5V + 5)$

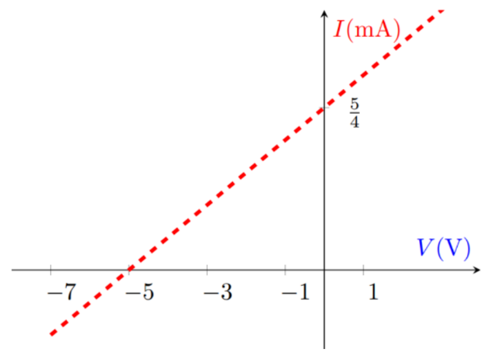
Question 2: 35 Marks

a) You are provided with the following circuit elements: [CO3] 5

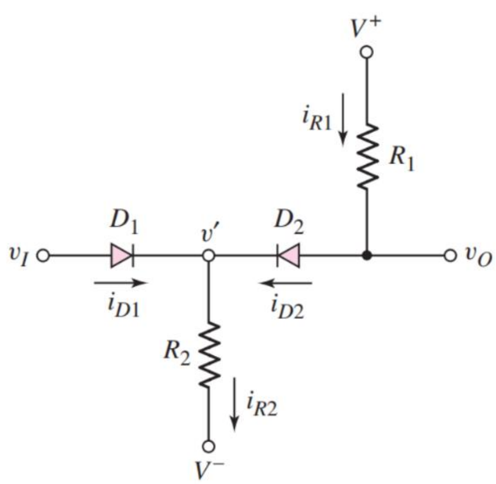
- **Two** 8 kΩ resistors
- A 3 V voltage source
- A 2 V voltage source

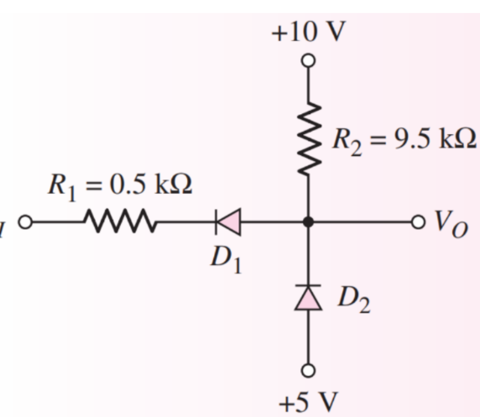
Can you **implement** a circuit element **X** that has an IV-characteristics, as seen in the **right** figure below, but by **ONLY USING THE ELEMENTS MENTIONED ABOVE**? The voltage polarity and current direction should be as shown in the left figure.





b) For the circuit **below (left)**, assume the following circuit parameters: $\boldsymbol{R_1 = 5\ \mathrm{k\Omega}}$, $\boldsymbol{R_2 = 10\ \mathrm{k\Omega}}$, $\boldsymbol{V_{DO} = 0.7\ \mathrm{V}}$, $\boldsymbol{V^+ = 5\ \mathrm{V}}$, $\boldsymbol{V^- = 5\ \mathrm{V}}$. Determine v_o, i_{D1} and i_{D2} for $\boldsymbol{v_I = 0}$ and $\boldsymbol{v_I = 4\ \mathrm{V}}$. [CO2] 3



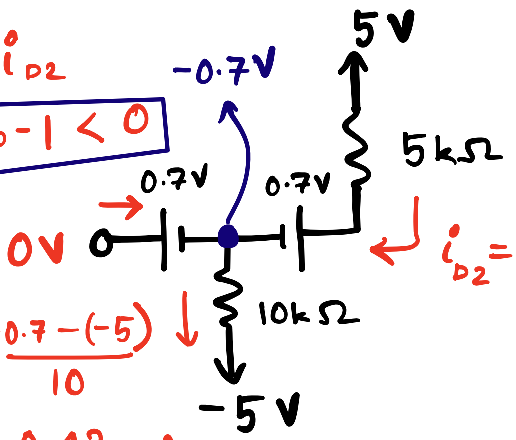


c) For the circuit **above (right)**., assume the following circuit parameters: $\boldsymbol{V_{DO} = 0.6\ \mathrm{V}}$. Plot $\boldsymbol{v_o}$ versus $\boldsymbol{v_I}$, for $\boldsymbol{0 \le v_I \le 10\ \mathrm{V}}$. [CO2] 7

2(b) (i) $\rightarrow v_I = 0\text{ V}$

Initial assumption: $D_1 \rightarrow$ Forward Bias.

$D_2 \rightarrow$ Forward Bias.



$i_{D1} = i_{R2} - i_{D2}$

$\boxed{i_{D1} = 0.43 - 1 < 0}$

$i_{D2} = \dfrac{5-(-0.7+0.7)}{5} = 1\text{ mA} > 0$

[Assumption for D_2 is correct]

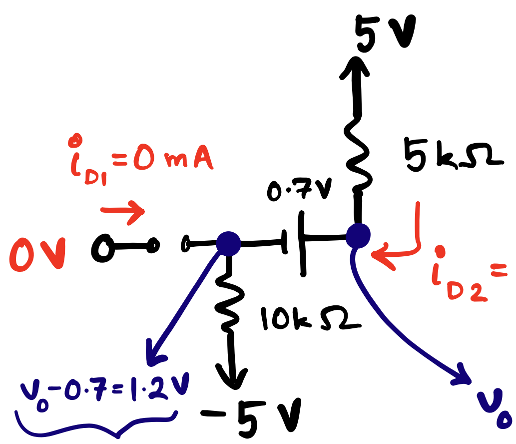
$i_{R2} = \dfrac{-0.7-(-5)}{10}$

$i_{R2} = 0.43\text{ mA}$

[Assumption for D_1 false] $\longrightarrow$ New assumption:

$D_1 \rightarrow$ Reverse Bias.

$D_2 \rightarrow$ Forward Bias.



$i_{D1} = 0\text{ mA}$

$i_{D2} = \dfrac{5+5-0.7}{5+10} = \underline{\underline{0.62\text{ mA}}}$

[Assumption for D_2 is correct]

$\underbrace{v_o - 0.7 = 1.2\text{ V}}$

[Assumption for D_1 is correct as $v_d = -1.2\text{ V} < 0.7\text{ V}$]

$v_o = 5 - 5 i_{D2} = \underline{\underline{1.9\text{ V}}}$

Question 2: 35 Marks

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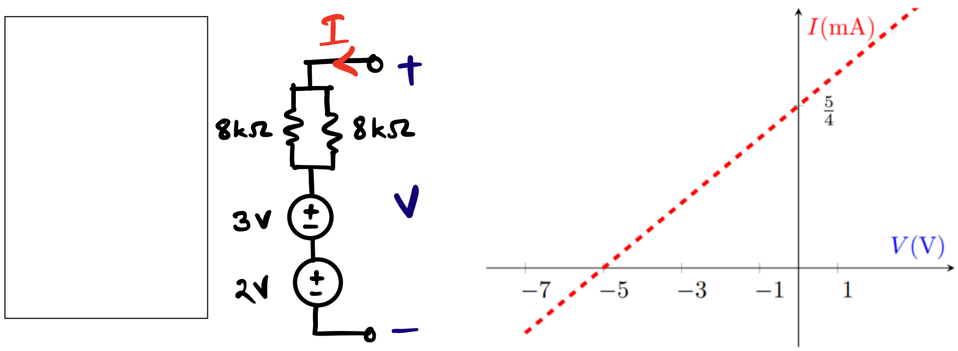
Can you **implement** a circuit element **X** that has an IV-characteristics, as seen in the **right** figur below, but by **ONLY USING THE ELEMENTS MENTIONED ABOVE**? The voltage polarity an current direction should be as shown in the left figure.



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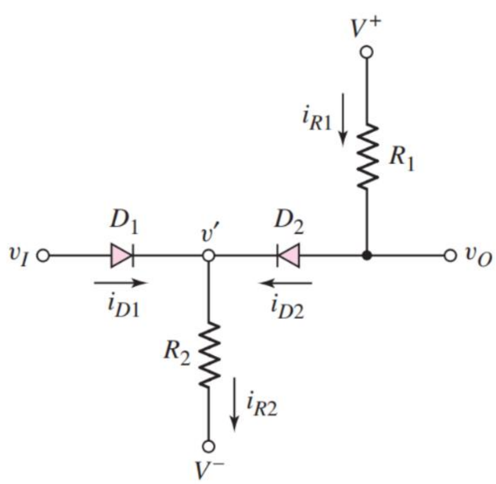
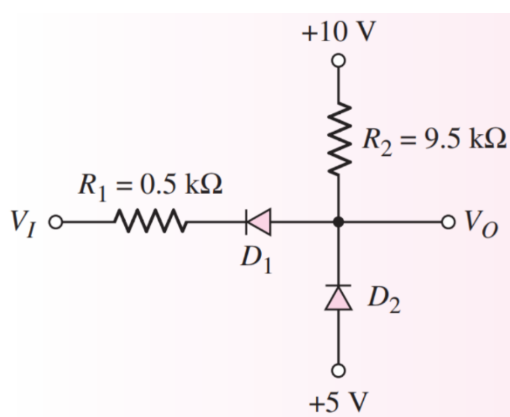




c) For the circuit **above (right).**, assume the following circuit parameters: $\boldsymbol{V_{DO} = 0.6\ \mathrm{V}}$. Plot $\boldsymbol{v_o}$ versus $\boldsymbol{v_I}$, for $\boldsymbol{0 \le v_I \le 10\ \mathrm{V}}$. [CO2] 7

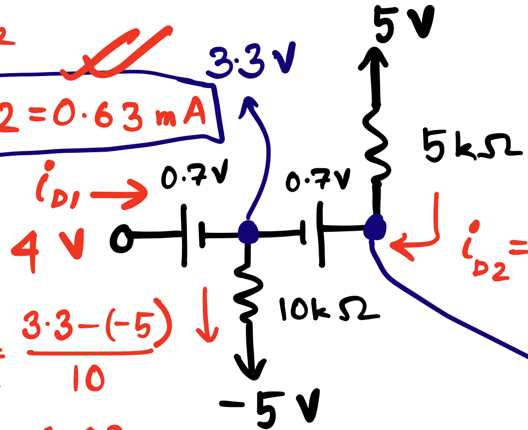
2(b) (i) $\rightarrow v_I = 4\,V$

Initial assumption: $D_1 \rightarrow$ Forward Bias.

$D_2 \rightarrow$ Forward Bias.

$i_{D1} = i_{R2} - i_{D2}$

$\boxed{i_{D1} = 0.83 - 0.2 = 0.63\,mA}$



$i_{D2} = \dfrac{5-(3.3+0.7)}{5} = 0.2\,mA > 0$

[Assumption for D_2 is correct]

$i_{R2} = \dfrac{3.3-(-5)}{10}$

$i_{R2} = 0.83\,mA$

[Assumption for D_1 TRUE]

$V_o = (3.3 + 0.7)\,V$

$= 4\,V$

2(c) Find out the graph in three stages.

Stage 1: D_1: Forward biased.

D_2 Forward biased.

Stage 2: D_1: Forward biased.

D_2: Reverse biased.

Stage 3: D_1: Reverse biased.

D_2: Reverse biased.

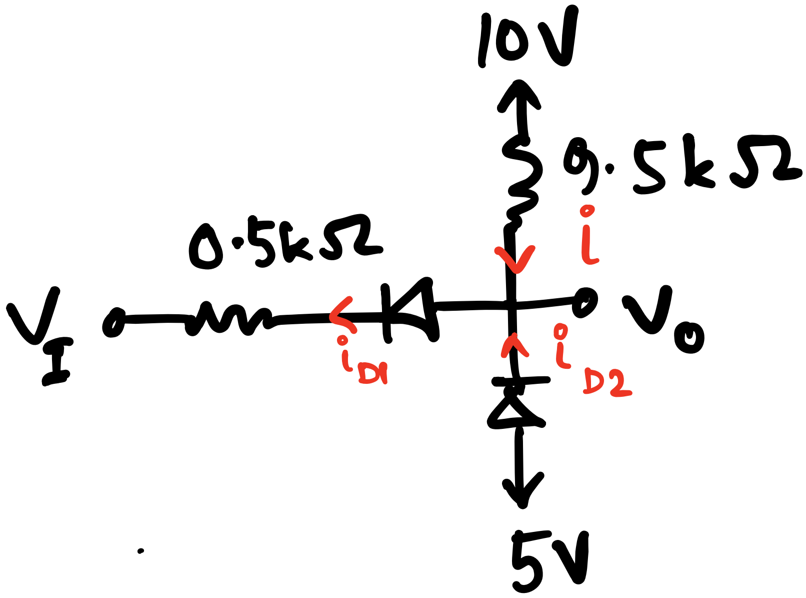
Stage 1

If D_1 is forward biased:

$i_{D1} > 0$

$\Rightarrow \dfrac{V_0 - V_{D0} - V_I}{0.5} > 0$ $\quad$ 0.6V

$V_0 - V_I > 0.6\ V$



If D_2 is forward biased,

$$\boxed{V_o = 5 - V_{D0} = 4.4V}$$

$i_{D2} = i_{D1} - i > 0$ $\quad$ $i_{D1} > i$

$$\Rightarrow \frac{V_o - V_{D0} - V_I}{0.5} - \frac{10 - V_o}{9.5} > 0 \quad \text{------------}(i)$$

At the edge of forward bias: $V_o = 4.4\,V$.

$$(i) \cdots\cdots \Rightarrow \frac{4.4 - 0.6 - V_I}{0.5} > \frac{10 - 4.4}{9.5}$$

$$\Rightarrow \boxed{V_I < 3.505\,V}$$

So, both D_1 & D_2 are F.B when:

$$V_I < 3.505 \ \&\ V_o = 4.4\,V \ \&\ V_o - V_I > 0.6$$

Stage 1

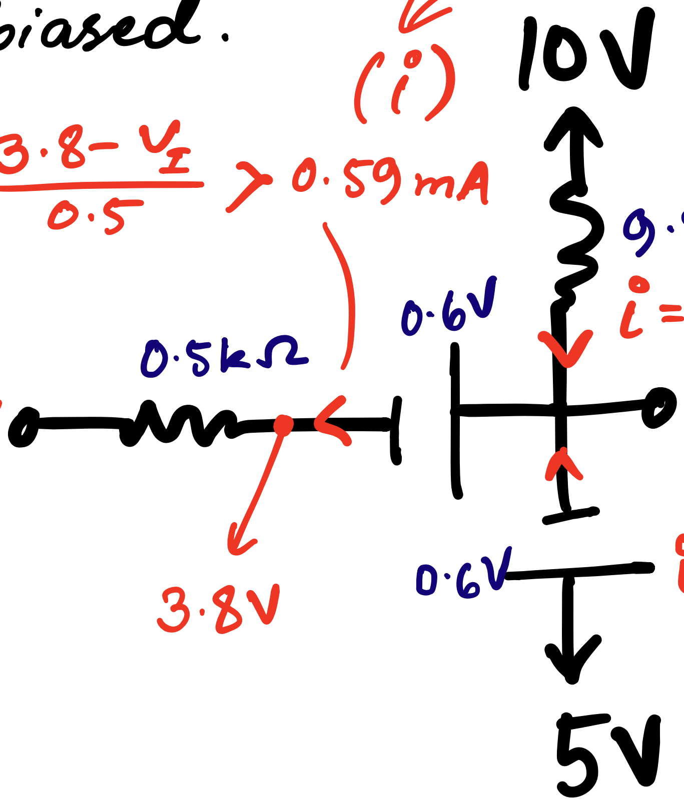
D_1: Forward biased.

D_2 Forward biased.

(i)

$i_{D1} = \frac{3.8 - V_I}{0.5} > 0.59\,mA$

$i = \frac{5.6}{9.5} = 0.59\,mA$



$(0 < V_I < 3.505)\,V$

$V_o = 4.4\,V$

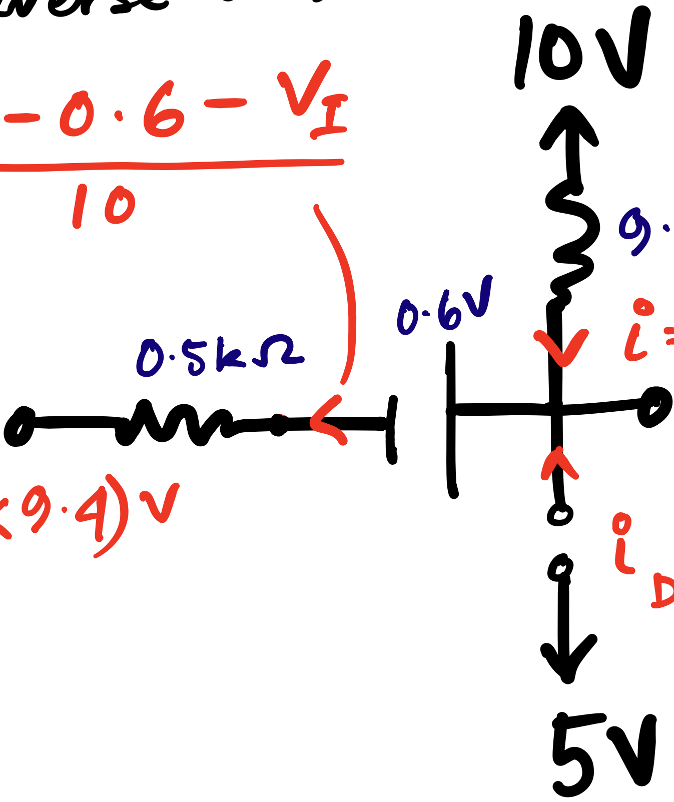
$i_{D2} = i_{D1} - 0.59.$

Stage 2

D_1: Forward biased.

D_2: Reverse biased.

$i_{D1} = \frac{10 - 0.6 - V_I}{10}$



$i = i_{D1}$

$\boxed{V_o = 0.95\,V_I + 1.07}$

$(3.50 < V_I < 9.4)\,V$

$i_{D2} = 0\,mA$

Stage 2

When D_2 is Reverse biased: $V_I > 3.505\,V$

$i_{D_2} = 0$: $i_{D_1} = i$ (D_1 is still forward biased)

$$\Rightarrow \frac{V_0 - 0.6 - V_I}{0.5} = \frac{10 - V_0}{9.5}$$

$$\Rightarrow \boxed{V_0 = 0.95 V_I + 1.07}$$

Since D_1 is still forward biased.

$$V_0 - V_I > 0.6$$

$$0.95 V_I + 1.07 - V_I > 0.6$$

$$\Rightarrow \boxed{V_I < 9.4\,V}$$

At the edge of forward biased D_1: $V_I = 9.4\,V$

$$V_0 = 0.95 V_I + 1.07 = 10\,V.$$

Stage 3:

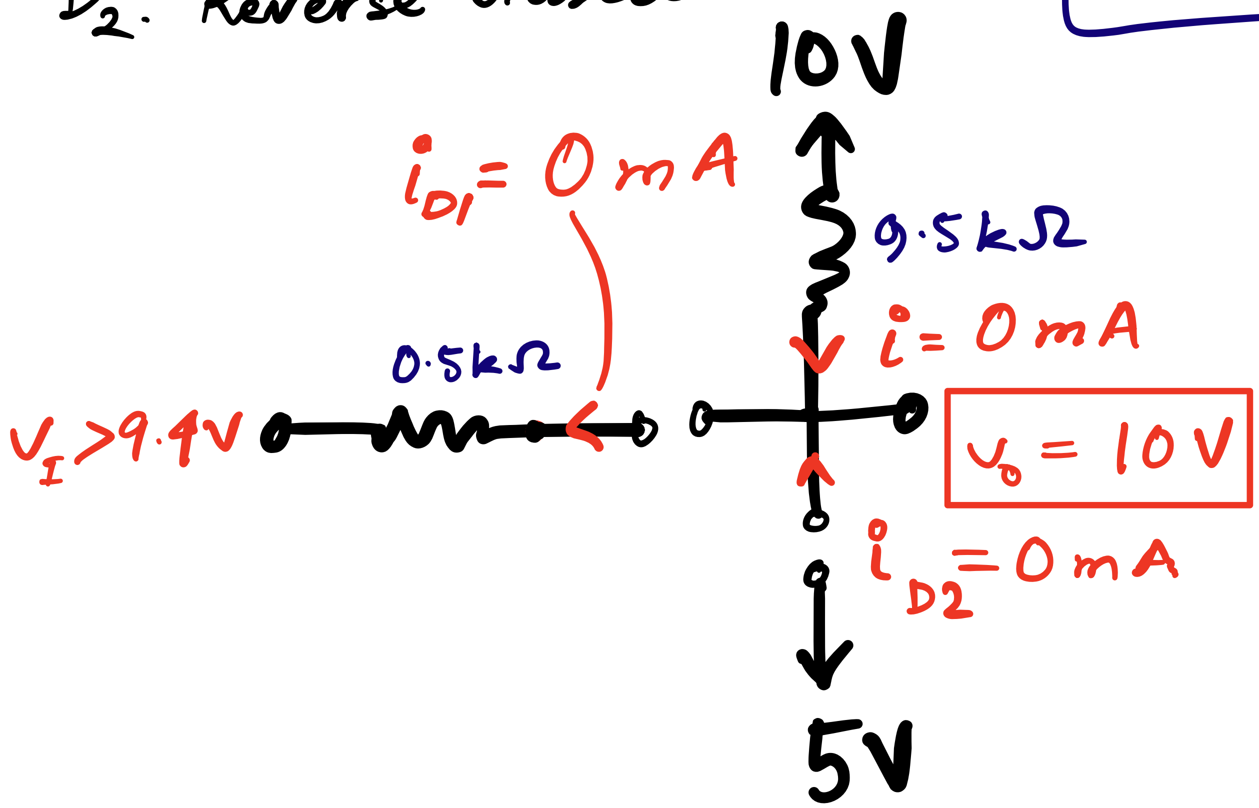
But if $V_0 = 10\,V$; $i = 0$; $i_{D_1} = 0$; $i_{D_2} = 0$ $\rightarrow V_I > 9.4\,V$

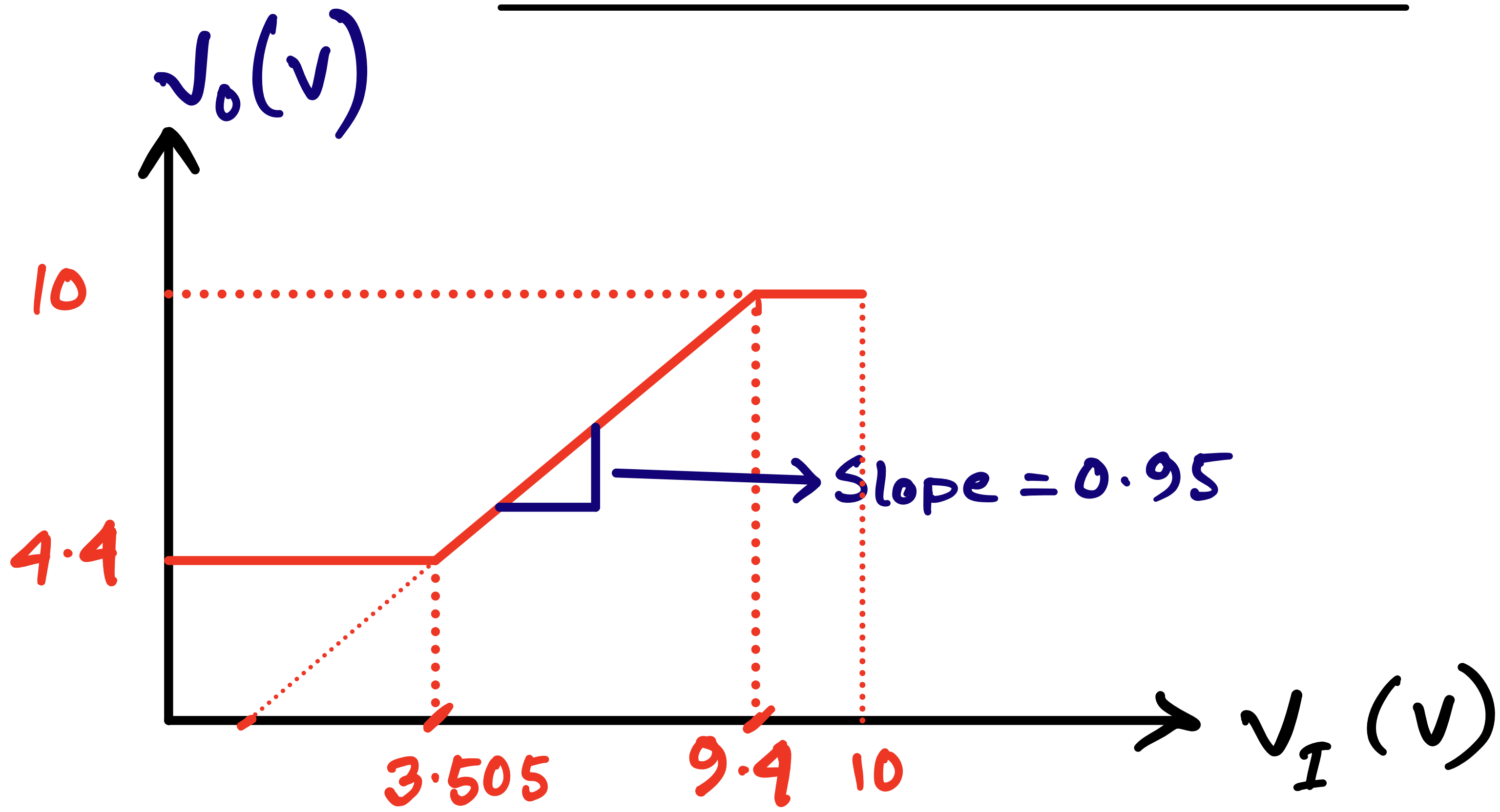
Both D_1 & D_2 are Reverse biased.

D_1: Reverse biased.

D_2: Reverse biased.

Stage 3

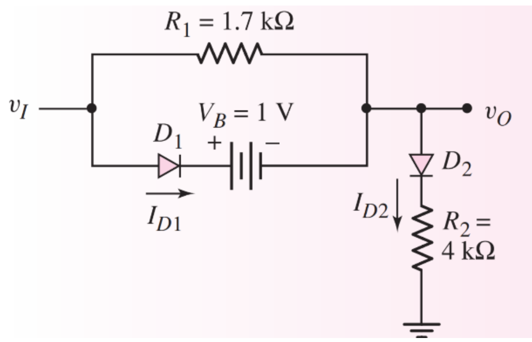




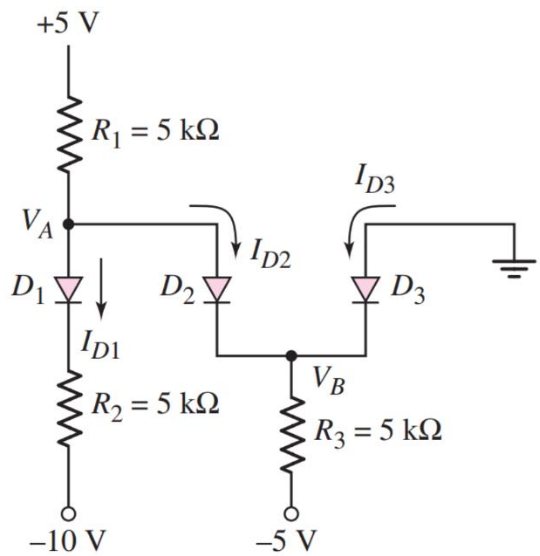
d) For the circuit below, the cut-in voltage for all the diodes are $V_{DO} = 0.7\ \mathbf{V}$. [CO2] 10

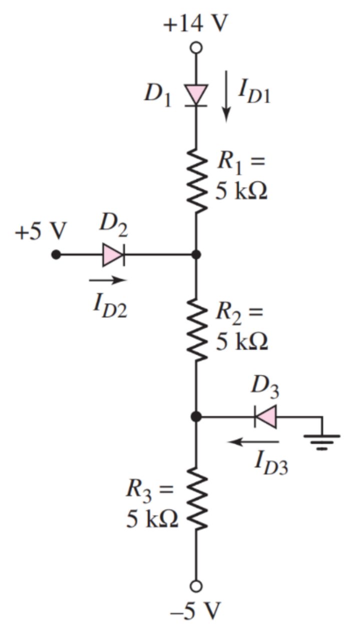
i. Let $v_I = 5\ \mathbf{V}$. Assume both diodes are conducting. Is this a correct assumption? Why or why not? Determine I_{R1}, I_{D1}, I_{D2} and v_O

ii. Repeat part (i) for $v_I = 10\ \mathbf{V}$



e) Determine the current in each diode (I_{D1}, I_{D2} and I_{D3}) and the voltages V_A and V_B in the multi-diode circuit shown in the figure **below (left)**. Let, $V_{DO} = 0.7\ \mathbf{V}$ for each diode. [CO2] 5

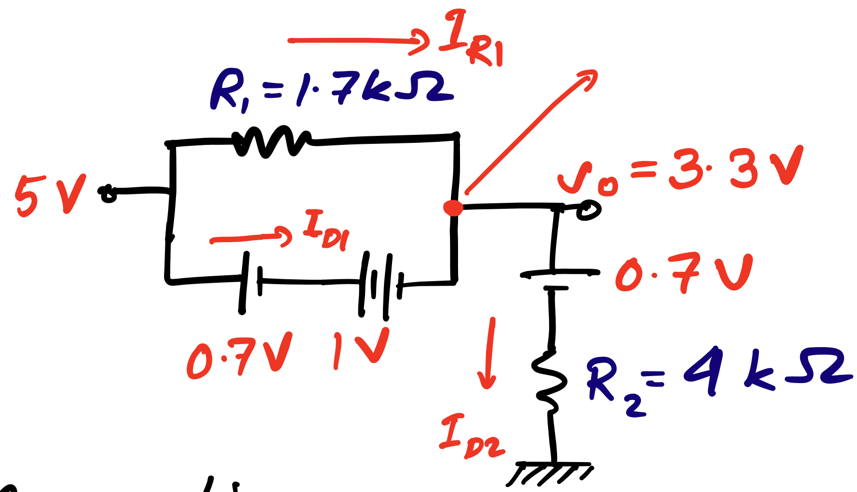




f) Determine I_{D1}, I_{D2} and I_{D3} and the voltages V_A and V_B for the circuit **above (right).** $V_{DO} = 0.7\ \mathbf{V}$ for each diode. [CO2] 5

2(d)i If both diodes are conducting:

$V_o = (5-0.7-1)\,V = 3.3\,V$



$$I_{D2} = \frac{3.3-0.7}{4}\,mA$$

$$\boxed{= 0.65\,mA > 0}$$

Assumption correct.

$I + I_{D_1} = I_{D2}$

$$I_{D1} = I_{D2} - I_{R1}$$

$$= \left(0.65 - \frac{5-3.3}{1.7}\right) mA$$

$$= 0.65 - 1 = \boxed{-0.35\,mA < 0}$$

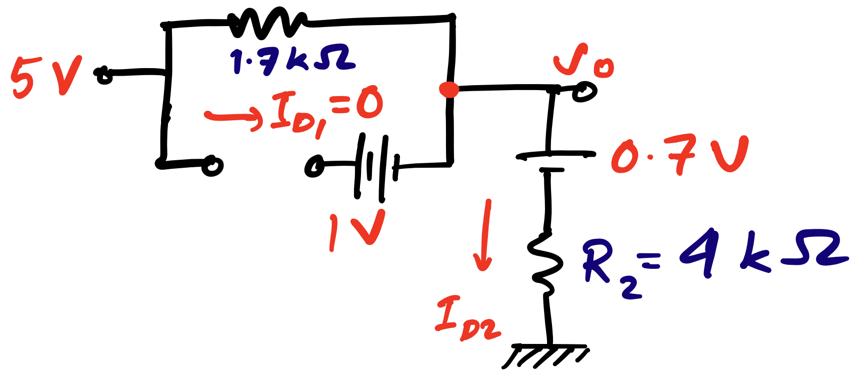
Assumption false

Correct assumption: D_1: Reverse biased.

D_2: Forward biased

$$\boxed{\begin{aligned} I_{D2} = I_{R1} &= \frac{5-0.7}{4+1.7}\,mA \\ &= 0.7544\,mA \\ V_o &= (5 - 1.7 \times 0.7544)\,V \\ &= 3.717\,V \\ I_{D1} &= 0\,mA \end{aligned}}$$

$I_{R1} = I_{D2} = \frac{5-0.7}{5.7} = 0.75\,mA$



2(d)(ii)

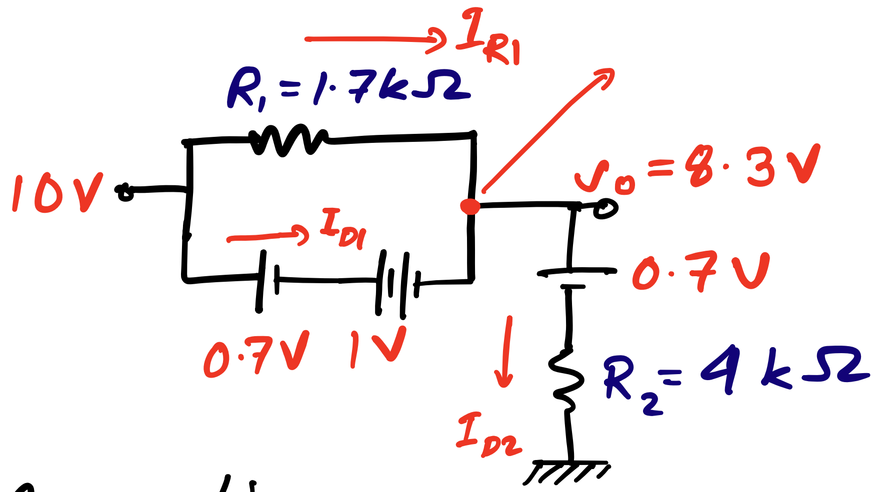
If both diodes are conducting:

$V_0 = (10 - 0.7 - 1)\,V = 8.3\,V$

$I_{D2} = \dfrac{8.3 - 0.7}{4}\,mA$

$\boxed{= 1.9\ mA > 0}$

Assumption correct.



$I + I_{D1} = I_{D2}$

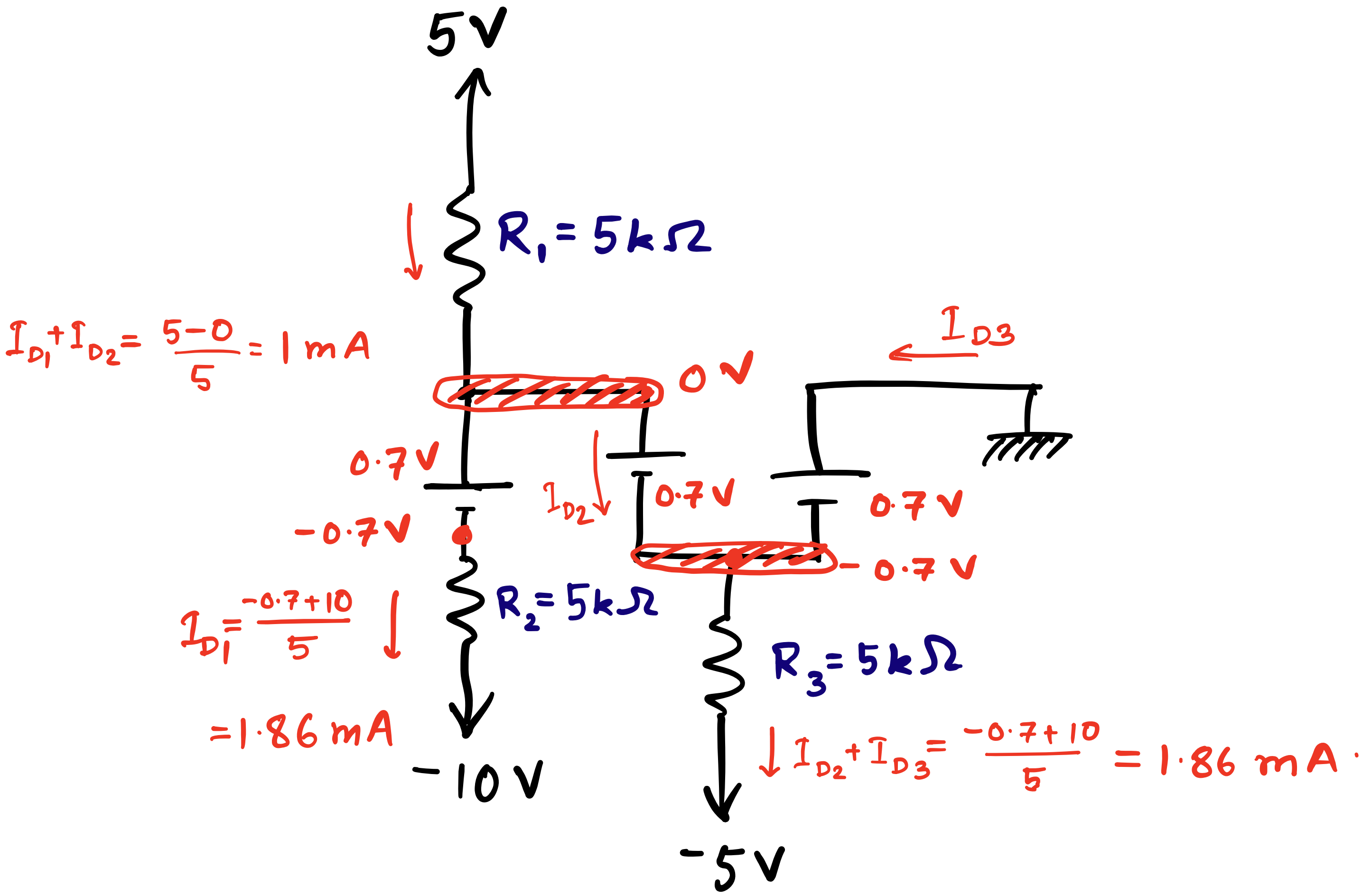
$I_{D1} = I_{D2} - I_{R1}$

$= \left(1.9 - \dfrac{10 - 8.3}{1.7}\right) mA$

$= 1.9 - 1 = \boxed{0.9\ mA > 0}$

Assumption correct.

2(e) D_1 : F.B
D_2 : F.B
D_3 : F.B



$I_{D_1} = 1.86\ mA$

$I_{D_1} + I_{D_2} = 1\ mA$

$\therefore \boxed{I_{D_2} = 1 - I_{D_1} = 1 - 1.86 = -0.86\ mA} \rightarrow$ Assumption false

$I_{D_3} + I_{D_2} = 1.86\ mA$

$I_{D_3} = 2.72\ mA$

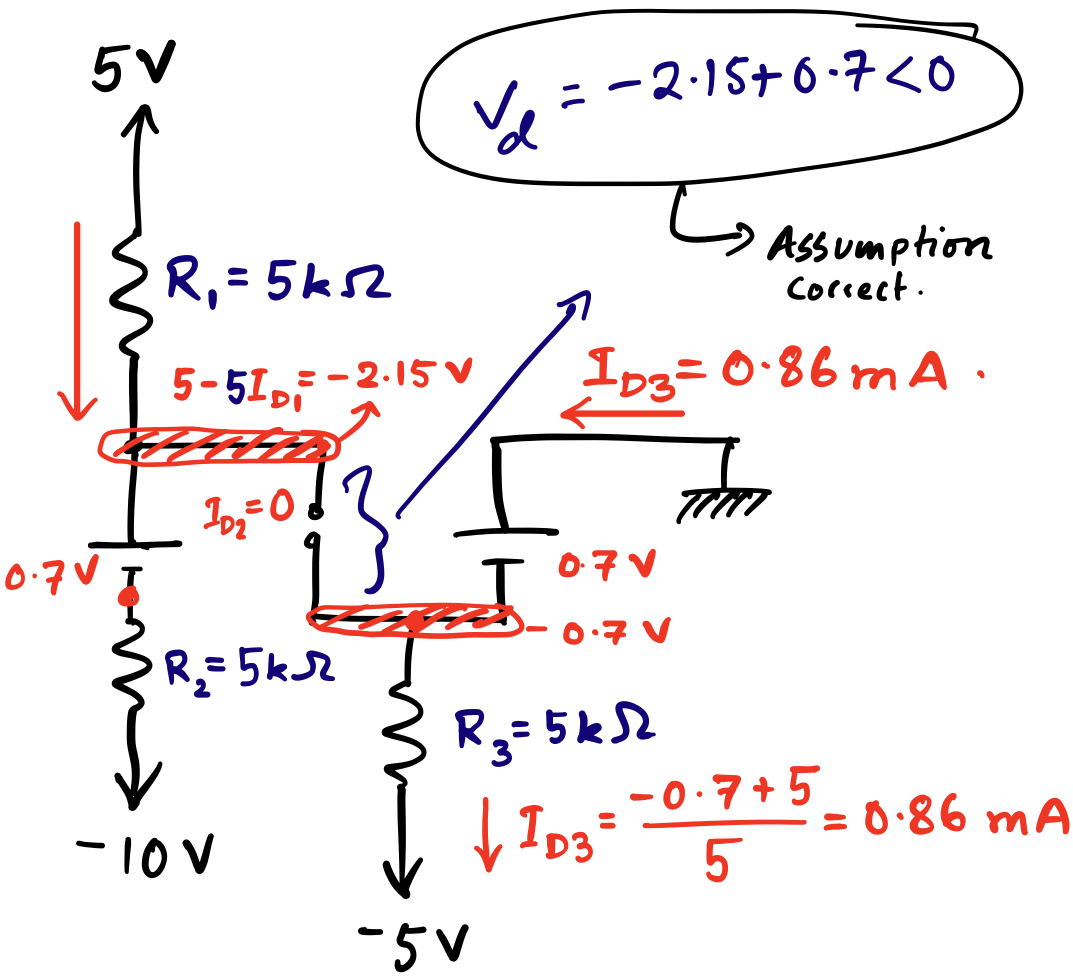
New Assumption:

D_1 : F·B

D_2 : R·B

D_3 : F·B

$$I_{D1} = \frac{5-0.7+10}{5+5} = 1.43\ mA$$



$I_{D1} = 1.43$ mA

$I_{D2} = 0$

$I_{D3} = 0.86$ mA

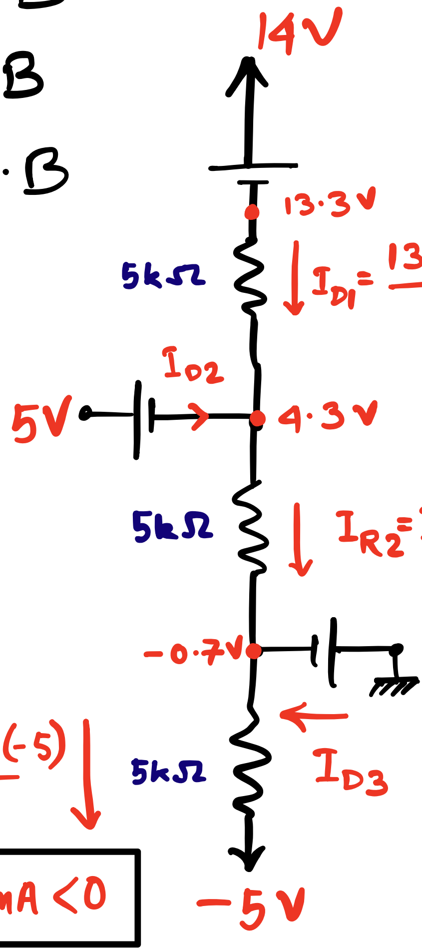
$V_A = -2.15$ V

$V_B = -0.7$ V

2(f) D_1 : F.B

D_2 : F.B

D_3 : F.B



$I_{D1} = \frac{13.3-4.3}{5} = 1.8\,mA$

$I_{R2} = I_{D2} + I_{D1} = \frac{4.3-(-0.7)}{5} = 1\,mA$

$\boxed{\therefore I_{D2} = (1-1.8)\,mA = -0.8\,mA}$

Assumption for D_2 false.

$I_{R2} + I_{D3} = \frac{-0.7-(-5)}{5}$

$\boxed{\therefore I_{D3} = \left(\frac{4.3}{5} - 1\right) mA < 0}$

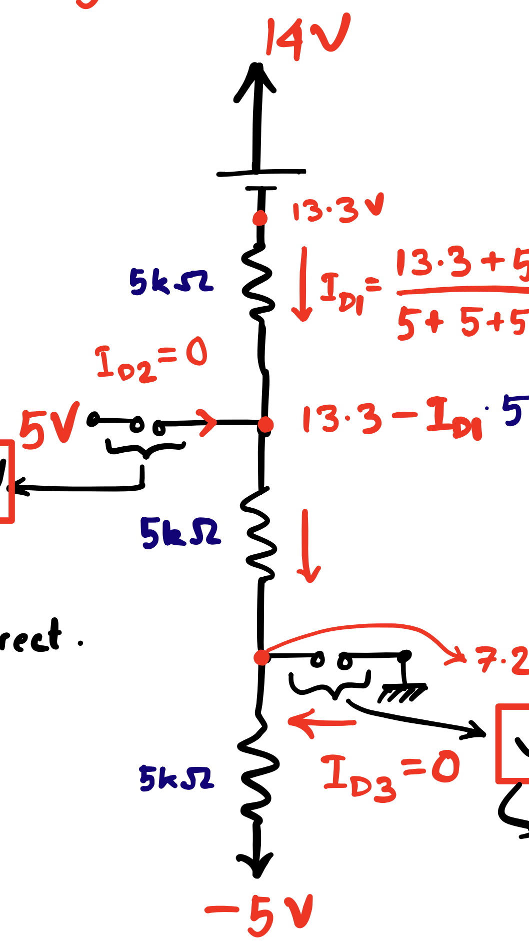
Assumption for D_3 false.

New Assumption:

D_1 : F.B

D_2 : R.B

D_3 : R.B.



$I_{D1} = \frac{13.3+5}{5+5+5} = 1.22\,mA$

$13.3 - I_{D1} \cdot 5 = 7.2V\ (V_A)$

$\boxed{V_d = 5 - 7.2 < 0.7V}$

Assumption for D_2 correct.

$7.2 - 5I_{D1} = 1.1V\ (V_B)$

$\boxed{V_d = (0-1.1)V < 0.7V}$

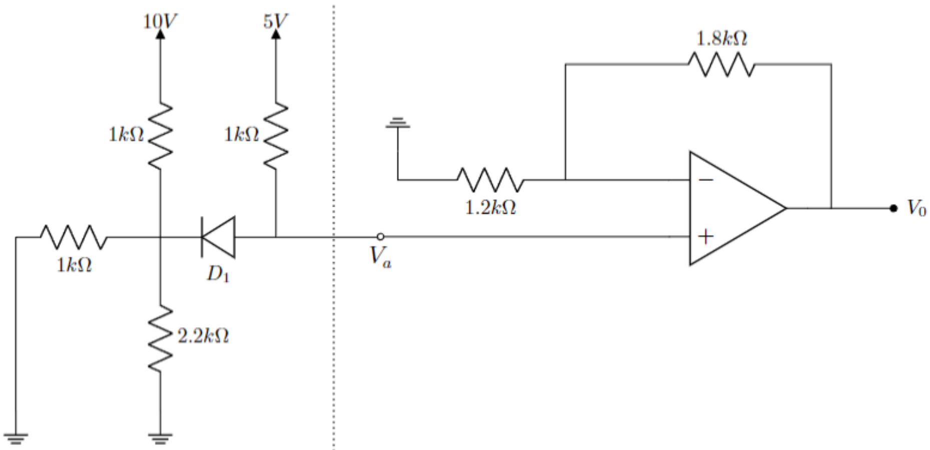
Assumption for D_3 correct.

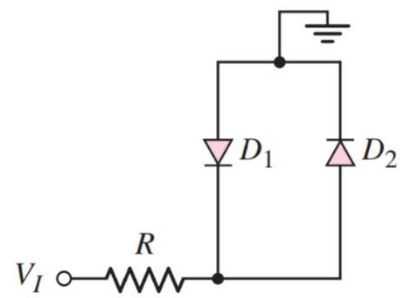
$$\boxed{\begin{aligned} I_{D1} &= 1.22\,mA \\ I_{D2} &= I_{D3} = 0 \\ V_A &= 7.2V \\ V_B &= 1.1V. \end{aligned}}$$

Question 3: 20 Marks

The saturation voltages of the Op-Amp on the **left below**, are given as $+V_{\text{sat}} = +10\text{ V}$ and $-V_{\text{sat}} = -10\text{ V}$. The forward voltage drop of the diode, $\boldsymbol{V_{DO}}$ is 0.7 V. [CO2] 10

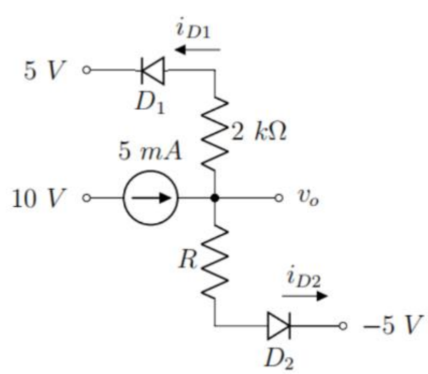
a) **Determine** the operating mode diode, D1. Verify your assumption with necessary calculations.
b) **Calculate** the voltage at –
   i. Node '$\boldsymbol{V_a}$'
   ii. Non-inverting terminal of the Op-Amp,
   iii. Inverting terminal of the Op-Amp.
c) Find out the output voltage, $\boldsymbol{V_O}$ of the Op-Amp.



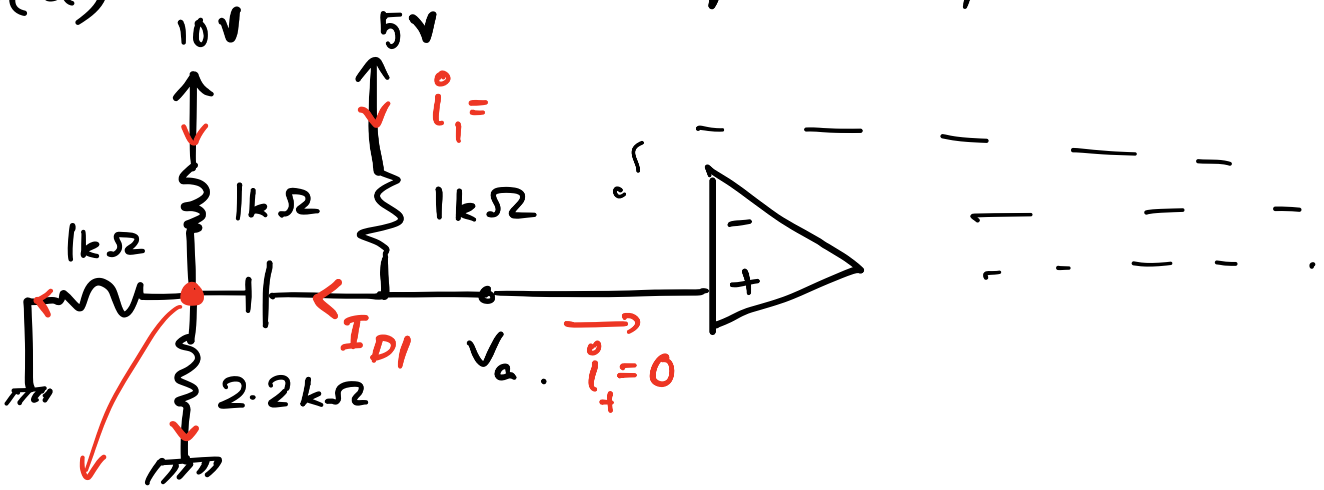


d) The parameters of D1 and D2 in the circuit shown in **above right** are $V_{Do} = 1.7\text{ V}$ and $r_f = 20\ \Omega$. The current in each diode is to be limited to $\boldsymbol{I_D} = \mathbf{15\ mA}$ for $\boldsymbol{V_I} = \pm\mathbf{5}\ \boldsymbol{V}$. **Determine** the required value of R. [CO3] 5

e) Find $\boldsymbol{V_o}, \boldsymbol{i_{D1}}$ and $\boldsymbol{i_{D2}}$ for $\boldsymbol{R} = \mathbf{1\ k\Omega}$. Assume diode constant voltage drop model with $\boldsymbol{V_{DO}} = \mathbf{0.7\ V}$. In each case, write down the states of the diodes (ON/OFF). You must verify your assumptions. [CO2] 5



3(a) Assumption: D_1 is in F.B.



$V_a - 0.7$

Node Equation at supernode $V_a\,(V_a - 0.7)$:

$$\frac{5-V_a}{1} = V_a - 0.7\left(\frac{1}{1}+\frac{1}{2.2}\right) - \frac{10-(V_a-0.7)}{1}$$

$$V_a + (V_a - 0.7)\left(2 + \frac{1}{2.2}\right) = 5 + 10$$

$$\boxed{V_a = \frac{15 + \frac{189}{110}}{\frac{38}{11}}\ V = 4.839\ V}$$

b (i)

$$\boxed{I_{D1} = \frac{5-4.839}{1} > 0\ mA} \longrightarrow \text{Assumption about } D_1 \text{ true.}$$

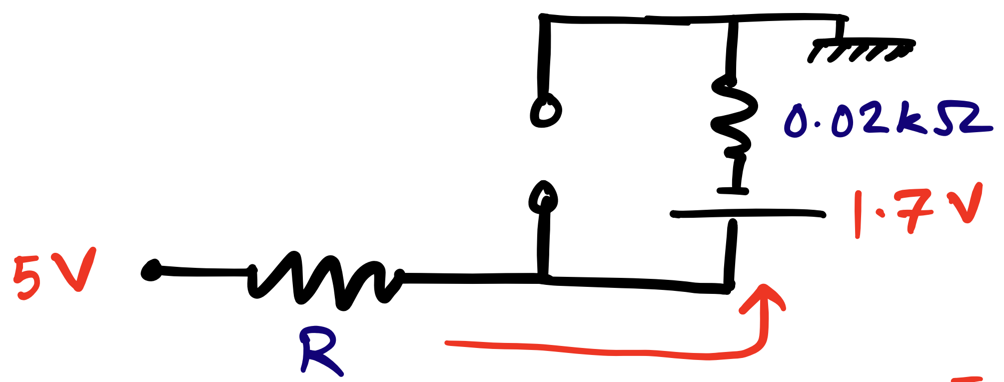
b (ii) $V_a = 4.839\ V = V_{(+)}$

(iii) $V_{(-)} = V_{(+)} = V_a = 4.839\ V$

(c) $V_o = \left(1 + \frac{1.8}{1.2}\right) V_a = 12.099\ V$

3 (d) From the configuration, it is obvious that Both diodes cannot be simultaneously in Forward bias.

When $V_I = 5V$: D_1 is R.B
D_2 is F.B .



$$I_D = 15\ mA = \frac{5-1.7}{R+0.02}$$

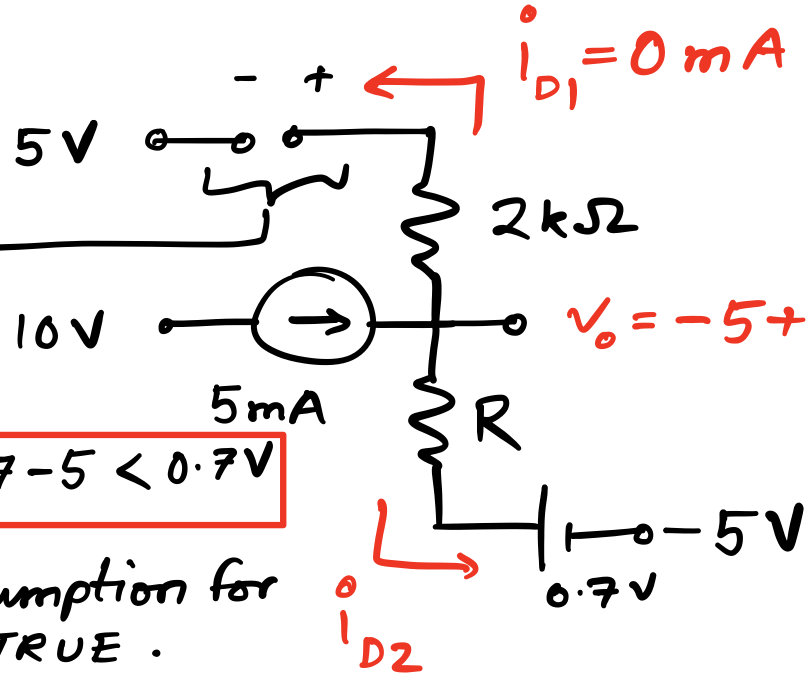
$$\Rightarrow \frac{3.3}{R+0.02} = 15$$

$$R = \frac{3.3 - 0.02\times 15}{15} = 0.2\ k\Omega$$

$\therefore R \geqslant 0.2 k\Omega$

$\boxed{\text{or, } R \geqslant 200\Omega}$

3 (e) Assuming: D_1 : R.B
D_2 : F.B .



$V_o = -5 + 0.7 + 5 = 0.7\ V$

$\boxed{V_d = 0.7 - 5 < 0.7V}$

Assumption for D_1 TRUE .

$i_{D1} + i_{D2} = 5$

$i_{D2} = 5\ mA$.

$\therefore\ V_o = 0.7V$