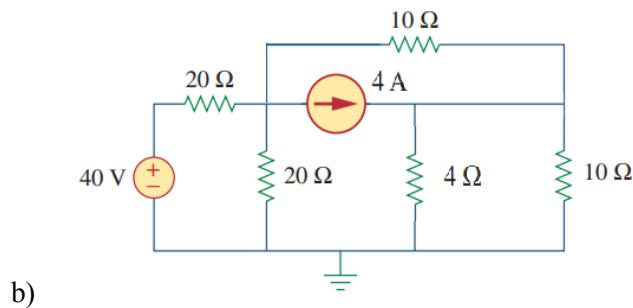
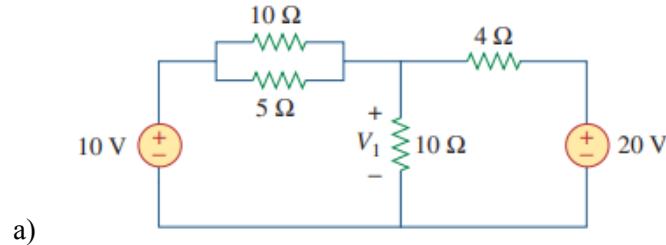
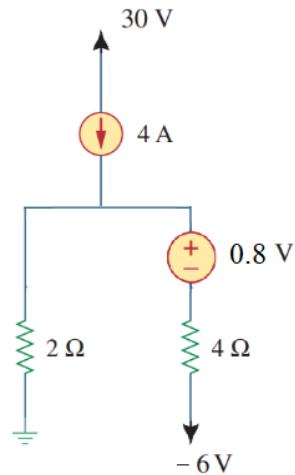


CSE250 [Review]

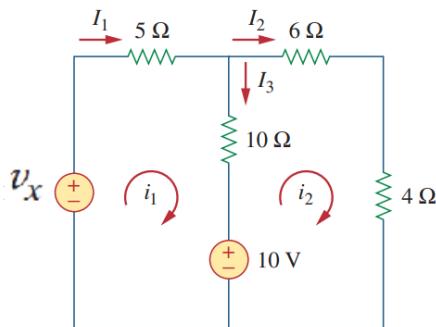
1. Draw the alternate representations of the following circuits [Note that the number of floating sources should be minimized].



2. Find the loop representation of the following circuit:



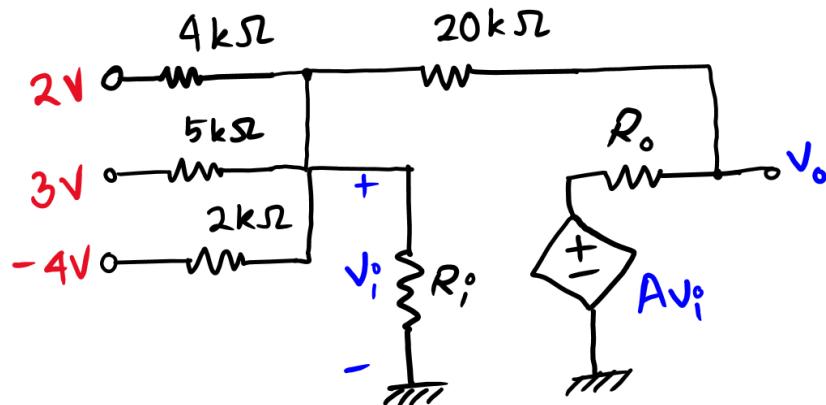
3. Here, $v_x = (10 + \text{last digit of your ID}) \text{ V}$



(i) Draw the alternate circuit representation of the circuit shown in the Figure above [Note that the number of floating sources should be minimized].

(ii) Apply KCL and KVL on the circuit drawn in (i) and calculate I_1 , I_2 , and I_3 .

4.



In the above circuit $A = 100$, $R_i = 100 \text{ k}\Omega$ and $R_o = 1 \text{ k}\Omega$. Answer the following questions

a) Write the node equations for the nodes indicated by v_i and v_o . [CO1] 4

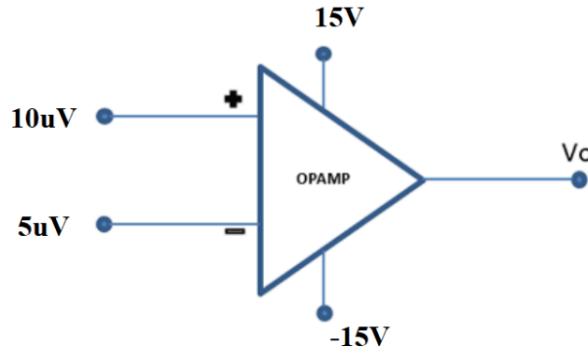
b) Solve the node equations to find the values of v_i and v_o . [CO2] 3

c) Can circuit theorems based on the linearity principle (such as the superposition principle) be applied to the above circuit? Explain in short why or why not. [CO1] 3

Find more practice problems [here](#)

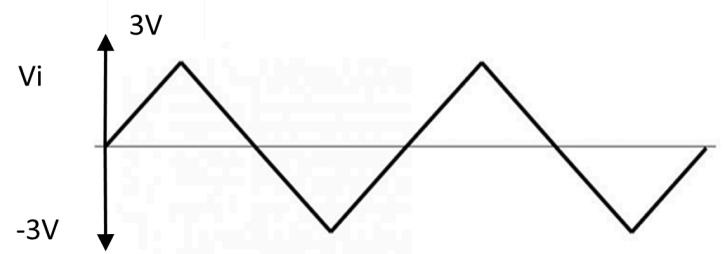
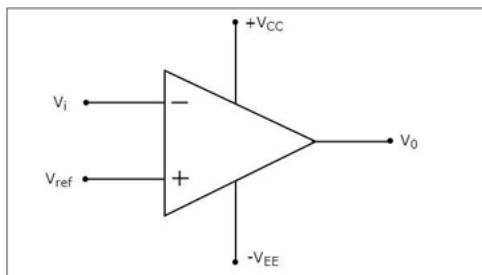
Op-Amp

1. Observe the following circuit.



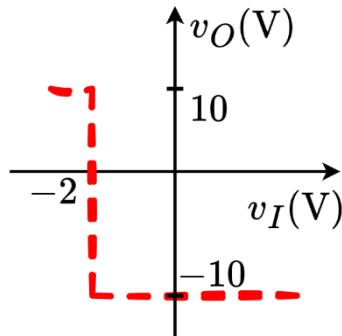
Calculate the value of V_o . Repeat the problem with $V_+=1$ mV and $V_-=0.2$ mV. Consider $A=2105$.

2. Draw output V_o for the following op-amp circuit.



$V_{CC} = 15V = -V_{EE}$, $V_{ref} = 1.5V$, Vi is a 6V p-p triangular signal as shown below.

3. Design a circuit using an **op-amp** that has the voltage transfer characteristics as shown in the figure below. $v_o(V)$ is the **output voltage**, and $v_i(V)$ is the **input voltage**.



5. A valve is used to release (when valve is OPEN) or maintain (when valve is CLOSED) water pressure in a water tank. The valve operates on **ACTIVE LOW** logic. (i.e., the valve is OPENED when given a LOW voltage of 1 V, but remains CLOSED when provided a HIGH voltage of 6 V.)

A pressure sensor is installed in the water tank that outputs a voltage linearly proportional to pressure, as shown in the table below.

At 0.5 atm pressure	At 1 atm pressure	At 1.5 atm pressure
$v_{0.5 \text{ atm}} = 0.5 \text{ V}$	$v_{1 \text{ atm}} = 3 \text{ V}$	$v_{1.5 \text{ atm}} = 5.5 \text{ V}$

The pressure in the water tank can be measured by the formula $P = h\rho g$, where P , (in **Pascal's (Pa)** unit) is the water pressure, h is the height of water in the tank (in *metres*), $\rho (= 1000 \text{ kg m}^{-3})$ is the density of water and g is the acceleration due to gravity (in ms^{-2}).

[1 atm = 101325 Pa]

- Design** a circuit using an Op-Amp comparator to automatically OPEN the valve if the water level exceeds **10 m**.
- Draw** the voltage transfer characteristics (VTC) of the designed Op-Amp.

6.

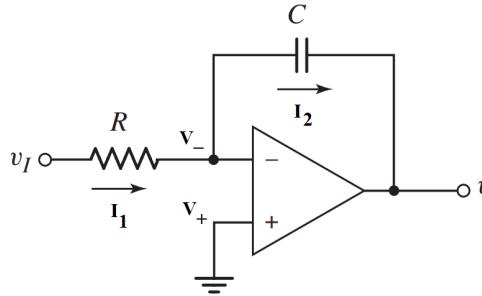


Figure 1 (a)

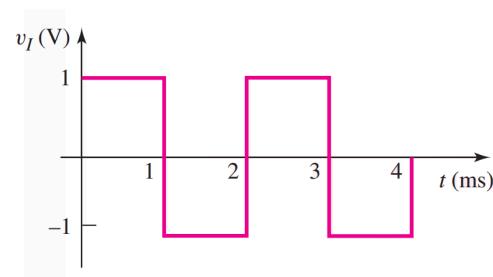


Figure 1 (b)

- (a) **Analyze** the circuit drawn in Fig. 1(a) and **determine** the voltage values at the inverting and non-inverting nodes (V_- and V_+). [0.5+0.5]
- (b) **Identify** the relation between I_1 and I_2 . [1]
- (c) **Analyze** the circuit to derive the expression of output voltage v_O . You have to **show** all the steps. [3]
- (d) Now consider the input wave v_I given in Fig. 1(b). For circuit parameters $R = 10 \text{ k}\Omega$ and $C = 0.1 \mu\text{F}$, **determine** the output voltage at $t = 1 \text{ ms}$. [1]
- (e) **Design** a circuit using Op-Amps to implement the following expression: [4]

$$f = \frac{1}{4}x + 7y - \frac{d}{dt}z$$

7.

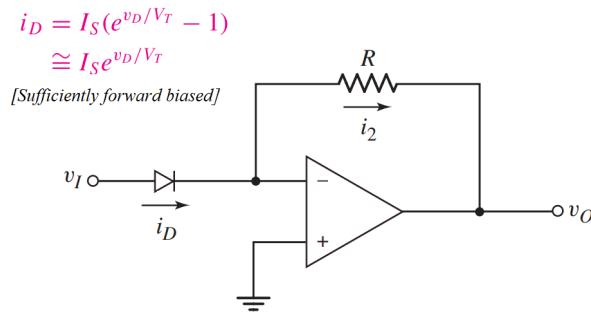
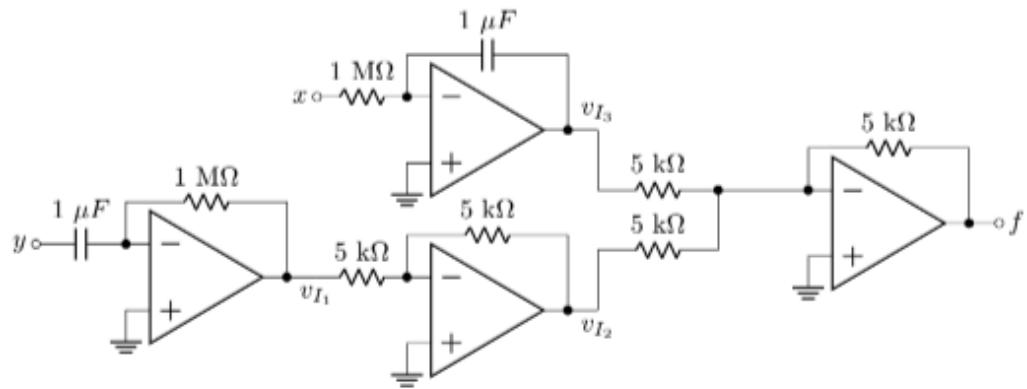


Figure 1

- (a) **Analyze** the circuit drawn in Fig. 1 and **determine** the voltage values at the inverting and non-inverting nodes (V_- and V_+). [0.5+0.5]
- (b) **Identify** and briefly explain the relation between i_2 and i_D . [1.5]
- (c) **Analyze** the circuit to derive the expression of output voltage v_O . You have to **show** all the steps. [3.5]
- (d) **Design** a circuit using Op-Amps to implement the following expression: [4]

8.



- (a) **Analyze** the circuit above to find an expression of f in terms of inputs x and y . Also, **determine** the intermediate outputs v_{I_1} , v_{I_2} , and v_{I_3} as denoted in the circuit. [4]
- (b) Draw the circuit of an inverting amplifier and **design** it in such a way that the voltage gain, $k = -4$. (i.e., find the values of R_1 and R_2). [3]
- (c) **Show** the input and output waveforms of the inverting amplifier of part (b) assuming a sinusoidal input of 0.5 V amplitude. **Calculate** the amplitude of the output. [2]
- (d) Consider the inverting amplifier of part (b) again. Assume the input voltage can provide a maximum current of $0.5 \mu\text{A}$. **Determine** the design changes required, if any, for the circuit to work. [1]

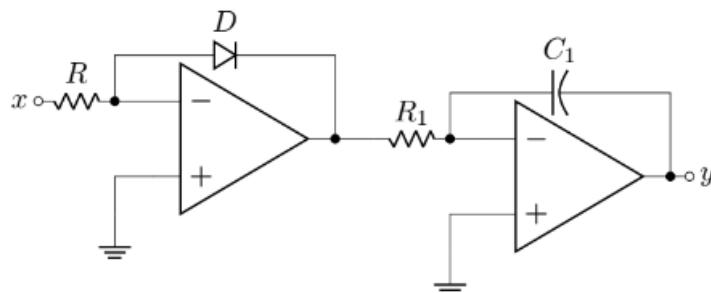
9.

- (a) **Design** a circuit using **Op-Amp comparator** to automatically turn ON (or OFF) the street lights. For this, you have a lux sensor installed on top of the street lights (facing above) that outputs a voltage proportional to amount of natural light, as listed below:

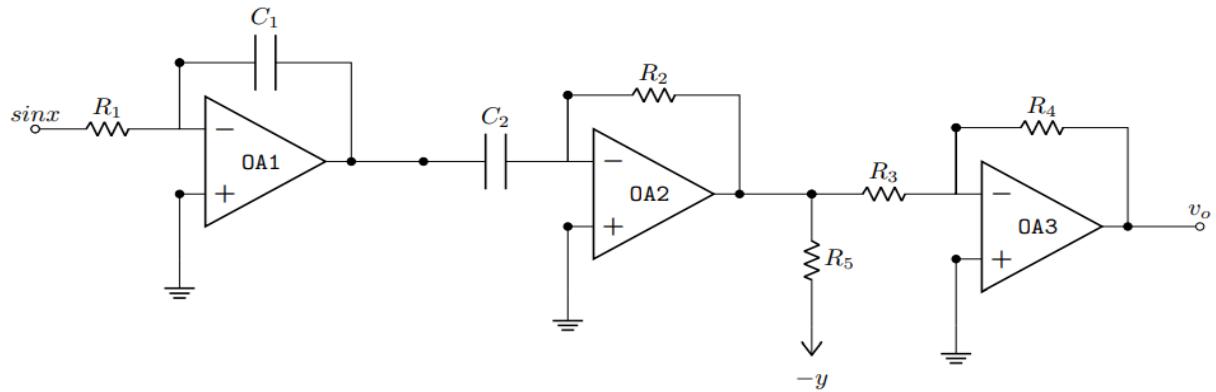
$$v_{\text{night}, 0 \text{ lux}} = 1 \text{ V} \quad v_{\text{dusk}, 20 \text{ lux}} = 2 \text{ V} \quad v_{\text{dawn}, 80 \text{ lux}} = 3 \text{ V}$$

The lights require 20 V and should be ON if the amount of light goes **below** 20 lux (at dusk). [3]

- (b) **Design** a circuit using Op-Amp to implement the expression: $f = -3 \frac{dx}{dt} + 2 \exp y + 4z$ [4]
- (c) **Analyze** the circuit below to find y as a function of x . For the diode, $I_S R = 1$ and $V_T = 1$. [3]



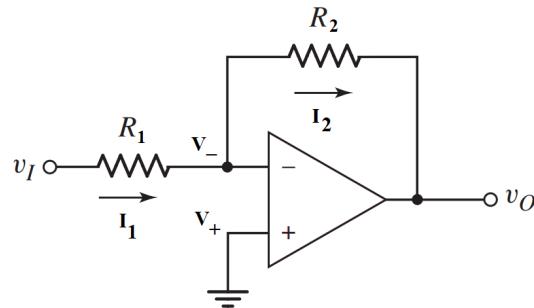
10. Deduce the expression for output, V_o , from the circuit above



11. Design a circuit using op-amps to implement $y=7x$ by an

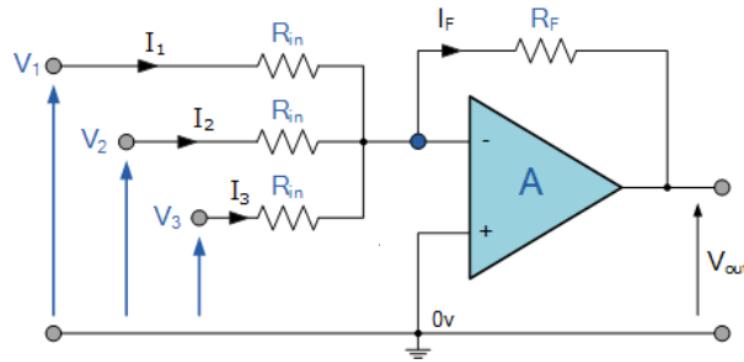
- (a) Inverting amplifier
- (b) Non-inverting amplifier

12.

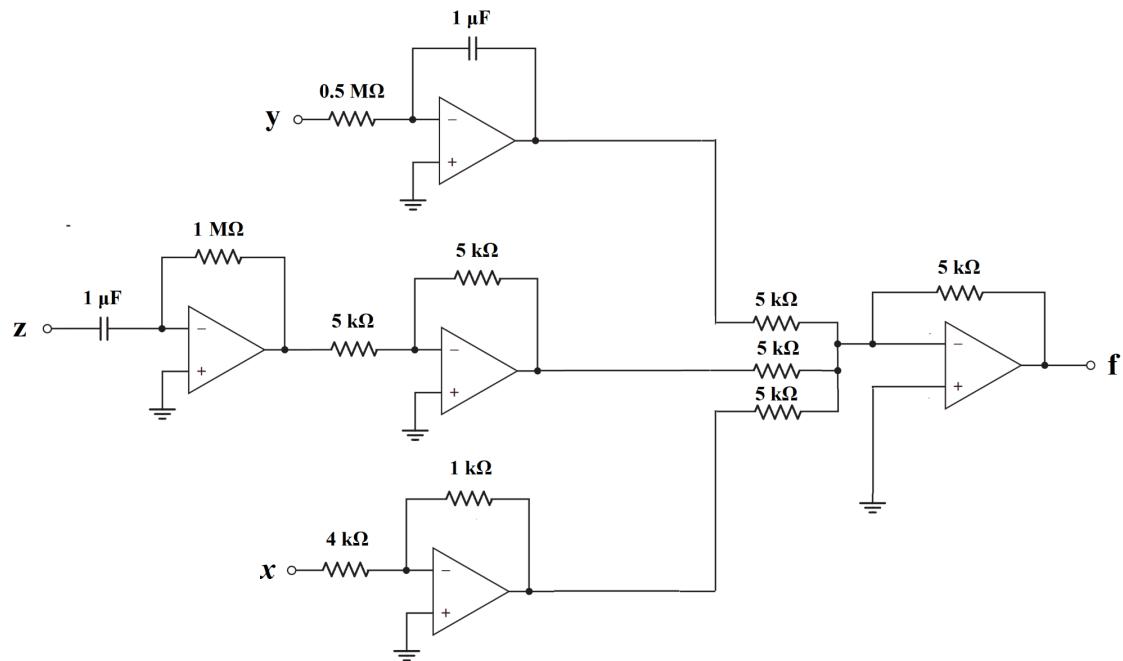


- (a) Design an inverting amplifier (i.e., find the values of R_1 and R_2 of the circuit shown in the Figure above) in such a way that the voltage gain is **-5**.
- (b) Consider the circuit you drew in (a) again. Assume the input $v_i = 0.1 \sin\omega t$ (V) has a maximum current rating of $5 \mu\text{A}$. What design changes, if any, are required for this input if the voltage gain remains the same?
- (c) Draw the input and output waveforms of the circuit you designed in (c).

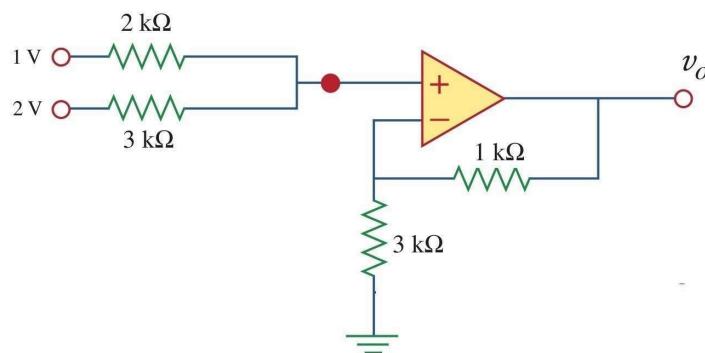
- Analyze the following circuit and derive the expression for the output voltage (V_{out}) in terms of the inputs. If $V_1=1$ V, $V_2 = 2$ V, and $V_3 = 1.5$ V, and all the resistors have equal values, calculate V_{out} .



13. Analyze the following circuit to find an expression of f in terms of x , y , and z .



14. Consider the Ideal Op-Amp and find the value of V_o .



15.

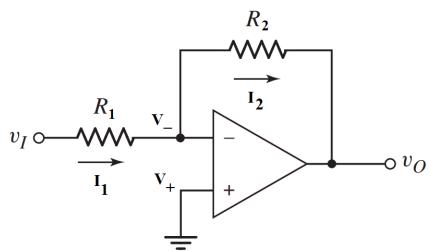
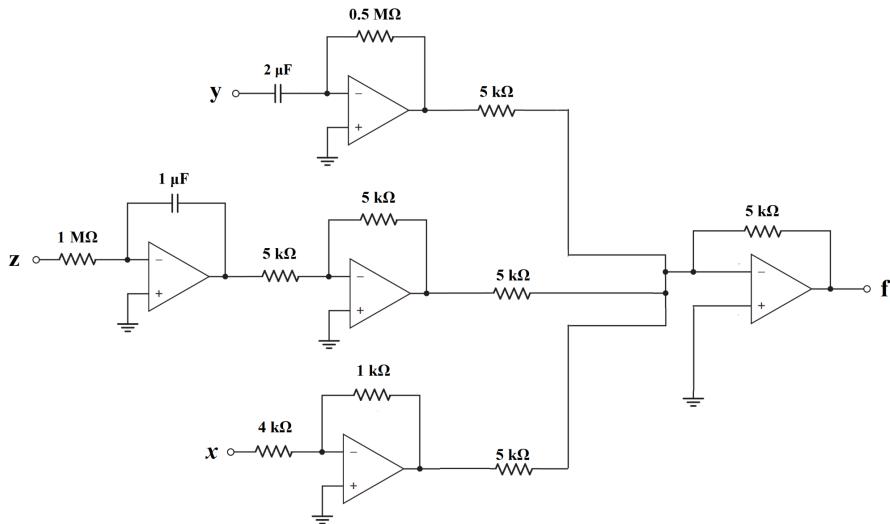


Figure 3(a)

Figure 3(b)

- Analyze the circuit in Fig. 3(a) to find an expression of f in terms of x , y , and z . [4]
- Design an inverting amplifier (i.e., find the values of R_1 and R_2 of the circuit shown in Fig. 3(b)) in such a way that the voltage gain is **-4**. [3]
- Draw the input and output waveforms of the circuit you designed in (b). [2]
- Consider the circuit in Figure 3(b) again. Assume the input $v_i = 0.1 \sin \omega t$ (V), has a maximum current rating of $4 \mu\text{A}$. What design changes, if any, are required for this input if the voltage gain remains the same?

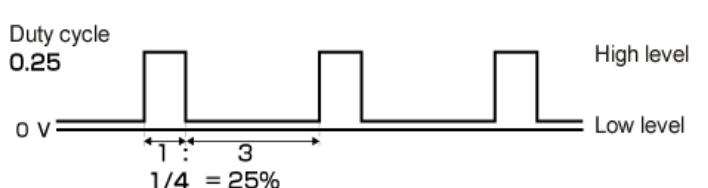
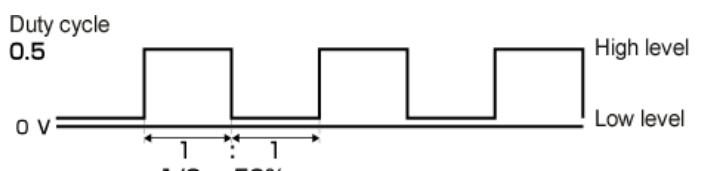
16.

Design an op-amp circuit to transform the sinusoidal voltage $v_i = 5 \cdot \sin(\frac{2\pi}{5} \cdot t)$ (t is in units of ms, and time-period T is 5 ms), to:

[You must evaluate V_{REF}]

- A square wave with a duty cycle of **50%**.
- A square wave with a duty cycle of **25%**.

[Duty Cycle: Time of positive half cycle ÷ Time period]

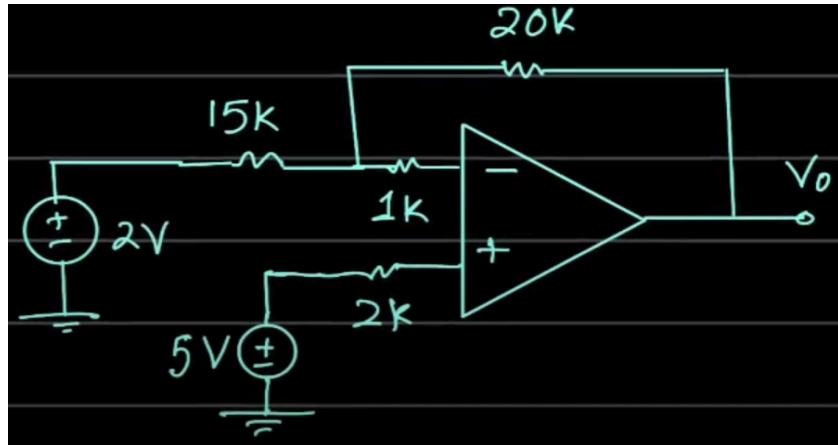


For more information on duty cycle, click [here!](#)

[Hint: If $y = (\theta)$ is a sinusoidal function with period of 2π then $\theta = (\frac{y}{A})$ and $\pi - (\frac{y}{A})$. So, for 25% duty cycle find the value of y for which $\Delta\theta = \left(\pi - (\frac{y}{A})\right) - \left(\frac{y}{A}\right) = \frac{\text{Time period}}{4} = \frac{\pi}{2}$]

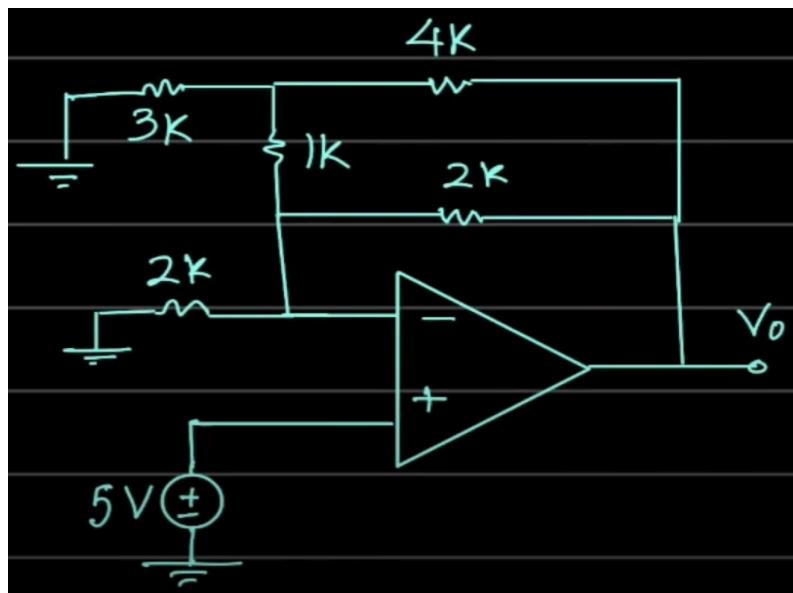
17. Miscellaneous

Determine the output voltage, v_0



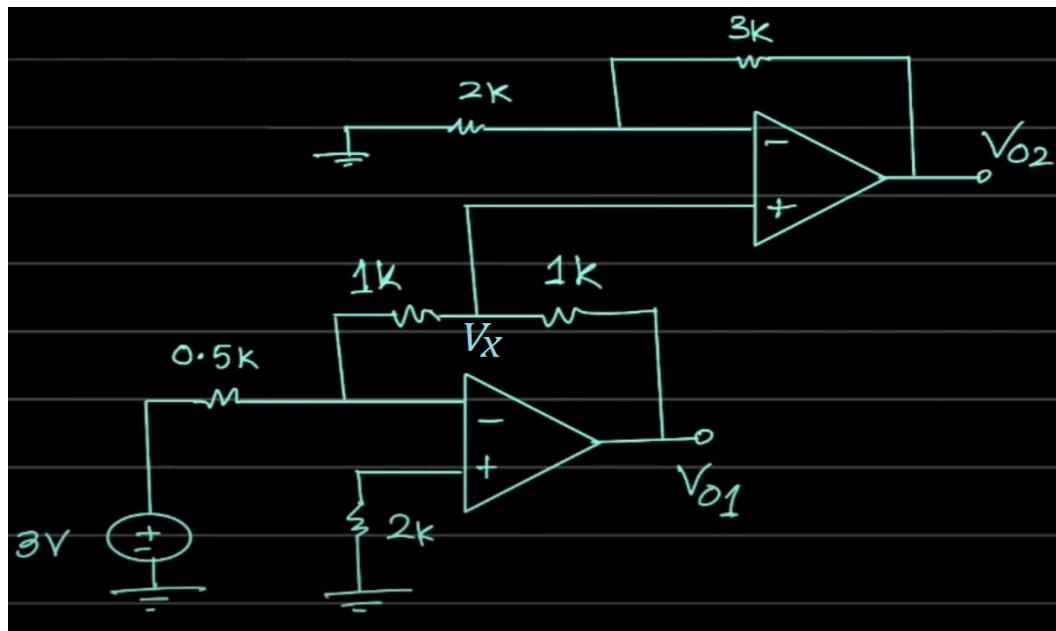
18. Miscellaneous

Determine the output voltage, v_0



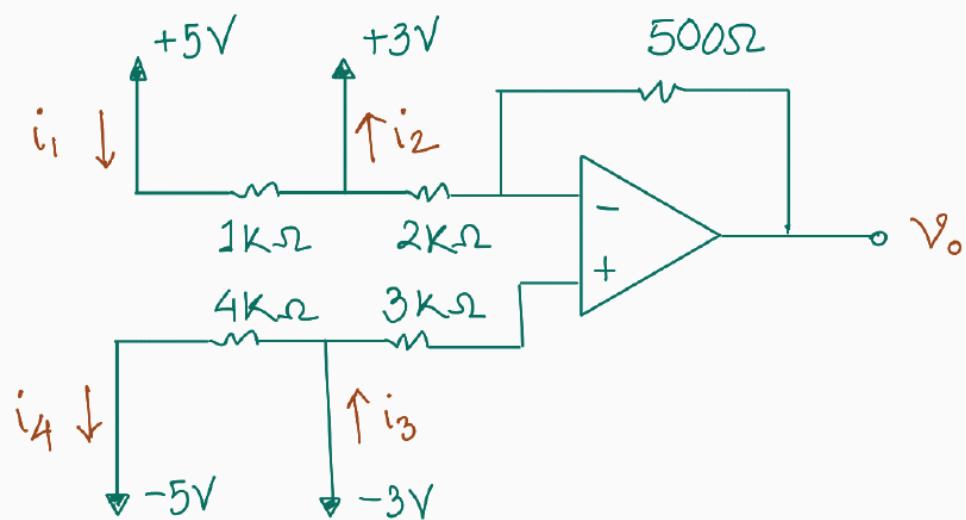
19. Miscellaneous

Determine the voltages: V_{01} , V_X , V_{02}



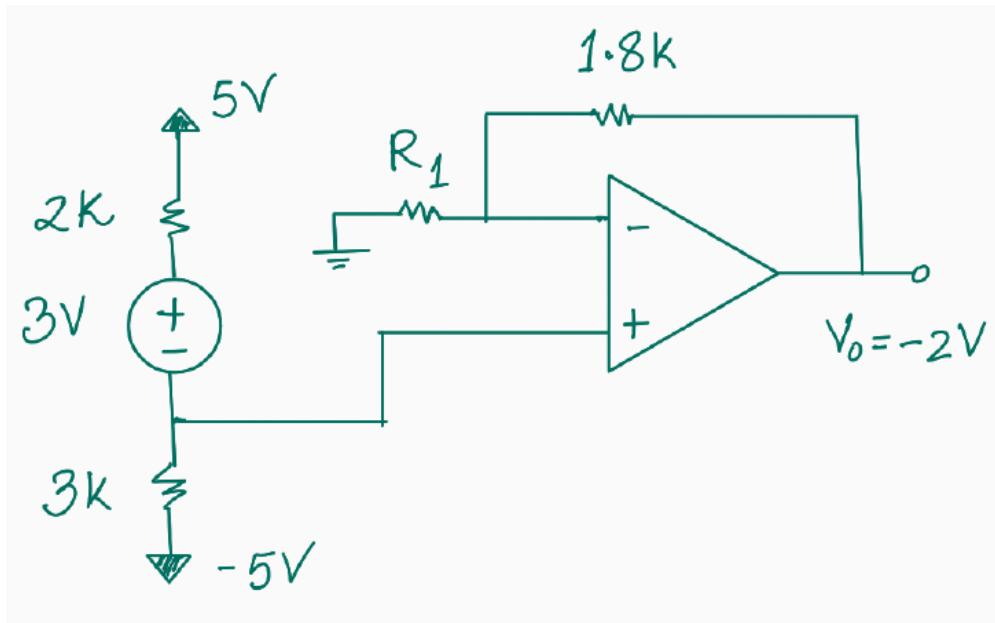
20. Miscellaneous

Determine the marked currents and the output voltage



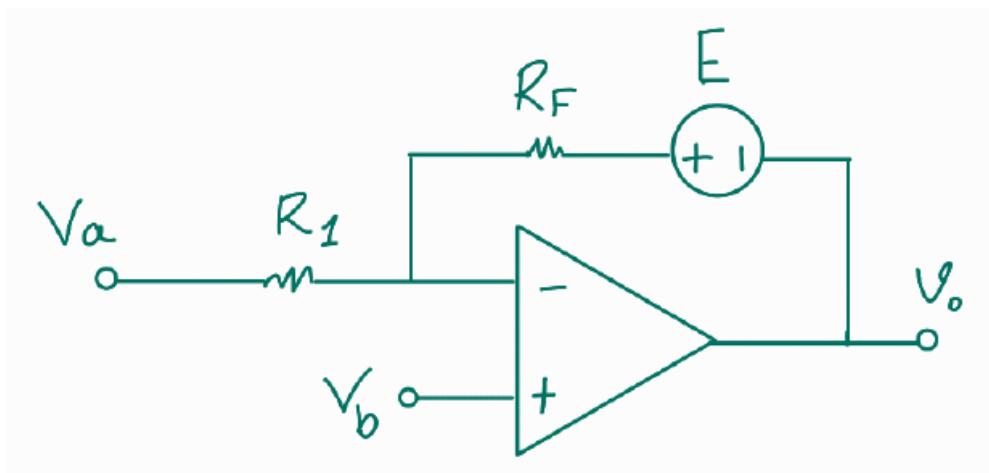
21. Miscellaneous

Determine the appropriate value of R_1



22. Miscellaneous

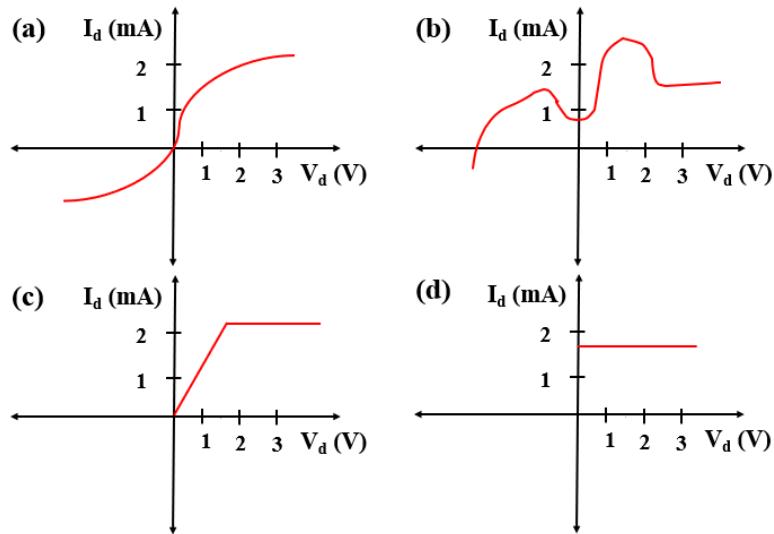
Express the output voltage v_o in terms of all the other quantities shown in the circuit below.



Find more practice problems [here](#) and [here](#)

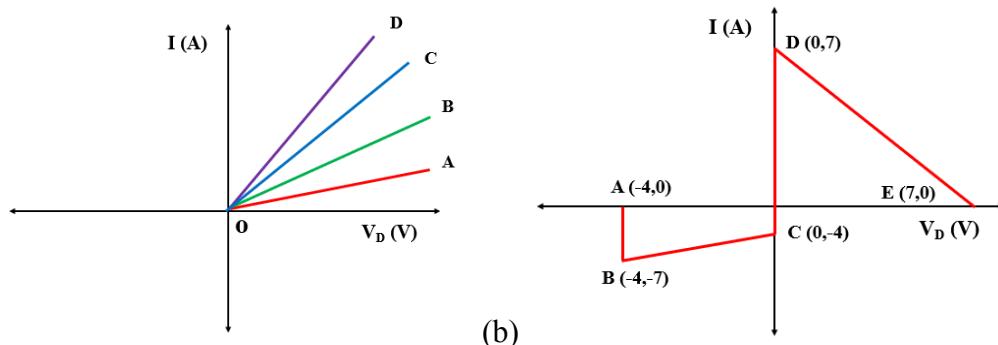
I-V

- Identify which of these I-V curves are Linear and which are Nonlinear:



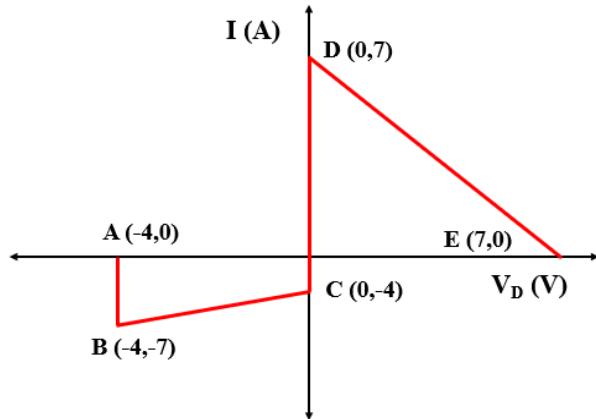
Ans: Linear: (d)

- Write down the slopes of these following regions in ascending order (you do not need to calculate the slopes)



Ans: (a) $|OA| < |OB| < |OC| < |OD|$, (b) Slopes of AB and CD are equal(infinity). The DE slope is negative. However, the value of the slope is higher than BC here. $|BC| < |DE| < |AB|$

- Find out the slope of the following curves



Answer: The Slope, $|m| = \left| \frac{y_2 - y_1}{x_2 - x_1} \right|$

$$|BC| = \left| \frac{y_2 - y_1}{x_2 - x_1} \right| = \left| \frac{-7 - 4}{-4 - 0} \right| = \frac{3}{4}$$

$$|DE| = \left| \frac{y_2 - y_1}{x_2 - x_1} \right| = \left| \frac{0 - 7}{7 - 0} \right| = 1 \quad [\text{Can you identify the issue in this curve?}]$$

$$|AB| = \left| \frac{y_2 - y_1}{x_2 - x_1} \right| = \left| \frac{-7 - 0}{-4 + 4} \right| = \infty$$

- Calculate and show 'C' and 'Io' in the figures

[Hint: use $\frac{V_o}{R} = Io = c$]

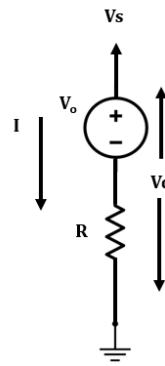
- Draw the alternative circuit diagram and I-V curve and calculate the parameters with the following information:

- $V_o = 5V, m = 2/k\Omega$
- $V_o = 3.5V, m = -2.5/k\Omega$
- $V_o = -5V, m = 5/k\Omega$

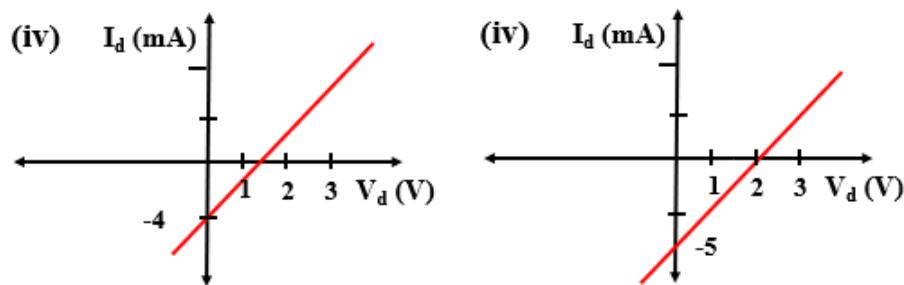
Solution:

- $|R| = \left| \frac{1}{m} \right|$ i.e. $\frac{1}{2} k\Omega, c = -\frac{V_o}{R} = -\frac{5}{0.5} mA = -2.5 mA$
- $|R| = \left| \frac{1}{m} \right|$ i.e. $\frac{1}{2.5} k\Omega, c = -\frac{3.5}{0.4} mA = -8.75 mA$
- $|R| = \left| \frac{1}{m} \right|$ i.e. $\frac{1}{5} k\Omega, c = -\frac{-5}{0.2} mA = 25 mA$

Alternative Diagram:

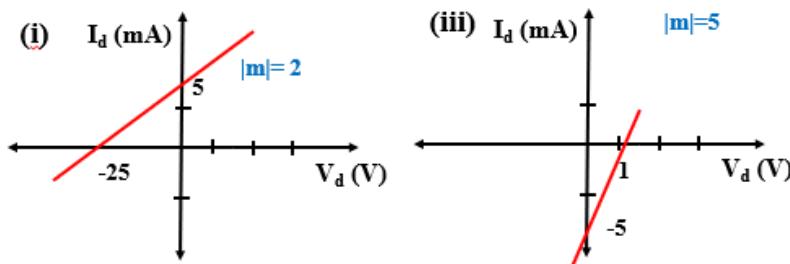


I-V curve:



- Calculate and show 'C' and 'Vo' in the figures

[Hint: Use $IoR = -Vo$]



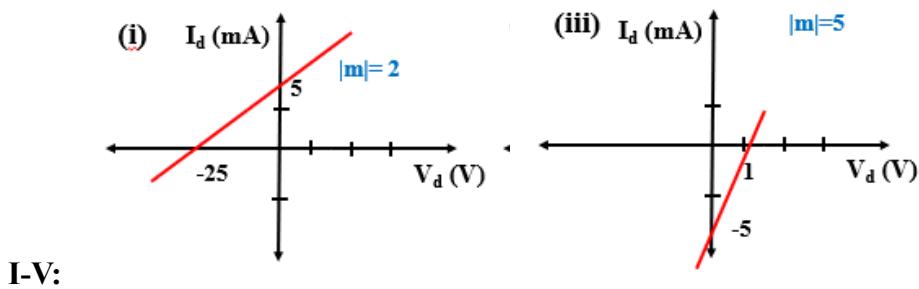
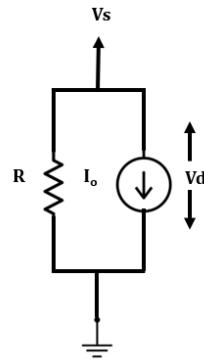
- Draw the alternative circuit diagram with the equivalent linear model and I-V curve, and calculate the parameters with the following information:

- i. $Io = 5 \text{ mA}$, $m = 2/k\Omega$
- ii. $Io = 3.5 \text{ mA}$, $m = -2.5/k\Omega$
- iii. $Io = -5 \text{ mA}$, $m = 5/k\Omega$

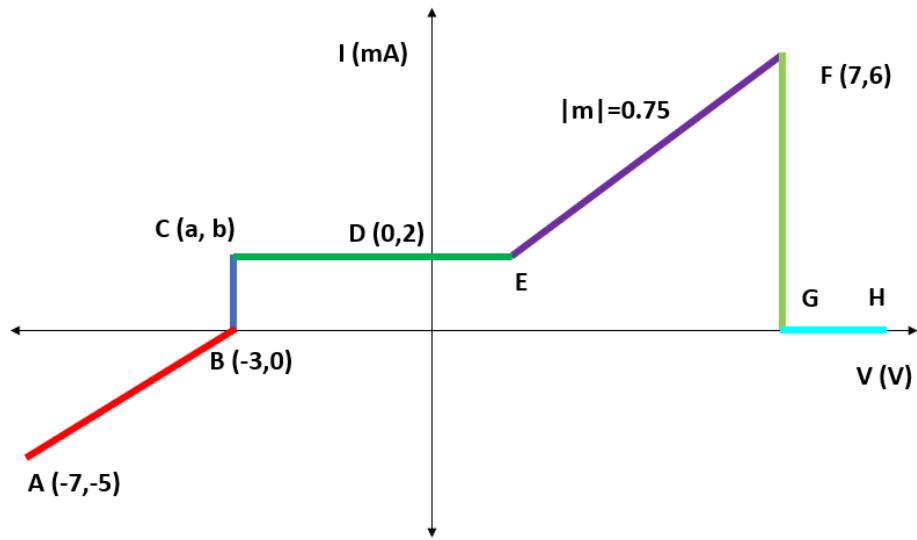
Solution:

- i. $|R| = |\frac{1}{m}|$ i.e. $\frac{1}{2} k\Omega$, $c = Io = 5 \text{ mA}$, $Vo = -IoR = -2.5 \text{ V}$
- ii. $|R| = |\frac{1}{m}|$ i.e. $\frac{1}{2.5} k\Omega$, $c = Io = 3.5 \text{ mA}$, $Vo = -(-IoR) = 1.4 \text{ V}$; as m is negative
- iii. $|R| = |\frac{1}{m}|$ i.e. $\frac{1}{5} k\Omega$, $c = Io = -5 \text{ mA}$, $Vo = -IoR = 1 \text{ V}$

Alternative diagram:



- From the I-V curve-
 - State the device model for each region,



Solution:

i.

AB: Voltage source in series with a resistor/ Current source in parallel with a resistor

BC: Voltage source

CD: Current source

EF: Voltage source in series with a resistor/ Current source in parallel with a resistor

FG: Voltage source

- A Voltage Source, $V_o = 10 \text{ V}$ in series with a resistor of $R = 3 \text{ k}\Omega$.
 - Write down the equation representing this curve
 - Determine the unknown parameters
 - Label the I-V curve

Solution:

- $y = mx + c$

Or, $I = m \cdot V_s - \frac{V_o}{R}$

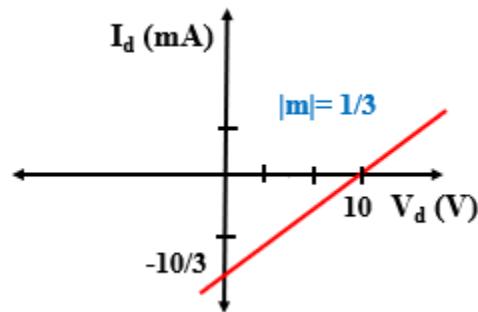
ii. $V_o = 10 \text{ V}$, $R = 3 \text{ k}\Omega$

$$|m| = \left| \frac{1}{R} \right| = \frac{1}{3}$$

Y-axis intersection: $c = -\frac{V_o}{R} = -\frac{10V}{3k\Omega} = -\frac{10}{3} \text{ mA}$

X axis intersection: $V_o = 10 \text{ V}$

iii.



- A Voltage Source, $V_o = -10 \text{ V}$ in series with a resistor of $R = 3 \text{ k}\Omega$.
 - Write down the equation representing this curve
 - Determine the unknown parameters
 - Label the I-V curve

Solution:

- $y = mx + c$

Or, $I = m \cdot V_s - \frac{V_o}{R}$

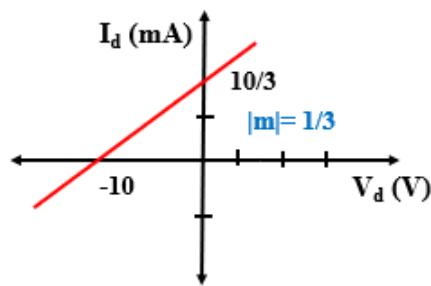
ii. $V_o = -10 \text{ V}$, $R = 3 \text{ k}\Omega$

$$|m| = \left| \frac{1}{R} \right| = \frac{1}{3}$$

Y-axis intersection: $c = -\frac{V_o}{R} = -\frac{-10V}{3k\Omega} = \frac{10}{3} \text{ mA}$

X-axis intersection: $V_o = -10 \text{ V}$

iii.



- A Current Source, $I_o = 5 \text{ mA}$ in parallel with a resistor of $R = 5 \text{ k}\Omega$.
 - i. Write down the equation representing this curve
 - ii. Determine the unknown parameters
 - iii. Label the I-V curve

Solution:

i. $y = mx + c$

Or, $I_s = \frac{V_s}{R} + I_o$

ii. $V_o = 10 \text{ V}$, $R = 5 \text{ k}\Omega$

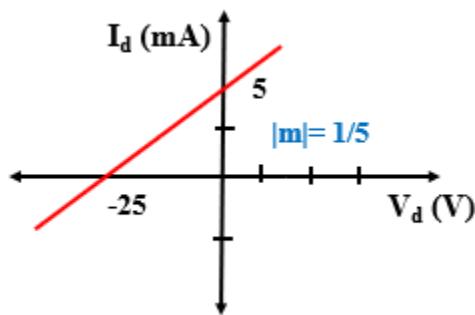
$$|m| = \left| \frac{1}{R} \right| = \frac{1}{5}$$

Y-axis intersection : $c = I_o = 5 \text{ mA}$

X-axis intersection: $I_o R = -V_o$

Or, $V_o = -5 * 5 \text{ V} = -25 \text{ V}$

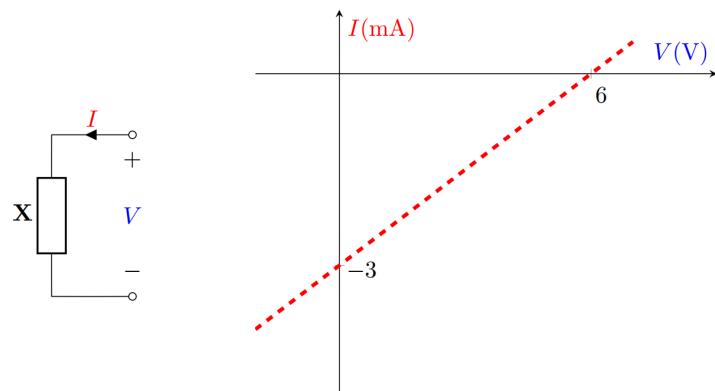
iii.



- You are provided with the following circuit elements:

- Two $1\text{ k}\Omega$ resistors
- A 4 V voltage source
- A 2 V voltage source

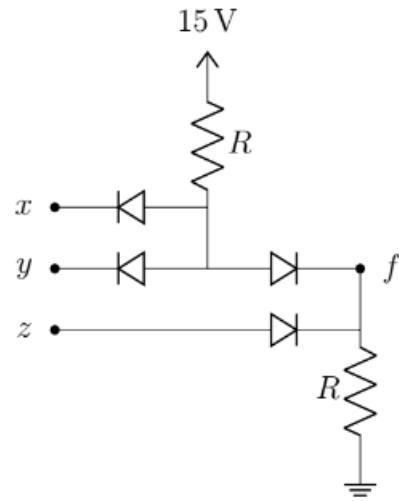
Can you implement a circuit element X that has an IV characteristic, as seen in the right figure below, but by **ONLY USING THE ELEMENTS MENTIONED ABOVE**? The voltage polarity and current direction should be as shown in the left figure.



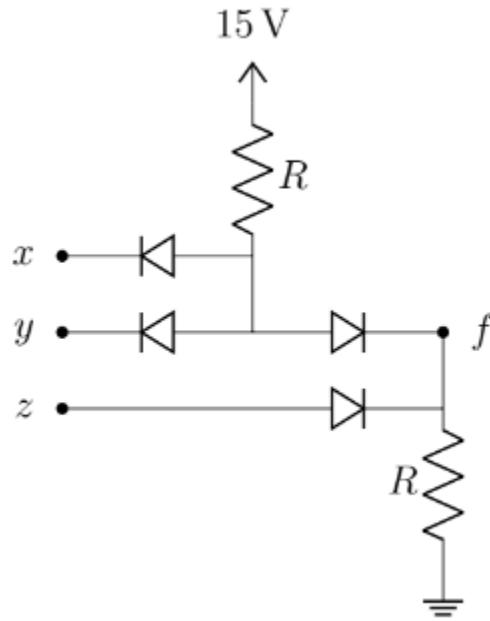
Diode Logic Gates

- Assuming x, y, and z are Boolean variables, analyze the circuits below to find an expression of “f” in terms of x, y, and z.

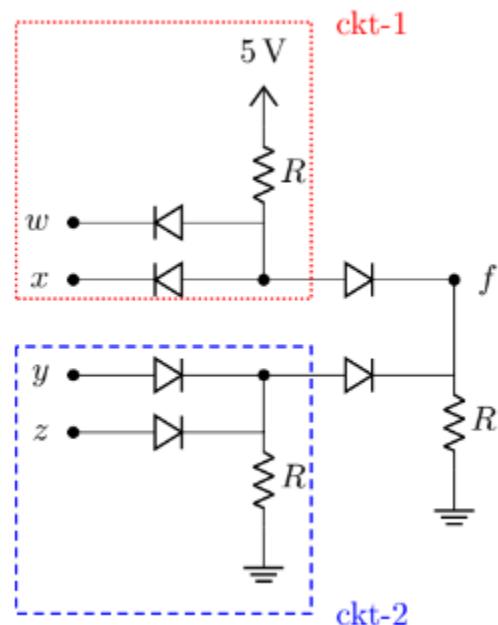
i.



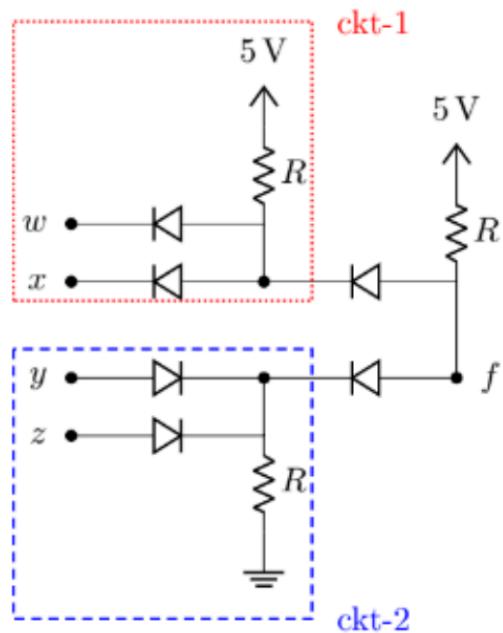
ii.



iii.



iv.



- Implement the following expressions using ideal diodes:
 - i. $xy + yz$
 - ii. XOR
 - iii. XNOR
 - iv. $(A+B)XY$
- Design a 4-input AND gate using ideal diodes
- Design a 3-input OR gate using ideal diodes
- There will be 5 questions from 5 different topics in your exam, and you will have to answer 4 out of these. You will need to fulfill the following conditions-
 - i. You **must** answer 3 questions from topics “A”, “B” and “C”
 - ii. You can answer one question from either “D” or “E.”

Deduce the logic function using boolean variables A, B, C, D, and E to implement your algorithm for choosing the questions.

- For this question, assume all the diodes are ideal.

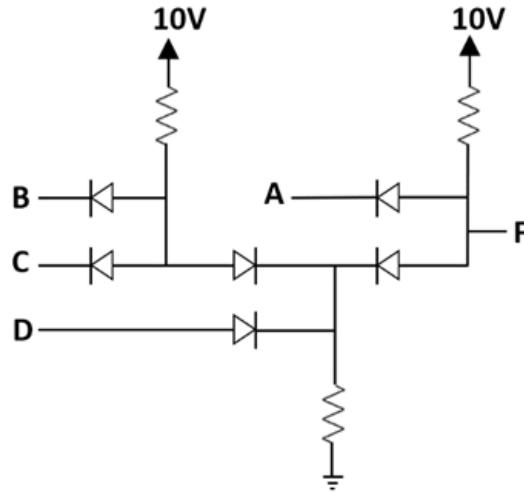


Figure 1

- Assuming A, B, C, and D are Boolean variables, analyze the circuit of Figure 1 to find an expression of F in terms of A, B, C, and D.
- Analyze the circuit in Figure 1 to find the output voltage(s) F and complete the table in Figure 2, assuming A, B, C, and D are voltage signals

A	B	C	D	F
4V	3V	4V	6V	
5V	3V	4V	2V	
13V	3V	4V	15V	

Figure 2

- Design a circuit using ideal diodes to implement the logic function

$$f = (x+y)z$$

- Maisha is designing a game where she needs to determine an algorithm for level upgrades. The quests in level 1 are expressed using Boolean variables A, B, C, D, and E. For upgrading from level 1 to level 2, she will need to fulfill the following conditions-

- Quest “A” and “B” must be completed
- At Least one quest has to be completed from “C”, “D”, and “E.”

(a) **Deduce** the logic function, F, using Boolean variables A, B, C, D, and E to implement Maisha’s algorithm. [3]

(b) **Determine** the values of “F” in the following table using the logic function from (a). [2]

A	B	C	D	E	F
0	0	1	0	1	?
0	1	1	1	0	?
1	0	0	0	0	?
1	1	1	0	0	?

(c) **Draw** the circuit diagram implementing the logic function from (a). [3]

(d) **Discuss** whether you can design a NAND gate with Si diodes. [2]

- In the **adjacent** figure, we have the following parameters:

$$V_{D1} = 0.3 \text{ V}, \quad V_1 = 2 \text{ V}$$

$$V_{D2} = 0.5 \text{ V}, \quad V_2 = 1.7 \text{ V}$$

$$V_{D3} = 0.7 \text{ V}, \quad V_3 = 1.5 \text{ V}$$

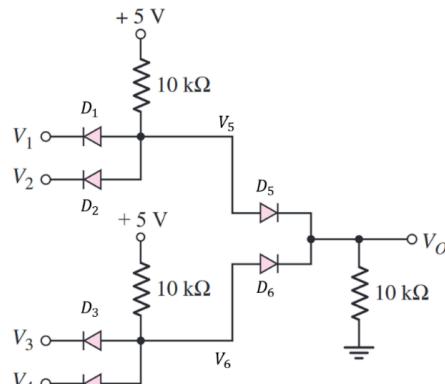
$$V_{D4} = 0.9 \text{ V}, \quad V_4 = 1.1 \text{ V}$$

$$V_{D5} = V_{D6} = 1.1 \text{ V}$$

i. Find V_5 and V_6 . [5]

ii. Find V_o . [5]

iii. **[BONUS – 5 Marks]:** Solve the circuit to get V_o when $V_1 = 7 \text{ V}$, $V_2 = 8 \text{ V}$ and all other parameters remain the same.

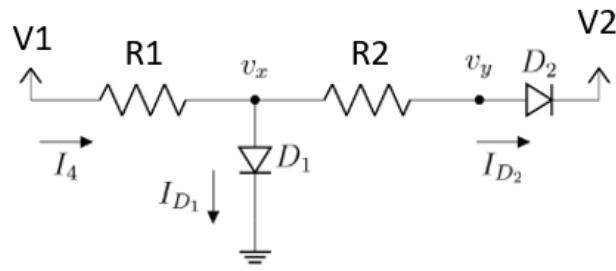


Find more problems [here](#)

Diode: Method of assumed states

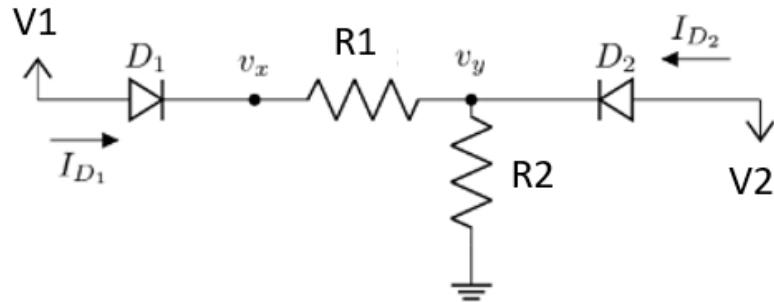
For the following circuits (a) Analyze the following circuit to find the values of I_{D1} , I_{D2} , V_x and V_y . Here, use the Method of Assumed State using the CVD model of diode with $V_{D0} = 0.3$ V. (b) Validate your assumptions about the states of the diodes.

1.



- i. $V1 = 10$ V, $V2 = -10$ V, $R1 = 10$ K, $R2 = 20$ K
- ii. $V1 = -5$ V, $V2 = 20$ V, $R1 = 10$ K, $R2 = 20$ K

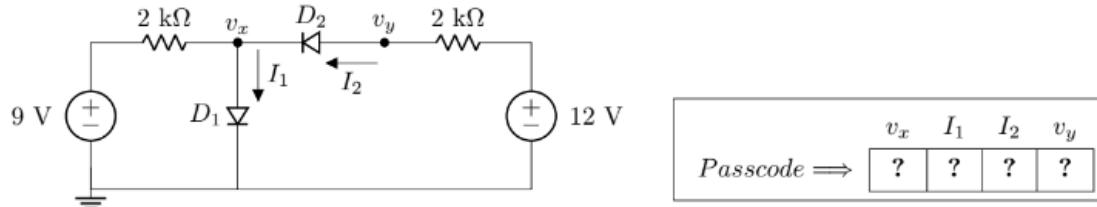
2.



- i. $V1 = 5$ V, $V2 = -3.5$ V, $R1 = 1$ K, $R2 = 10$ K
- ii. $V1 = 5$ V, $V2 = -3.5$ V, $R1 = 10$ K, $R2 = 10$ K

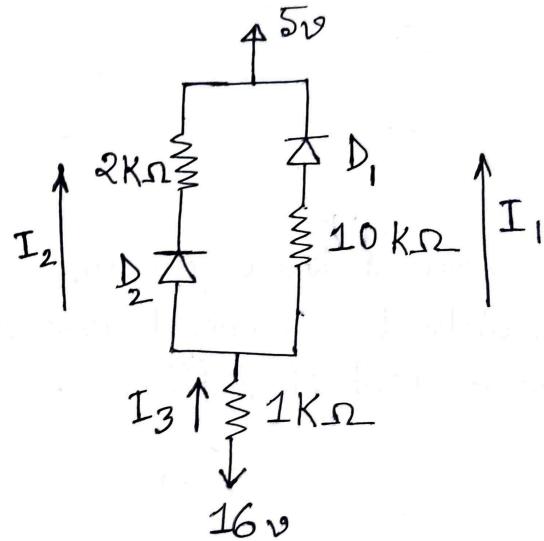
3.

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.



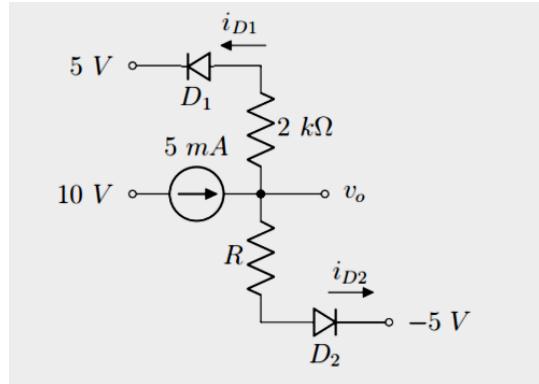
- (a) Show the alternative representation of the given circuit. [1.5]
- (b) Analyze the circuit to calculate the values of v_x , v_y , I_1 and I_2 , and hence the passcode. You must validate your assumption. Use the constant voltage drop model with a forward voltage drop, $V_{D0} = 1$ V. [5+2]
- (c)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

4.



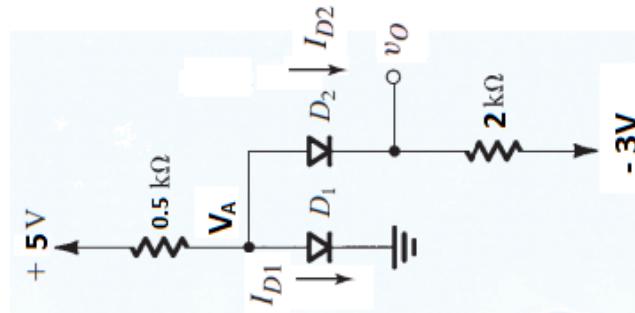
Analyze the circuit given above. Calculate the values of I_1 , I_2 , I_3 . You must validate your assumptions. Use the Constant-Voltage Drop model(CVD Model) with $V_{D0} = 0.8$ V.

5.



Find V_o , i_{D1} and i_{D2} for $R = 1 \text{ k}\Omega$. Assume the diode constant voltage drop model with $V_{D0} = 0.7\text{V}$. In each case, write down the states of the diodes (ON/OFF). You must verify your assumptions.

6.



Analyze the following circuit. Calculate the values of V_A , V_0 , I_{D1} , and I_{D2} . You must validate your assumptions. Use the Constant-Voltage Drop model with a cut in voltage of 0.6V [$V_{D0} = 0.6\text{V}$]. [Hints: You may start with calculating the voltage values first]

- Please find some other examples here: [Week 4 \(Method of Assumed State Examples\).pdf](#)

Find more problems [here](#)

Rectifiers

1. The input of a full-wave rectifier is a cosine voltage with peak $V_M = 5$ V and frequency 60 Hz, and output load resistance is $R = 2$ k Ω . Silicon diodes are used in this circuit for which the forward drop is $V_{D0} = 0.7$ V.

(a) Briefly explain the purpose of a rectifier and describe its operation.

(b) Show the input and output waveforms.

(c) Calculate the DC value of the output voltage.

Now, after connecting a capacitor in parallel with the load, the output becomes a ripple voltage

$$V_{\text{out}} = V_{DC} \pm 0.2 \text{ V}$$

(d) Calculate the **peak-to-peak ripple voltage**, and from that, the value of the capacitor.

(e) Calculate the average of the output voltage V_{DC} after connecting the capacitor. Compare this with the DC value determined in 'c' and comment on the difference between these two.

2. The input of a **Half-wave rectifier** is a sine voltage with peak $VM = 10$ V and frequency 55 Hz, and output load resistance is $R = 2.5$ k Ω . Silicon diodes are used in this circuit for which the forward drop is $V_{D0} = 0.4$ V.

(a) Calculate the DC value of the output voltage.

Now, after connecting a capacitor in parallel with the load, the output becomes a ripple voltage

$$V_{\text{out}} = V_{DC} \pm 0 \text{ V.}$$

(d) Calculate the **peak-to-peak ripple voltage**, and from that, the value of the capacitor.

(e) Calculate the average of the output voltage V_{DC} after connecting the capacitor. Compare this with the DC value determined in 'c' and comment on the difference between these two.

(f) Draw the **Voltage Transfer Characteristic (VTC) curve**

(g) What is the frequency of the Ripple voltage?

3. The input of a full-wave rectifier is expressed by $V_s(t) = 7\sin(400\pi t)$, and the output load resistance is $R = 5$ k Ω . Silicon diodes are used in this circuit for which the forward drop is $V_{D0} = 0.3$ V.

(a) Calculate the input and output wave frequency.

(b) Show the input and output waveforms.

(c) Calculate the DC value of the output voltage.

Now, after connecting a capacitor, $C = 100 \mu\text{F}$ in parallel with the load.

(d) Calculate the peak-to-peak ripple voltage,

- (e) Calculate the average of the output voltage V_{DC} after connecting the capacitor. Compare this with the DC value determined in 'c' and comment on the difference between these two.
(f) How can you provide better filtering for the output waves?
(g) What is the frequency of the Ripple voltage?

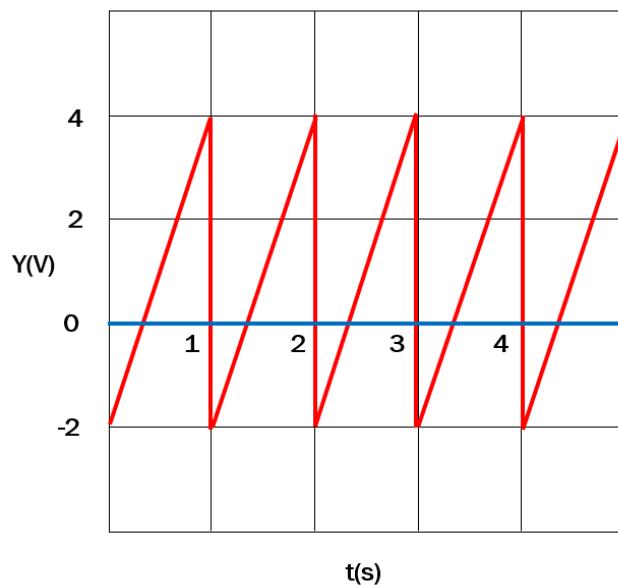
4. The input of a **Half-wave rectifier** is a **Square** wave voltage with peak $V_M = 15$ V and frequency 0.5 Hz, and output load resistance is $R = 5 \text{ k}\Omega$. Silicon diodes are used in this circuit for which the forward drop is $V_{D0} = 0.7$ V.

- Show the input and output waveforms.
- Draw the VTC curve

5. The input of a **full-wave rectifier** is a **Square** wave voltage with peak $V_M = 15$ V and frequency 0.5 Hz, and output load resistance is $R = 5 \text{ k}\Omega$. Silicon diodes are used in this circuit for which the forward drop is $V_{D0} = 0.7$ V.

- Show the input and output waveforms.
- Draw the VTC curve

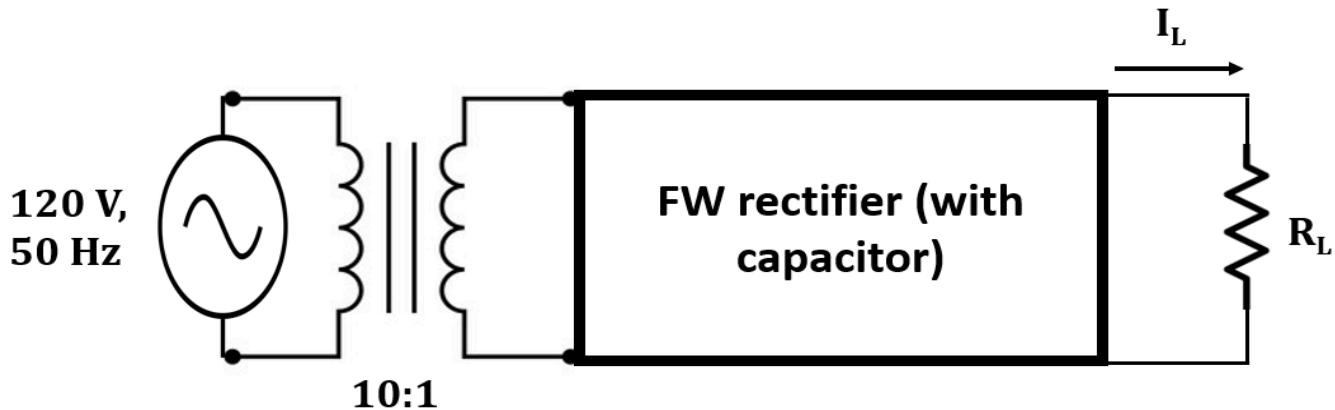
6.



The input of a Half-wave rectifier is exhibited in the Figure above, and the output load resistance is $R = 5 \text{ k}\Omega$. Silicon diodes are used in this circuit for which the forward drop is $V_{D0} = 0.7$ V.

- Show the input and output waveforms.
- Draw the VTC curve

7. A full-wave rectifier is designed to deliver a maximum current $I_L = 120 \text{ mA}$ to the load. The rectifier produces an output with a ripple of 5% of the peak output voltage. An input line voltage of 120 V (peak), 50 Hz is available. A 10:1 step-down transformer is used to transform the supply voltage to 12 V (peak).

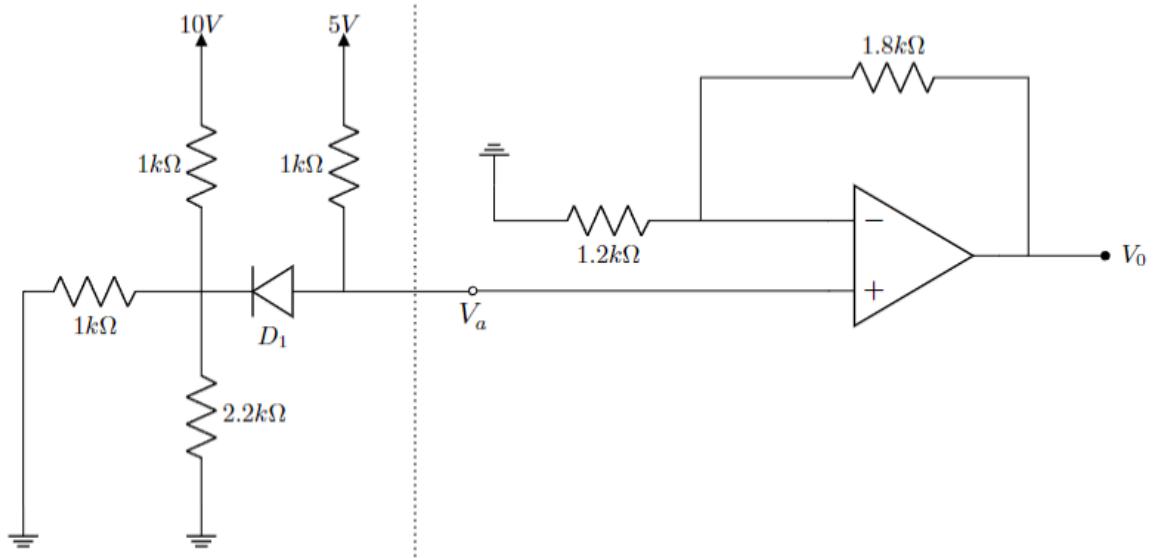


- (a) Draw the Voltage Transfer Characteristics of the full-wave rectifier. [2]
- (b) Calculate the peak output voltage. [1]
- (c) Determine the value of the Load Resistor to deliver a maximum load current of 120mA. [2]
- (d) Deduce the value of the Capacitor and the DC average value. [1]
- (e) Assume the transformer is removed and the rectifier is directly connected to the AC power supply line. Discuss the state of the diodes. [Hint: use the Peak Input Value of the rectifier input] [3]

Find more problems [here](#)

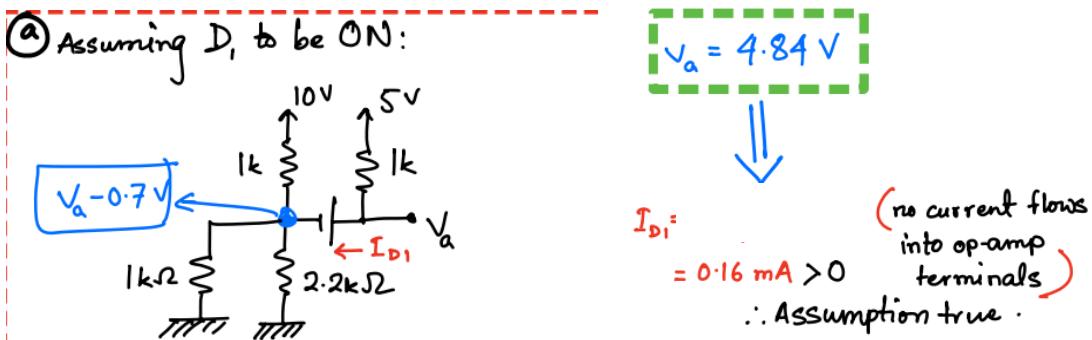
Hybrid Problems [Diode, OP-AMP]

1.



The saturation voltages of the Op-Amp are given as- $V_{sat}^+ = +10V$ and $V_{sat}^- = -10V$. The forward voltage drop of the diode V_D is 0.7V.

- (a) Determine the operating mode of diode D_1 . Verify your assumption with the necessary calculations.
- (b) Calculate the voltage at (i) node 'Va', (ii) non-inverting terminal of the Op-Amp, (iii) inverting terminal of the Op-Amp.
- (c) Find out the output voltage, V_0 of the Op-Amp.

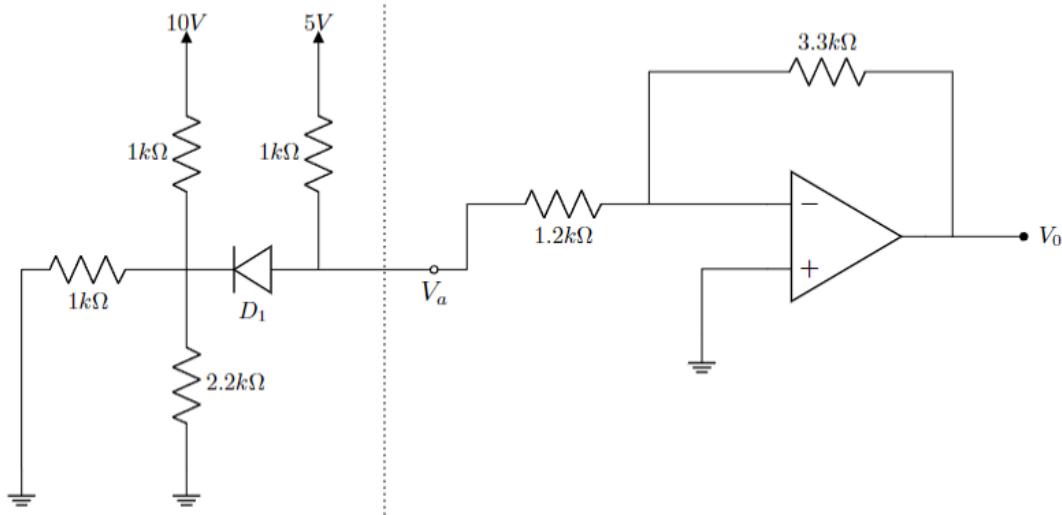


Node equation at supernode (V_a)

$$(V_a - 0.7) \left(1 + \frac{1}{2.2}\right) + V_a - 10 - 5 = 0$$

$V_a = 4.84 \text{ V}$

2.

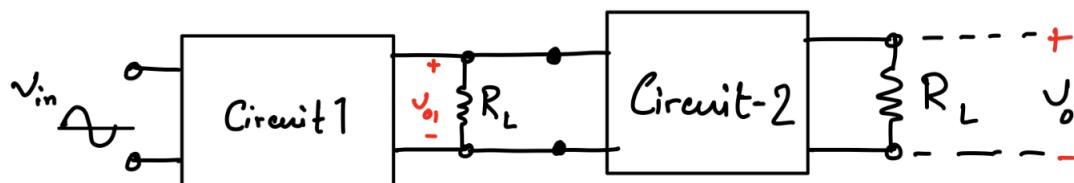


The saturation voltages of the Op-Amp are given as- $V_{sat}^+ = +10V$ and $V_{sat}^- = -10V$. The forward voltage drop of the diode V_D is 0.7V.

- (a) **Determine** the operating mode diode D_1 . Verify your assumption with the necessary calculations.
- (b) **Calculate** the voltage at (i) node 'Va', (ii) the non-inverting terminal of the Op-Amp, (iii) inverting terminal of the Op-Amp.
- (c) Find out the output voltage, V_o of the Op-Amp.

3.

You are provided with the diagram below as a starting point for designing an AC-to-DC converter. The input voltage source is a sinusoidal voltage source (V_{in}), with 2V peak-to-peak voltage (i.e., 1V amplitude), and the DC voltage is around 10V (with ripple) at the output terminals (v_o).



So, in order to solve this problem, you are provided with a single diode (with $V_{D0} = 0.7V$), two resistors (R_1 and R_2 , excluding the load resistors R_L), and a UA741 op-amp.

- (a) Design **circuit-1** with the single diode $R_L = 10 \text{ k}\Omega$ (R_L is already provided in the diagram as output terminals of **circuit-1**) to get a rectified voltage and determine the DC value of the output voltage (v_{o1}) of the circuit. [1+2]
- (b) Determine the ripple voltage of v_{o1} . [Ripple voltage is defined as the difference between the maximum and minimum value of a DC voltage.] [2]
- (c) What should be the value of a capacitor used at the output end of **circuit-1** R_L to reduce the ripple voltage v_{o1} to 0.1 V. How should the capacitor be connected with R_L in the diagram? [4+1]
- (d) Design an amplifier using an operational amplifier as **circuit-2** to increase the DC voltage level of the output voltage of the circuit designed in (c) to 10 V. Find the ripple voltage of the amplified voltage signal. [4+1]

Rectifiers

- The input of a full-wave rectifier is a cosine voltage with peak $V_M = 5 \text{ V}$ and frequency 60 Hz, and output load resistance is $R = 2 \text{ k}\Omega$. Silicon diodes are used in this circuit for which the forward drop is $V_{D0} = 0.7 \text{ V}$.
 - Briefly explain the purpose of a rectifier and describe its operation. [1]
 - Show the input and output waveforms. [2]
 - Calculate the DC value of the output voltage. [1]

Now, after connecting a capacitor in parallel with the load, the output becomes a ripple voltage $\mathbf{Vout} = V_{DC} \pm 0.2 \text{ V}$

 - Calculate the **peak-to-peak ripple voltage**, and from that, the value of the capacitor. [2]
 - Calculate the average of the output voltage V_{DC} after connecting the capacitor. Compare this with the DC value determined in 'c' and comment on the difference between these two. [2]
- The input of a **Half-wave rectifier** is a sine voltage with peak $VM = 10 \text{ V}$ and frequency 55 Hz, and output load resistance is $R = 2.5 \text{ k}\Omega$. Silicon diodes are used in this circuit for which the forward drop is $V_{D0} = 0.4 \text{ V}$.
 - Calculate the DC value of the output voltage. [1]

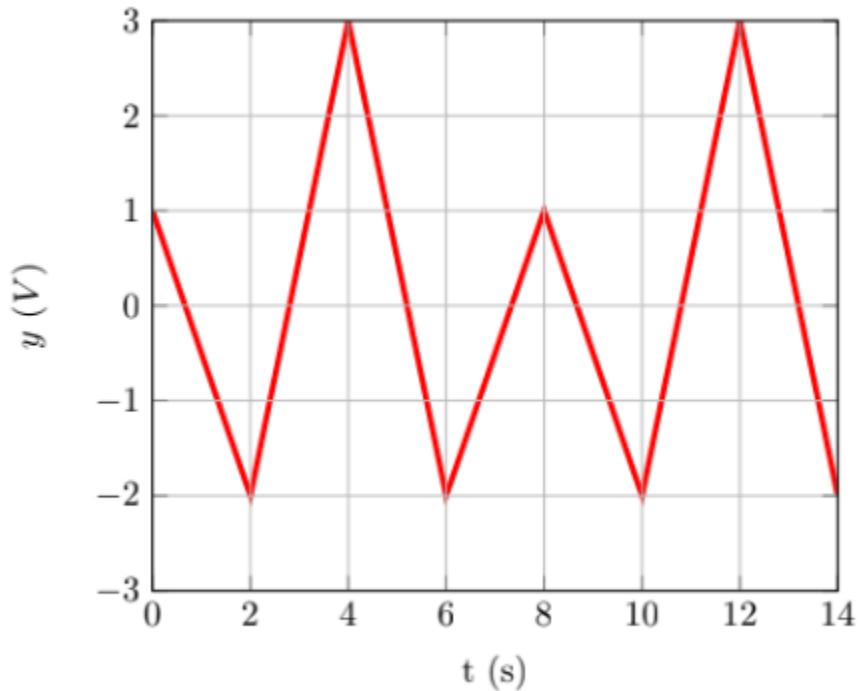
Now, after connecting a capacitor in parallel with the load, the output becomes a ripple voltage $\mathbf{Vout} = V_{DC} \pm 0.3 \text{ V}$.

 - Calculate the **peak-to-peak ripple voltage**, and from that, the value of the capacitor. [2]
 - Draw the **Voltage Transfer Characteristic (VTC) curve** [2]
- The input of a full-wave rectifier is expressed by $V_s(t) = 7\sin(400\pi t)$, and output load resistance is $R = 5 \text{ k}\Omega$. Silicon diodes are used in this circuit for which the forward drop is $V_{D0} = 0.3 \text{ V}$.
 - Calculate the input and output wave frequency. [2]
 - Show the input and output waveforms.

Now, after connecting a capacitor, $C = 100 \mu\text{F}$ in parallel with the load.

- Calculate the peak-to-peak ripple voltage,
- How can you provide better filtering for the output waves?

- (e) What is the frequency of the Ripple voltage?
4. The input of a **Half-wave rectifier** is a **Square** wave voltage with peak $V_M = 15 \text{ V}$ and frequency 0.5 Hz, and output load resistance is $R = 5 \text{ k}\Omega$. Silicon diodes are used in this circuit for which the forward drop is $V_{D0} = 0.7 \text{ V}$.
- Show the input and output waveforms. [4]
 - Draw the VTC curve [2]
5. The input of a **full-wave rectifier** is a **Square** wave voltage with peak $V_M = 15 \text{ V}$ and frequency 0.5 Hz, and output load resistance is $R = 5 \text{ k}\Omega$. Silicon diodes are used in this circuit for which the forward drop is $V_{D0} = 0.7 \text{ V}$.
- Show the input and output waveforms. [4]
 - Draw the VTC curve [2]

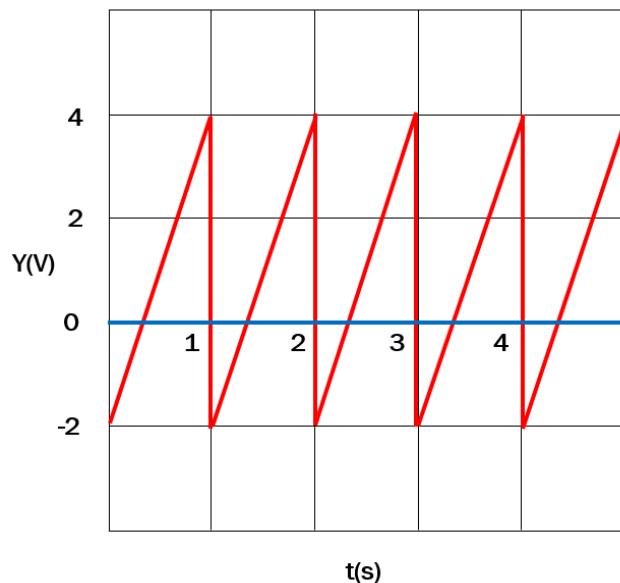


- 6.
- (b) Input of the FW rectifier

Part 2: A voltage waveform $V_i = 15 \sin(2000\pi t)$ V is fed into a Half-wave rectifier with a load resistance $R = 5 \text{ k}\Omega$. Silicon diodes are used in this circuit for which the forward drop is $V_{D_0} = 0.7 \text{ V}$.

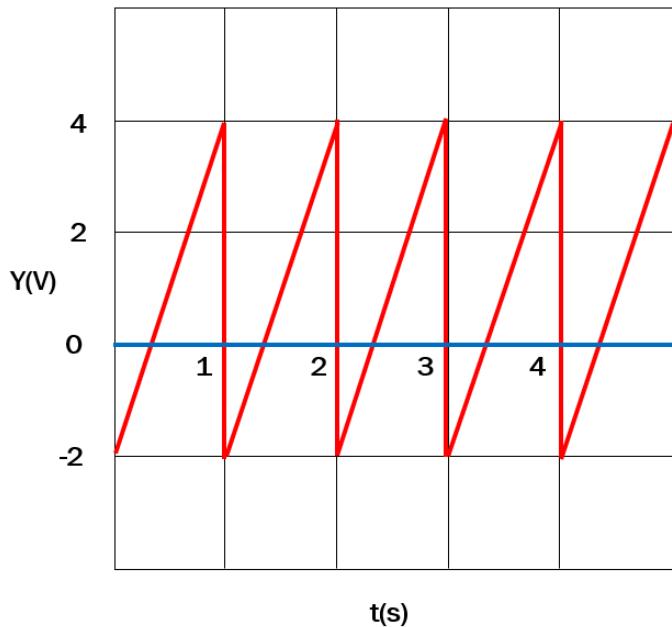
- (a) **Illustrate** the input and output waveforms in separate graphs. Label the graph and **indicate** the voltage levels properly. [2]
- (b) **Calculate** the DC/Average value of the output. [1]
- (c) A capacitor is now added to reduce the fluctuation of the output voltage, which makes the peak to peak ripple voltage 4% of the maximum output voltage V_P . **Deduce** is the value of the capacitor from the given data. [2]
- (d) The input of a Full-wave rectifier is shown in Figure 1(b) above and output load resistance is $R = 10 \text{ k}\Omega$. Germanium diodes are used in this circuit for which the forward drop is $V_{D_0} = 0.3 \text{ V}$. **Show** the input and output waveforms [1]

7.

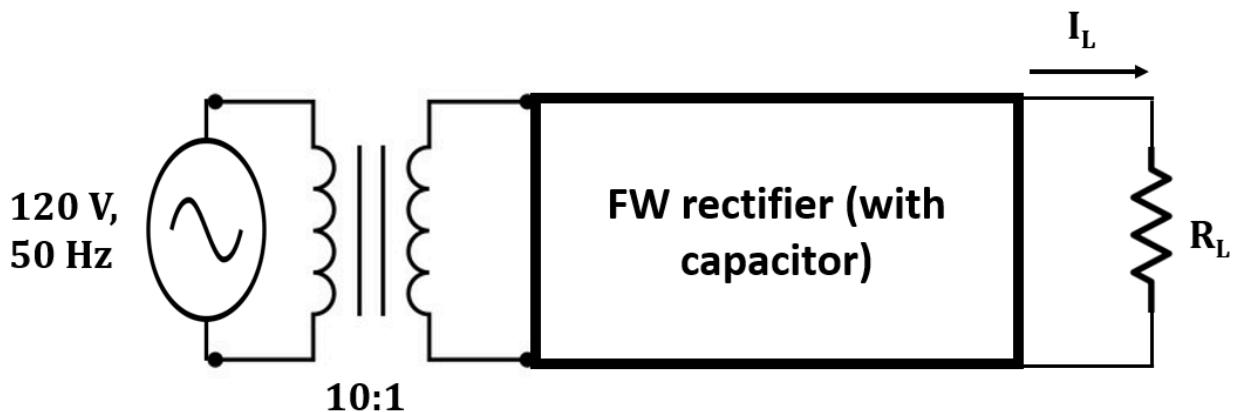


The input of a **Half-wave rectifier** is exhibited in the Figure above, and the output load resistance is $R = 5 \text{ k}\Omega$. Silicon diodes are used in this circuit for which the forward drop is $V_{D_0} = 0.7 \text{ V}$.

- i. Show the input and output waveforms. [3]
- ii. Draw the VTC curve [2]
- iii. Calculate input and output frequency [3]



8. The input of a **full-wave rectifier** is exhibited in the Figure above, and output load resistance is $R = 5 \text{ k}\Omega$. Silicon diodes are used in this circuit for which the forward drop is $V_{D0} = 0.7 \text{ V}$.
- Show the input and output waveforms. [3]
 - Draw the VTC curve [2]
 - Calculate input and output frequency [3]
9. A full-wave rectifier is designed to deliver a maximum current $I_L = 120 \text{ mA}$ to the load. The rectifier produces an output with a ripple of 5% of the peak output voltage. An input line voltage of 120 V (peak), 50 Hz is available. A 10:1 step-down transformer is used to transform the supply voltage to 12 V (peak).



- Draw** the Voltage Transfer Characteristics of the full-wave rectifier. [2]
- Calculate** the peak output voltage. [1]
- Determine** the value of the Load Resistor to deliver a maximum load current of 120mA. [2]
- Deduce** the value of the Capacitor and the DC average value. [1]
- Assume the transformer is removed and the rectifier is directly connected to the AC power supply line. **Discuss** the state of the diodes. [Hint: use the Peak Input Value of the rectifier input] [3]

Zener Diode

Q1. The 6.8-V Zener diode in the circuit of **Figure** is specified to have the following parameters. The supply voltage V^+ is nominally **10 V** but can vary by ± 1 V.

(a) Find V_o with no load and with V^+ at its nominal value

(b) (For $R_L = 0.5 \text{ k}\Omega$). Find the I_Z . In this scenario, calculate the Zener voltage V_o , load current I_L , and input current I

(c) Find the R_L that would give rise to worst-case scenario at worst case V^+ . In this worst-case scenario, calculate the Zener voltage V_o , load current I_L and input current I

(d) (For $R_L = 2 \text{ k}\Omega$). Find the I_Z . In this scenario, calculate the Zener voltage V_o , load current I_L , and input current I

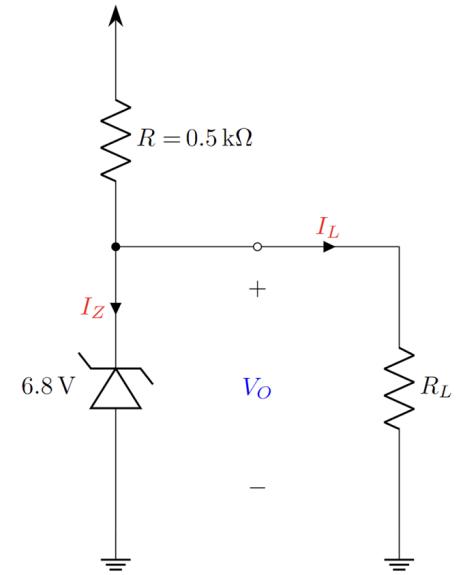
(e) Design the circuit, i.e., find the minimum value of the input voltage V^+ such that voltage regulation is maintained even in the worst-case scenario for $R_L = 2 \text{ k}\Omega$. (Forget that V^+ is 10 V)

(f) Determine whether the circuit will maintain regulation if V^+ is increased. If yes, argue if it should be increased or not.

$V^+ = 10 \pm 1 \text{ V}$

$V_Z = 6.8 \text{ V at } I_Z = 5 \text{ mA}$
$r_z = 20 \Omega$
$I_{ZK} = 0.2 \text{ mA}$

$V^+ (10 \pm 1 \text{ V})$

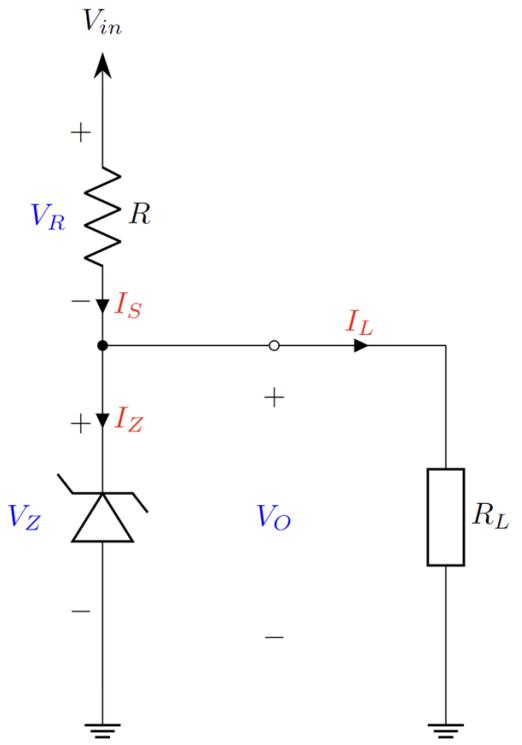


Q2

The Zener diode in the circuit of Figure is specified to have the following parameters. The supply voltage V_{in} is nominally **5 V** but can vary by $\pm 10\%$. Load current can vary from **0 mA** to **50 mA**.

$V_{in} = 5 \text{ V} \pm 10 \%$

$V_{z0} = 3 \text{ V}$
$r_z = 0 \Omega$
$I_{ZK} = 1 \text{ mA}$.



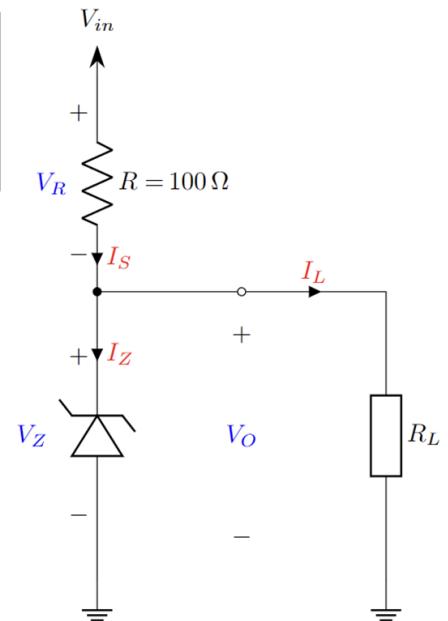
- a) Find minimum and maximum input Voltage, V_{in} (min) and V_{in} (max), maximum and minimum load current I_L (max) and I_L (min), and minimum diode current I_Z (min).
- b) Find the I_Z , V_{in} , and I_L at the worst-case scenario.
- c) For the worst case, what are I_S and V_R ?
- d) Find R for which diode maintains regulation at the worst-case scenario.

Q3

The Zener diode in the circuit of Figure is specified to have the following parameters.

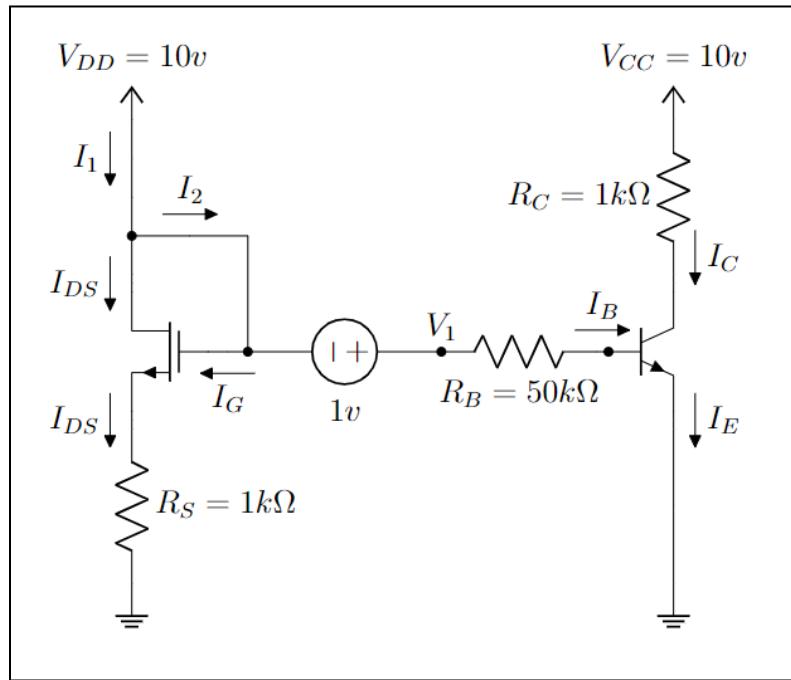
$V_{z0} = 3 \text{ V}$
$r_z = 20 \Omega, 0 \Omega$
$I_{ZK} = 1 \text{ mA}$.

- a. Find minimum input voltage, V_{in} (min) for which the diode maintains regulation when $R_L=10 \text{ k}\Omega$.
- b. Find worst case R_L if the input voltage V_{in} is nominally **5 V** but can vary by $\pm 10\%$



BJT

Q1

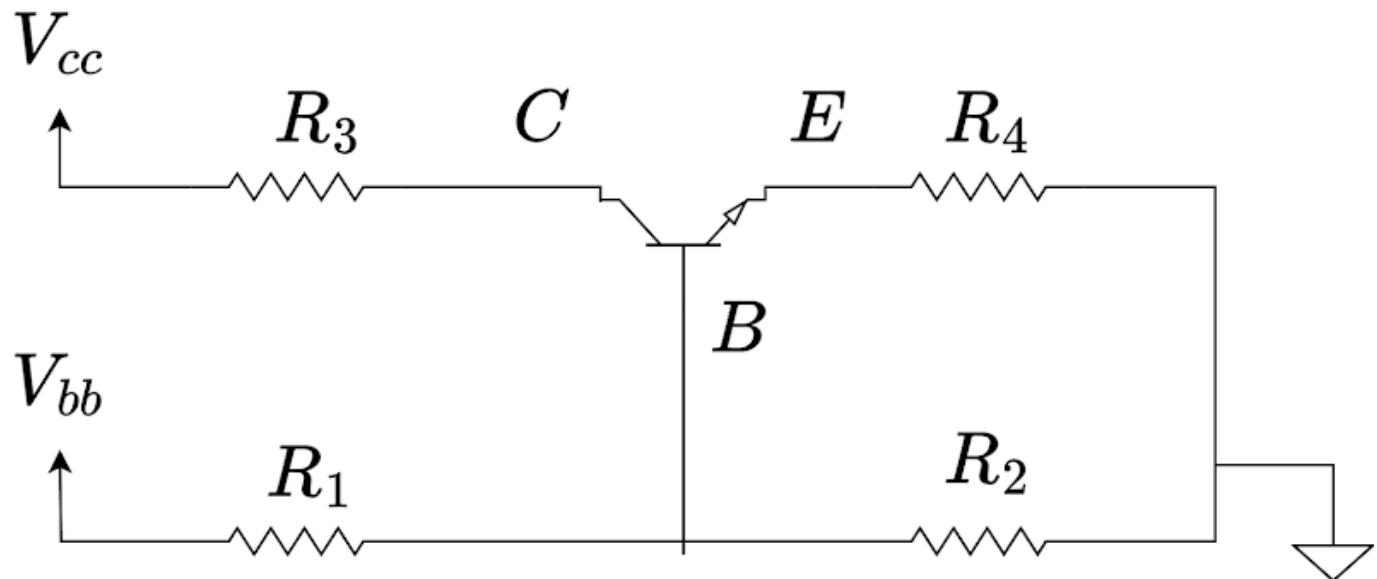


In the circuit above, the MOSFET and BJT have the following parameters,

$$K = 4 \text{ mA/V}^2, V_T = 0.9 \text{ v}, \beta = 100, V_{BE(\text{active})} = 0.7 \text{ v}, V_{BE(\text{sat})} = 0.8 \text{ v}$$

- (a) Find out the gate voltage of the MOSFET.
- (b) Calculate V_1 .
- (c) Find out the expression for V_{GS} , V_{DS} , and V_{ov} .
- (d) Find the operating mode of the MOSFET using the expressions from ©. [Hint: You don't need any assumption]
- (e) Calculate I_{DS} and V_{DS} using the given parameters.
- (f) Assume that the BJT is in saturation mode. Now, calculate I_B , I_C , and I_E . You must validate the given assumption.

Q2



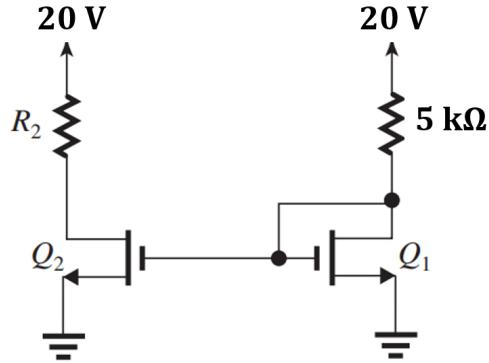
In the above circuit, $V_{bb} = 5V$, $V_{cc} = 15V$, $R_1 = 20k\Omega(40k\Omega)$, $R_2 = 80k\Omega(60k\Omega)$, $R_3 = 2k\Omega$ and $R_4 = 1k\Omega$. Also, assume current gain, $I_c/I_b = 100$.

- a) Draw the equivalent circuit of BJT during saturation and active modes. [2]
- b) Solve the above circuit and calculate I_B , I_C , I_E , V_{CE} , and V_C using the method of assumed states. [Hint: try to find the Thevenin equivalent of the left-hand side circuit from the B terminal and ground] [3]
- c) If V_{bb} is changed from 5V to 5.1V, what happens to the outputs of the circuits? Calculate I_B , I_C , I_E , V_{CE} , and V_C again. Now, for a 0.1V increase in input V_{bb} , what is the change of I_c ? Use $\Delta I_C = I_{C,new} - I_{C,old}$. [3+1]
- d) Explain any use case of the differences in voltage increase between input and output. What could the use case be for such a phenomenon? [1]

Find more problems [here](#)

MOSFET

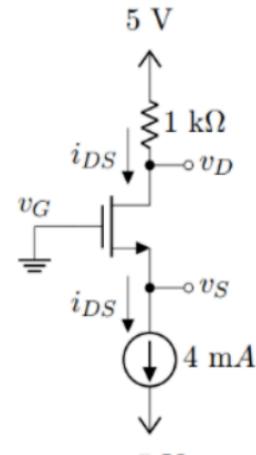
Q1.



In the circuit above, the MOSFETs have the following parameters: $k'n=2 \text{ mA/V}^2$, $W/L= 2.5$, $V_T=0.5 \text{ V}$.

- Find out** the operating mode of Q1 [Hint: For Triode mode $V_{ds} < V_{ov}$ and for Saturation $V_{ds} \geq V_{ov}$]
- Determine** the value of R_2 that results in Q2 operating at the edge of the saturation region.
- Calculate the on-state resistance**, R_{on} for Q2. Assume the gate voltage of Q2 is 20 V.
- An inverter is designed using Q2 and a 10K resistor. **Draw** the VTC graph for the inverter.

Q2.

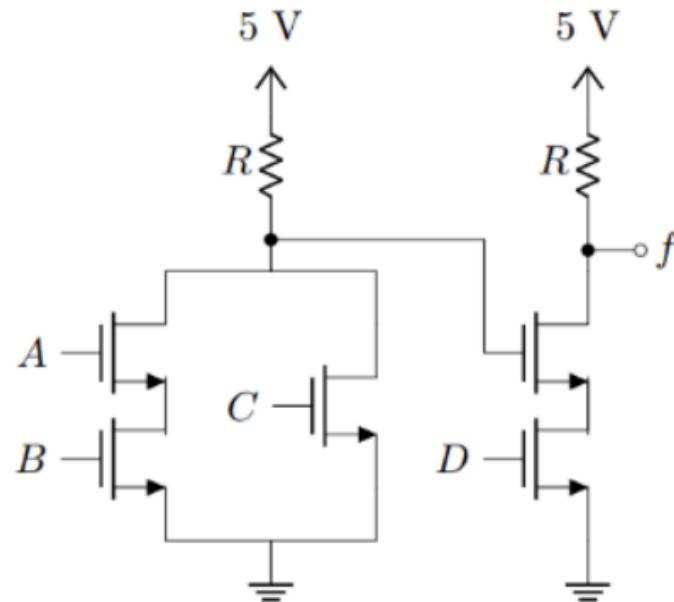


Circuit 1

Refer to the **Circuit** above. For the MOSFET, $V_T = 1$ V and $k = k'_n \frac{W}{L} = 4$ mA/V².

- Identify** the value of the gate voltage v_G and the drain-source current i_{DS} .
- Calculate** the value of the drain voltage v_D using the 1 kΩ resistor.
- Analyze** the circuit to find v_S . Here, **use** the Method of Assumed State. You must **validate** your assumptions. [Hint: assume $v_S = x$]

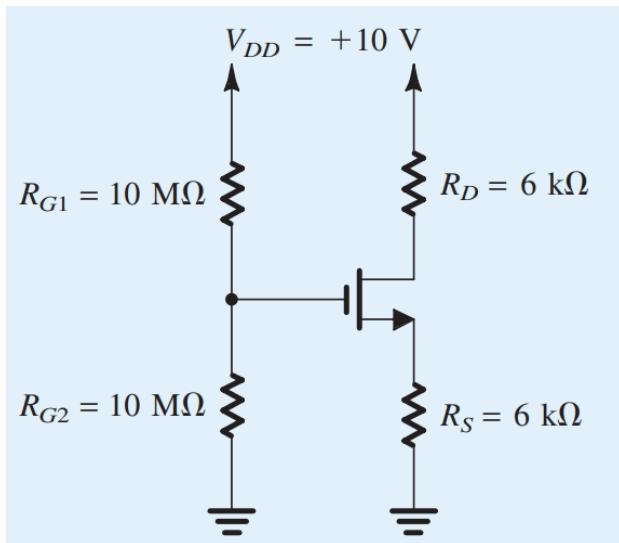
Q3. For the following circuit, find **f** in terms of Boolean inputs **A**, **B**, **C**, and **D**.



Q4. Use MOSFET to implement the Boolean Logic function, $F = \underline{AB} + \underline{C}$

Q5. Draw the VTC of a NOR gate using the MOSFET S-model. ii. Draw the VTC of a NOR gate using the MOSFET SR model. Let, $R_{on} = 100$ ohms, $R_L = 10$ Kohms, $V_{ss} = 5$ V.

Q6



Analyze the circuit to find i_D and v_D using the Method of Assumed State. You must validate your assumptions.

Here, $V_T = 1\text{ V}$, $k = 5\text{ mA/V}^2$

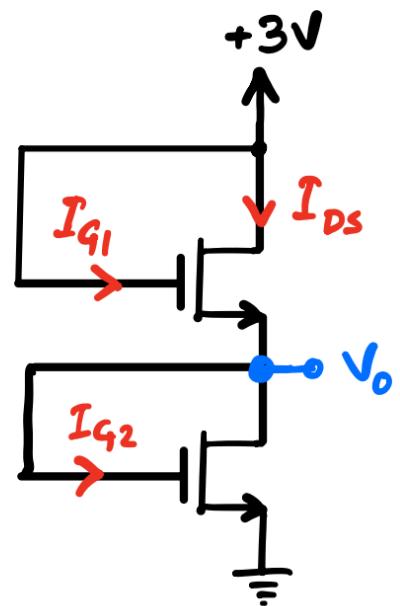
Q7

- (a) $f = (A + B)C$
- (b) $f = (\overline{A}\overline{B} + CD)$
- (c) $f = AB + A + CD$ (with and without simplifying the logic)

Q8

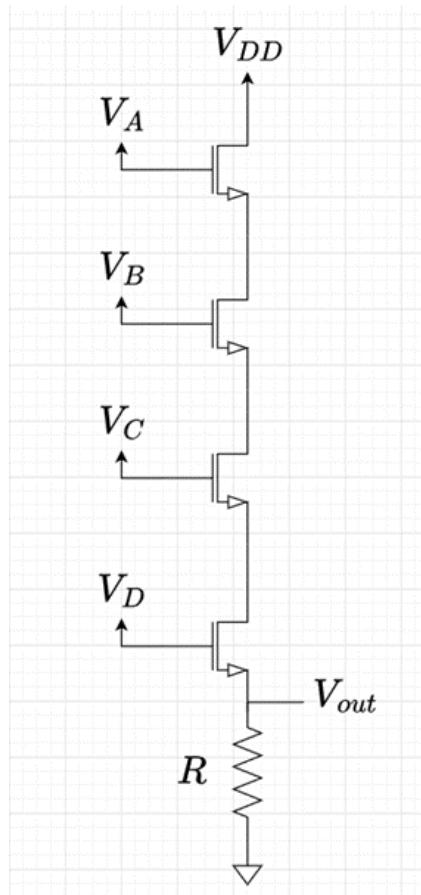
In the circuit shown in the figure below, the transistor is characterized by $V_T = 1\text{ V}$, $k = 1\text{ mA/V}^2$. (Hint: Identify the modes of the two MOSFET, and equate the two currents.)

- (a) [3 marks] Find the value of V_O indicated in the figure.
- (b) [3 marks] Find the values of I_{DS} , I_{G1} and I_{G2} .

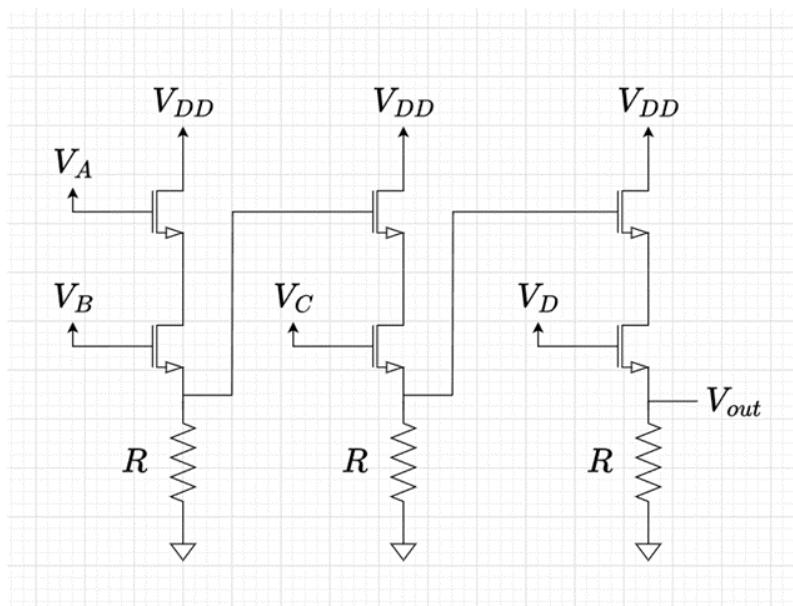


Q9 (1st ckt has too many equations and variables to solve by hand, 2nd ckt can be solved, each mosfet ckt should give you 2 equations in 2 variables with appropriate substitutions, try to solve 2nd ckt to get some practice solving with SR models)

Another hint: SR model is simply the approximate of the MOSFET equation, $Id = k(Vov * Vds - Vds^2/2)$ with Vds^2 negligible, thus giving us, $Id = k * Vov * Vds$. This should be clear since voltage by current is resistance, and here, $Vds / Id = 1 / (k * Vov) = Ron$, as we learned. So, the SR model is a simpler model of the MOSFET equation in the triode region!



Circuit-1



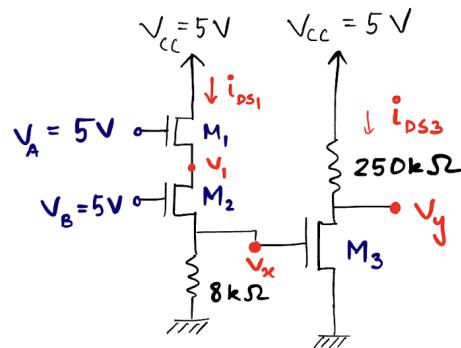
Circuit-2

The above 2 circuits are implemented for logic gates using n-MOSFETs. All input voltages, VDD, VA, VB, VC, and VD, are 5V. Given, each n-MOSFET has the following parameters for its SR model: $V_T = 1V$, $k = 2.5 \times 10^{-4} A/V^2$ (be wary of units!), and $R_{on} = 1/(kV_{OV} \Omega)$. Also given, $V_{OV} = V_{GS} - V_T$ (For this problem, approximate VGS to be equal to VG)

- Write down the SR model of an n-MOSFET. [1]
- Find the logic expressions for circuit-1 and circuit-2. [2]
- Using the SR-model of MOSFET, solve circuit-1 and circuit-2 and find the output voltage, V_{out} , when all inputs, VA, VB, VC, and VD, are high(+5V). Given $R = 800 \Omega$. Do the two circuits give the correct output as per their logic expressions? [3]
- If the outputs of the two circuits are used as gate voltage to a similar n-MOSFET, will it work as intended? That is, will a logical high in output be seen as a logical high in the input of any n-MOSFET? If not, what can you do to remedy this? Explain with necessary calculations. [4]

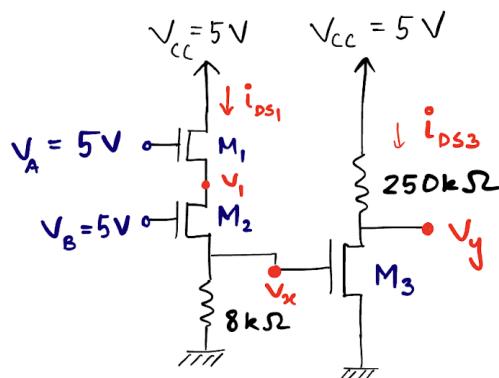
Q10

MOSFET Design



For the following circuit with MOSFETs, assume that $V_T = 1 \text{ V}$, $k_n' = 50 \mu\text{A/V}^2$ and the aspect ratio W/L is 1 for all the MOSFETS.

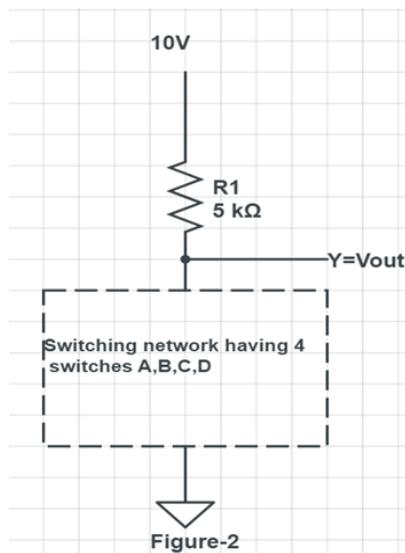
- If the gate voltage to M3 MOSFET, $V_x = 0.938 \text{ V}$, and MOSFET M2 is in triode mode, find the voltage V_1 . [3]
- Find V_y . [2]
- If W/L=2, then $V_1 = 2.1454 \text{ V}$. Find V_x for this case. [2]
- Can you explain whether there will be any changes in the output voltage at V_y for W/L = 2 from that in ('b')? Also, comment on whether a larger or smaller value of W/L ratio is preferred in this case. [2+1]



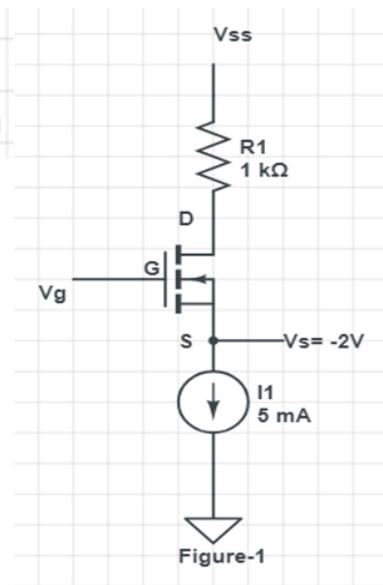
For the following circuit with MOSFETs, assume that $V_T = 1 \text{ V}$, $k_n' = 20 \mu \text{A/V}^2$ and the aspect ratio W/L is 1 for all the MOSFETS.

- (a) If the gate voltage to M3 MOSFET, $V_x = 0.492 \text{ V}$, and MOSFET M2 is in triode mode, find the voltage V_1 . Verify the modes for both M1 and M2 [3]
- (b) Find V_y . [2]
- (c) If W/L=4, then $V_1 = 2.04 \text{ V}$. Find V_x for this case. [2]
- (d) Can you explain whether there will be any changes in the output voltage at V_y for W/L = 4 from that in 'b'? Also, comment on whether a larger or smaller value of W/L ratio is preferred in this case. [2+1]

Q11



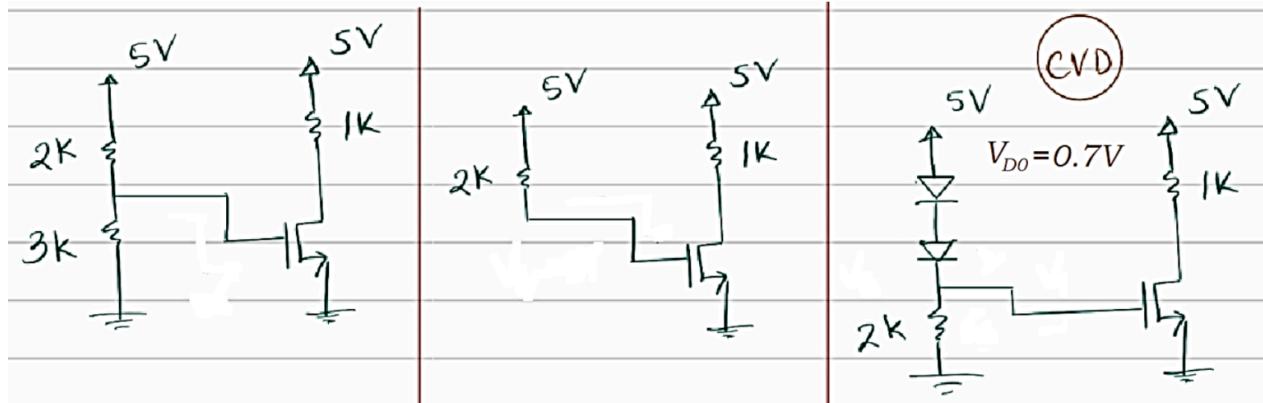
Conditions for Network on
 i) switch A must be on
 ii) Switches B,C simultaneously on or D on



- a) For figure-2, place the switches as nmos devices and write the output logic function Y in terms of A, B, C, D assuming nmos switch model. [2]
- b) From figure-2, assuming SR model for nmos find the output voltage when only A and D switches are ON(Assume Ron= 0.1 KΩ) [3]
- c) For figure-1, $k=2 \text{ mA/V}^2$, $V_T = 1 \text{ V}$ [3+2]
 i) Find the gate voltage so that the mosfet is in saturation mode.
 ii) Then, find the minimum supply voltage Vss to operate the device in this condition. [Hints, $V_{ov}=V_{DS}$]
- d) **Bonus** - from figure-2, is it possible to drive a not gate cascaded to Vout?

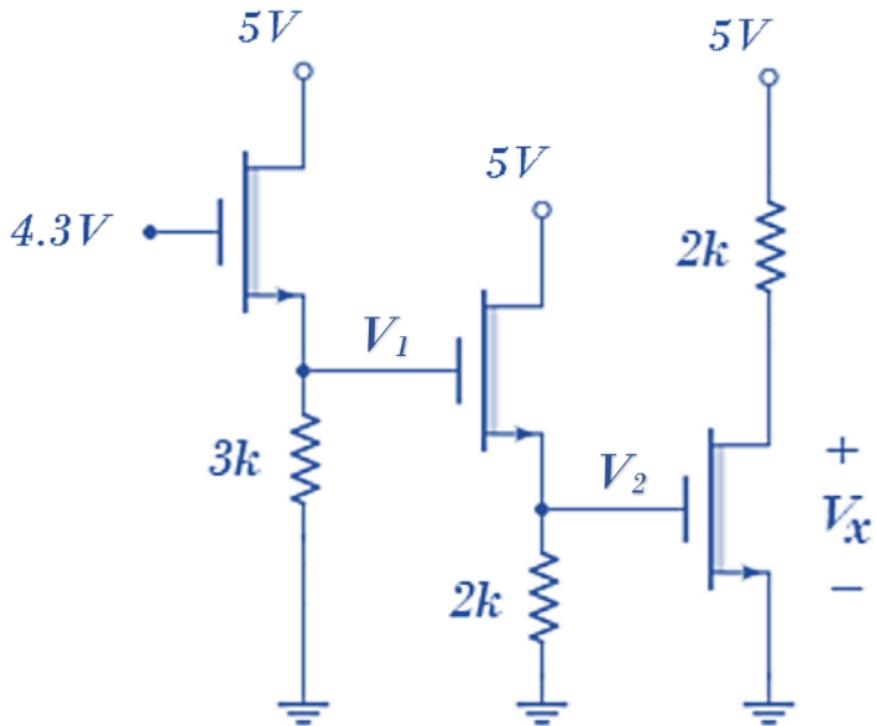
Q12 (MOSFET + Diode)

For all three circuits below, you are given $V_T = 1V$, $K_n = 1 \text{ mA/V}^2$. Determine which one of the three $1k\Omega$ dissipates the most power?

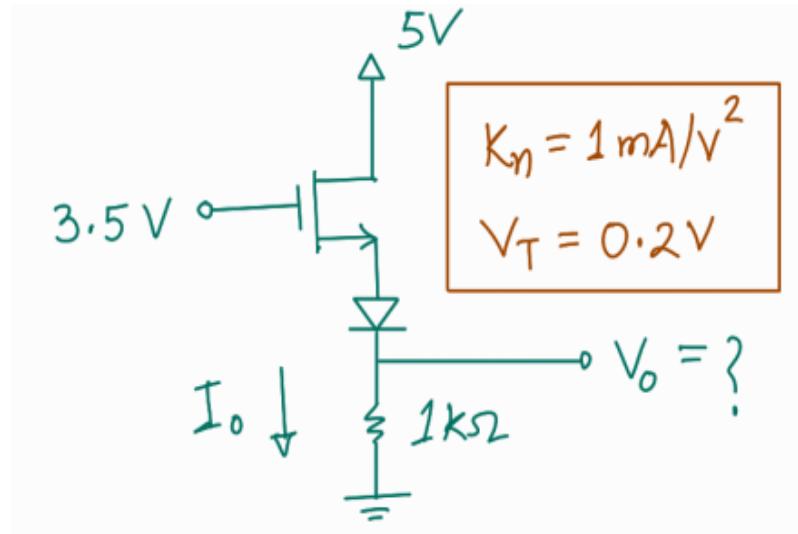


Q13

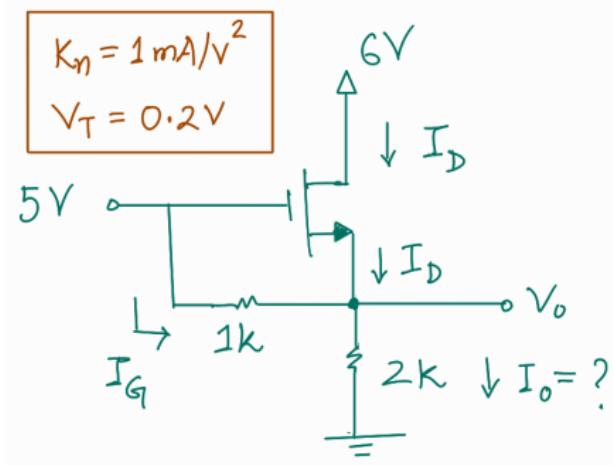
Using $V_T = 1V$, $K_n = 2 \text{ mA/V}^2$, determine V_x for the circuit below.



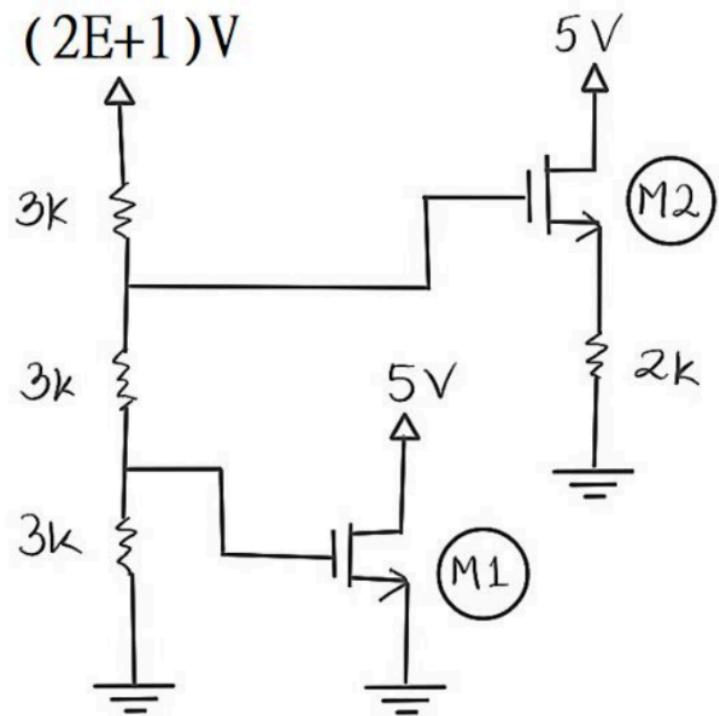
Q14 (MOSFET+Diode)



Q15



Q16. You are given (i) E=2 or (ii) E=5. Determine the operation modes of the M_1 and M_2 MOSFETs. Also, find the power dissipated in the $2k\Omega$ resistor.

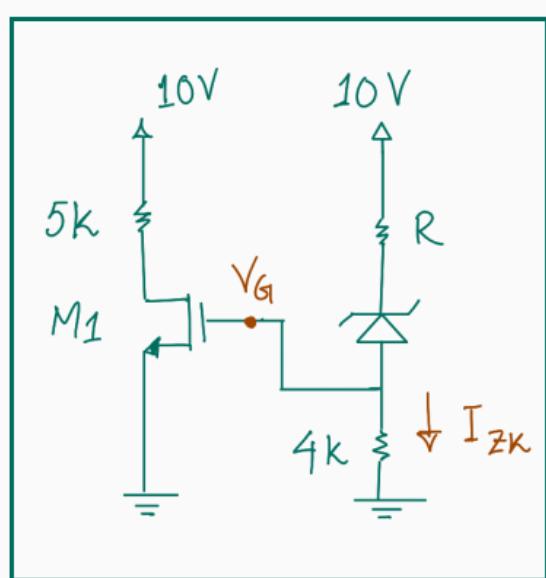


For both mosfets,
 $V_T = 0.3 V$
 $k_n = 0.1 mA/V^2$

Find more problems [here](#)

Hybrid

Q1 [MOSFET, Zener]



* Given, $r_z = 100\Omega$, $I_{ZK} = 1.2 \text{ mA}$
 $V_{Z0} = 3.3 \text{ V}$

(Q1) : Find the maximum value of R so that the zener diode stays in knee-voltage condition

(Q2) : Find the operating region of the Mosfet M_1 using the value of R in (Q1).

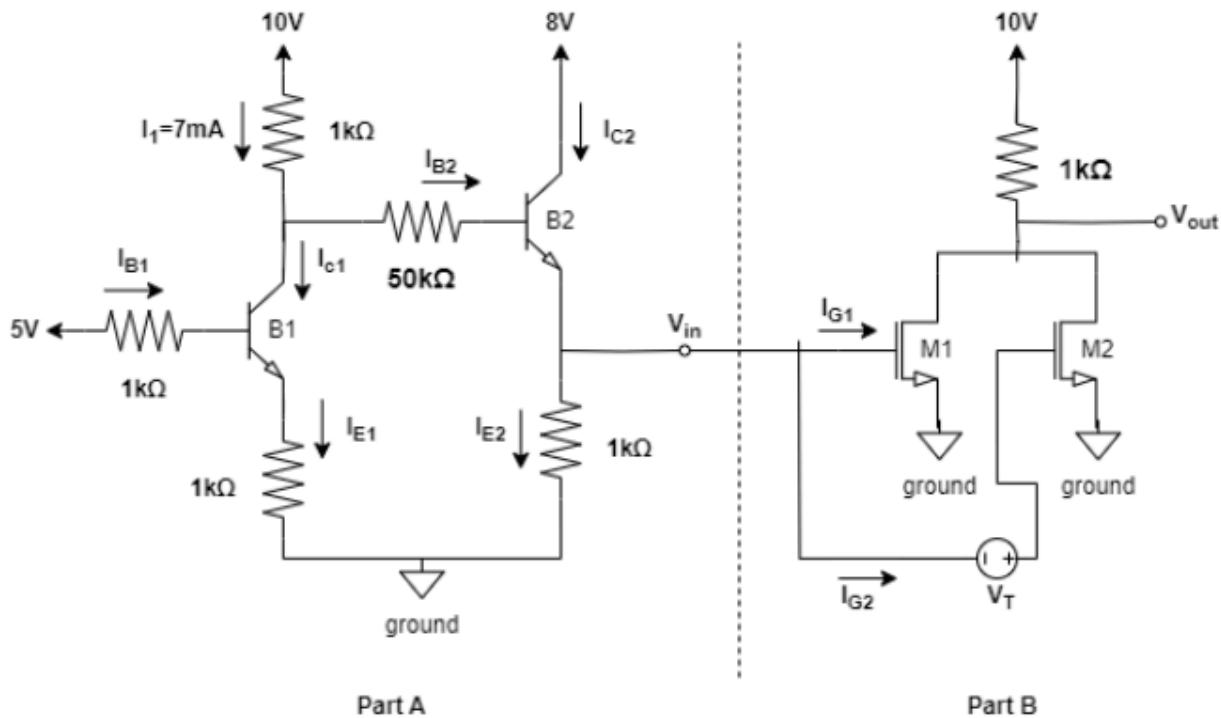
$$K_n = 1 \text{ mA/V}^2$$

$$V_T = 0.2 \text{ V}$$

Hint : (Q1) At worst case scenario, KVL gives us : ($R = R_{\max}$)
 $\Rightarrow 10 = I_{ZK} \cdot R + (I_{ZK} r_z + V_{Z0}) + 4 I_{ZK} \rightarrow R_{\max} = 1.48 \text{ k}\Omega$

$$(Q2) \quad V_G = 10 - R \cdot I_{ZK} - V_z \\ \Rightarrow V_G = 10 - R \cdot I_{ZK} - (V_{Z0} + I_{ZK} r_z) \quad \left. \begin{array}{l} \\ \\ \end{array} \right\} \text{Then use "Method of Assumed States"} \\ \text{&}, \quad I_G = 0 \text{ mA } (***)$$

Q2 [MOSFET, BJT]



In the circuit above, the BJTs have the following specification: $\beta=100$, Forward Active Region: $V_{BE} = 0.7 \text{ V}$, $I_C = \beta I_B$, Saturation Region: $V_{BE} = 0.8 \text{ V}$, $V_{CE} = 0.2 \text{ V}$, or the MOSFETs: $V_T = \text{Threshold Voltage of } M1 \text{ and } M2$.

- (a) Determine i_{g1} and i_{g2}
 - (b) **Justify** why the SR model of MOSFET is more efficient than the S model ? [1]
 - (c) Assume, B1 and B2 are in the **Saturation region**. Calculate i_{c2} .
 - (d) Assume, B1 is in the **Forward Active region**. Calculate V_{in} .
 - (e) **Draw the VTC** of Part- B assuming, $V_T = 8 \text{ V}$. [Use S model of MOSFETs]

