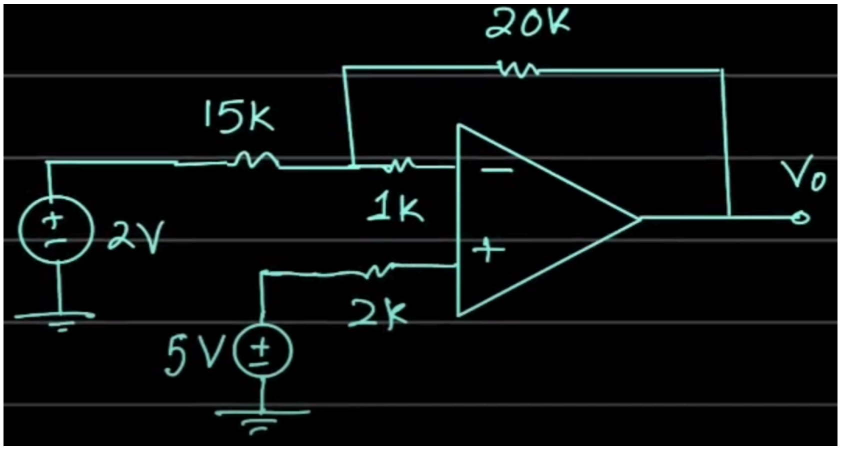
17. Miscellaneous

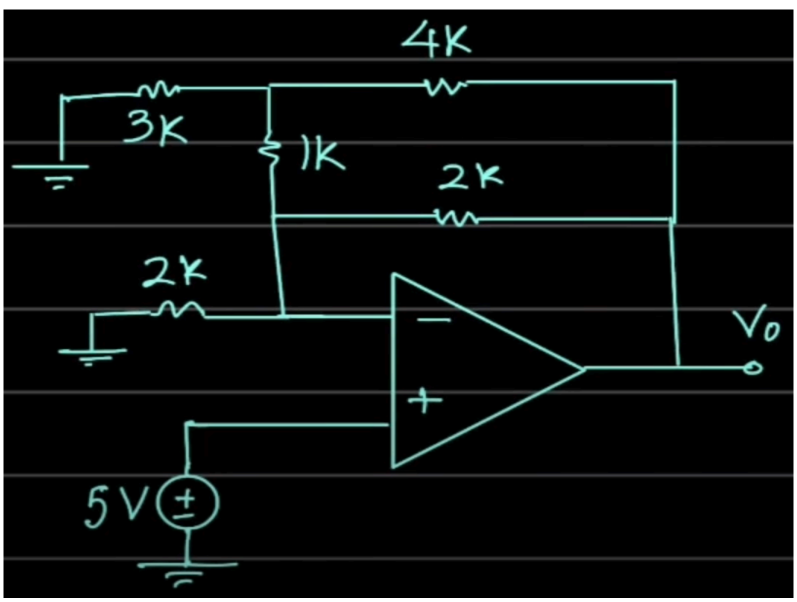
Determine the output voltage, v_0



Solution: (from central playlist)
https://youtu.be/KBWfa-NuYzk?list=PLPf6M92pkd7DRilBZLzKot-39S215ksSw&t=617

18. Miscellaneous

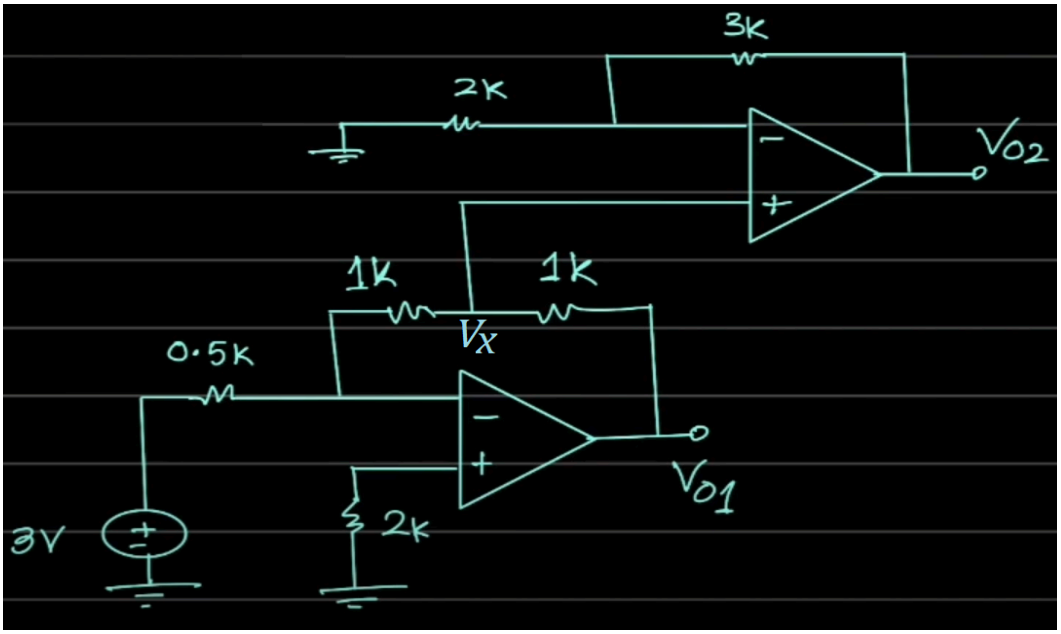
Determine the output voltage, v_0



Solution: (from central playlist)
https://youtu.be/KBWfa-NuYzk?list=PLPf6M92pkd7DRilBZLzKot-39S215ksSw&t=890

19. Miscellaneous

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

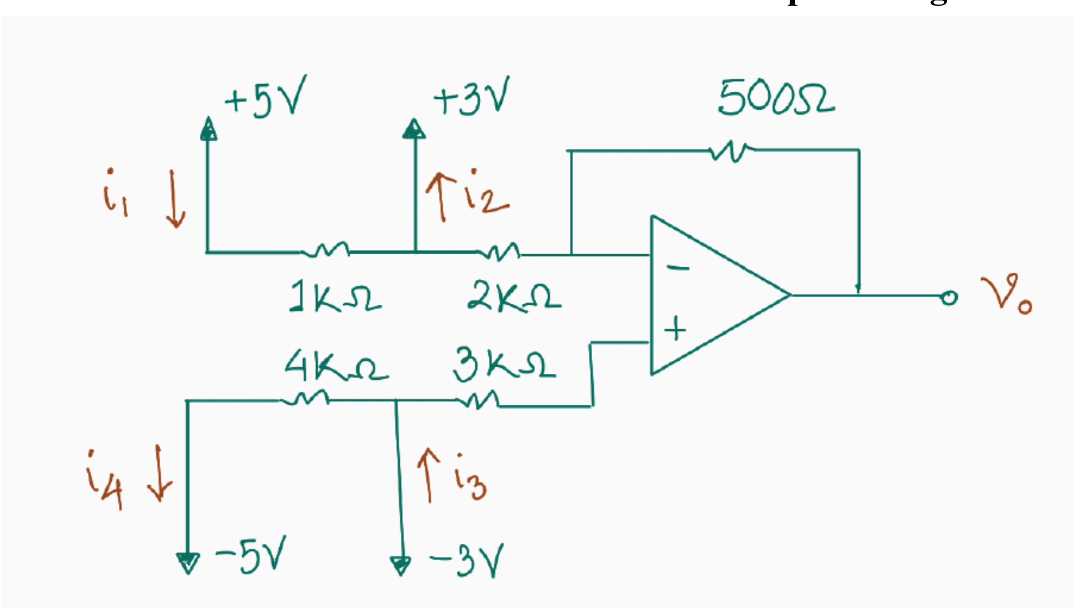


Solution: (from central playlist)
https://youtu.be/KBWfa-NuYzk?list=PLPf6M92pkd7DRilBZLzKot-39S215ksSw&t=1198

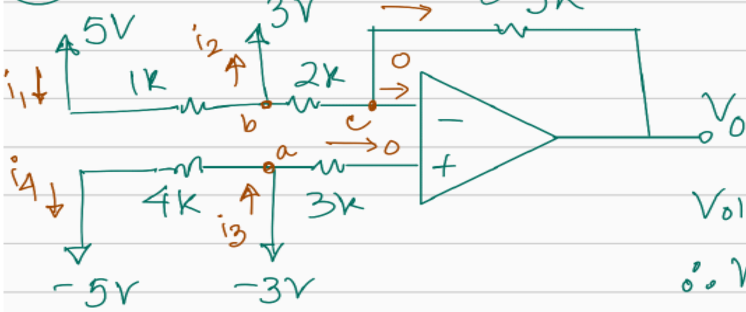
Additional Hint for finding V_X : Use Nodal Analysis on the V_X node instead of the current method shown in the video link above.

20. Miscellaneous

Determine the marked currents and the output voltage



(20)



KCL at a : $i_3 = i_4$

$\therefore i_3 = i_4 = \frac{-3+5}{4}$

$= -0.5 mA$

Voltage at a $= -3V = V_a$

$\therefore$ Voltage at c $= -3V = V_c$

Voltage at b $= 3V = V_b$

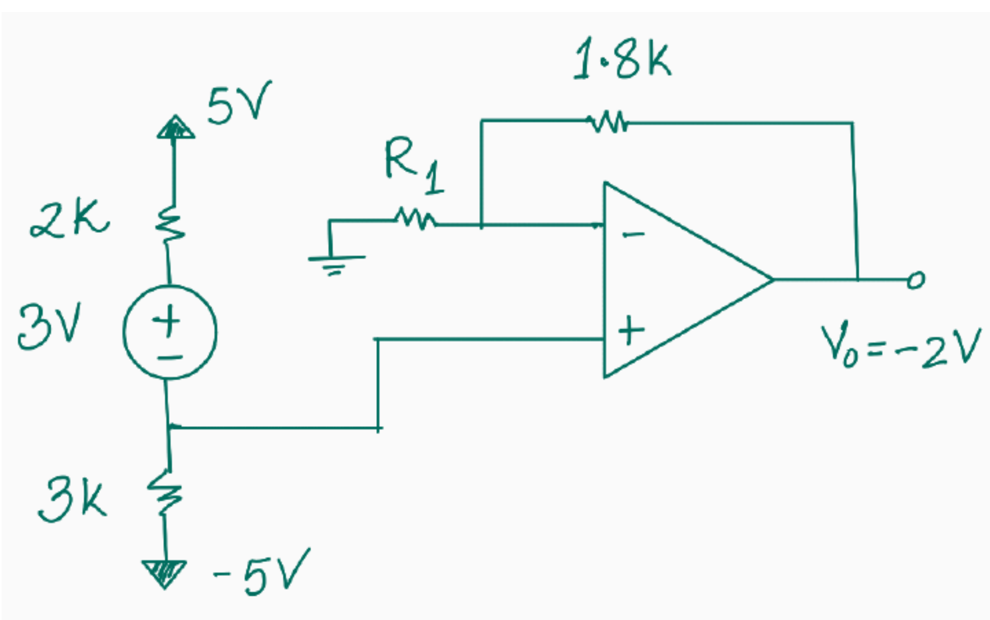
Nodal at c : $\frac{V_c - V_0}{0.5} + \frac{V_c - V_b}{2} = 0 \Rightarrow V_o = -4.5V$

And, $i_1 = \frac{5-3}{1} = 2mA$; $i_2 = i_1 - i_F = 2 - \frac{V_c - V_0}{0.5}$

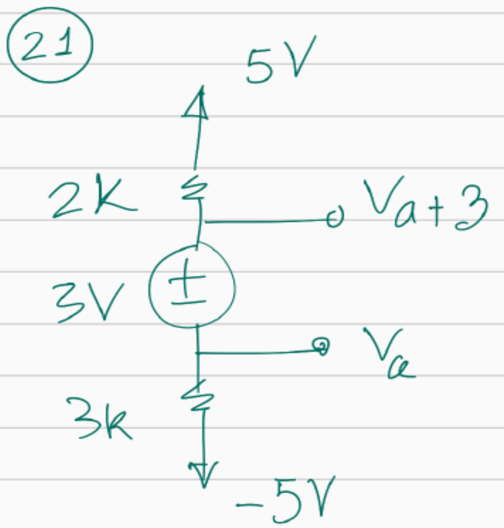
$= -1 \ mA$

21. Miscellaneous

Determine the appropriate value of R_1



21



Nodal at V_a & (V_a+3):

$$\frac{V_a+5}{3} + \frac{V_a+3-5}{2} = 0$$

$$\Rightarrow V_a = -0.8V.$$

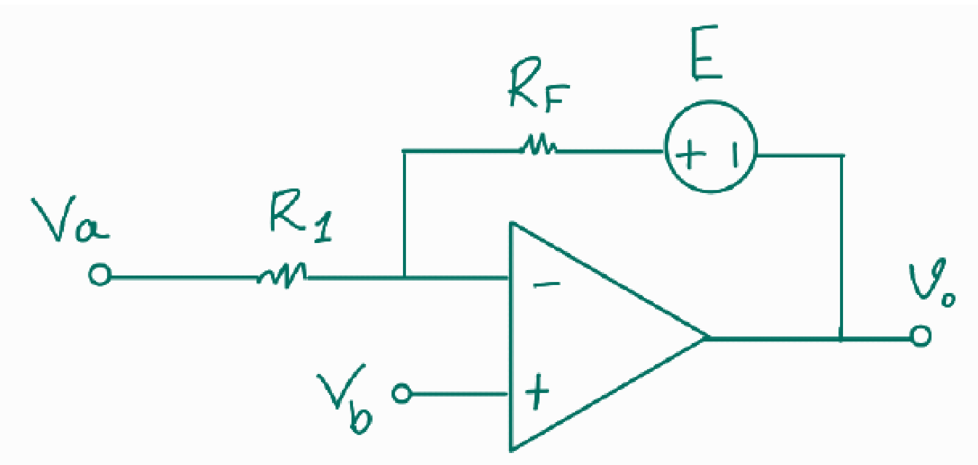
V_a is connected to a non-inverting amplifier

$$\therefore V_o = -2 = V_a\left(1+\frac{1.8}{R1}\right)$$

$\hookrightarrow$ Solve for R_1

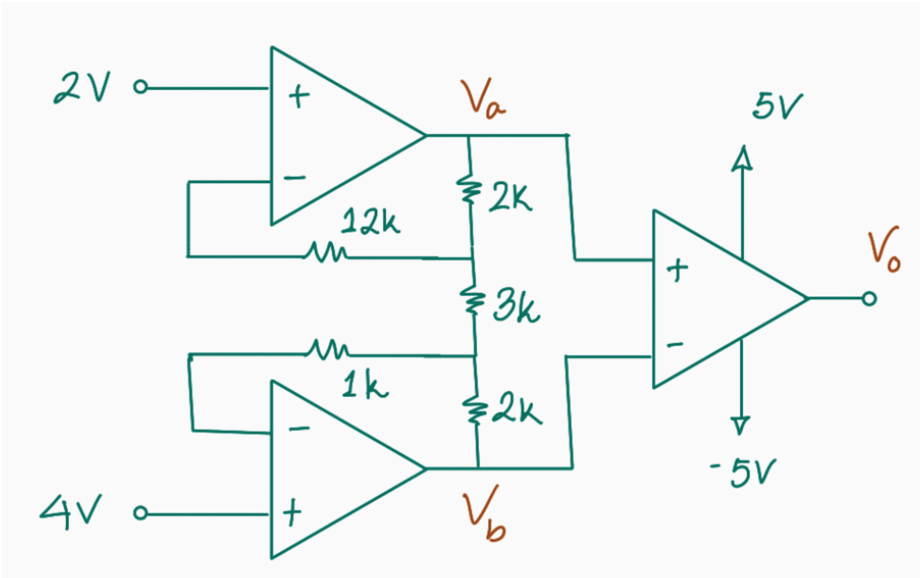
22. Miscellaneous

Express the output voltage v_0 in terms of all the other quantities shown in the circuit below.

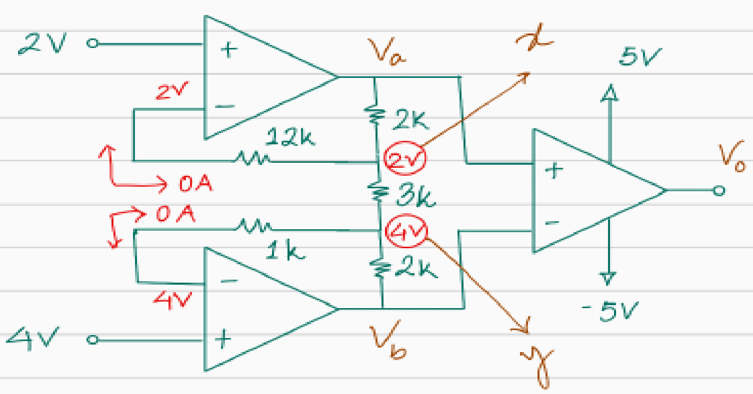


23. Miscellaneous

Determine the output of the comparator, V_0 after finding V_a and V_b.



23



Applying Nodal on the x :

$$\frac{x - V_a}{2} + \frac{x - y}{3} = 0$$

$$\Rightarrow \frac{2 - V_a}{2} + \frac{2 - 4}{3} = 0 \Rightarrow V_a = 0.67V$$

Also Nodal on y node : $V_b = 5.33V$

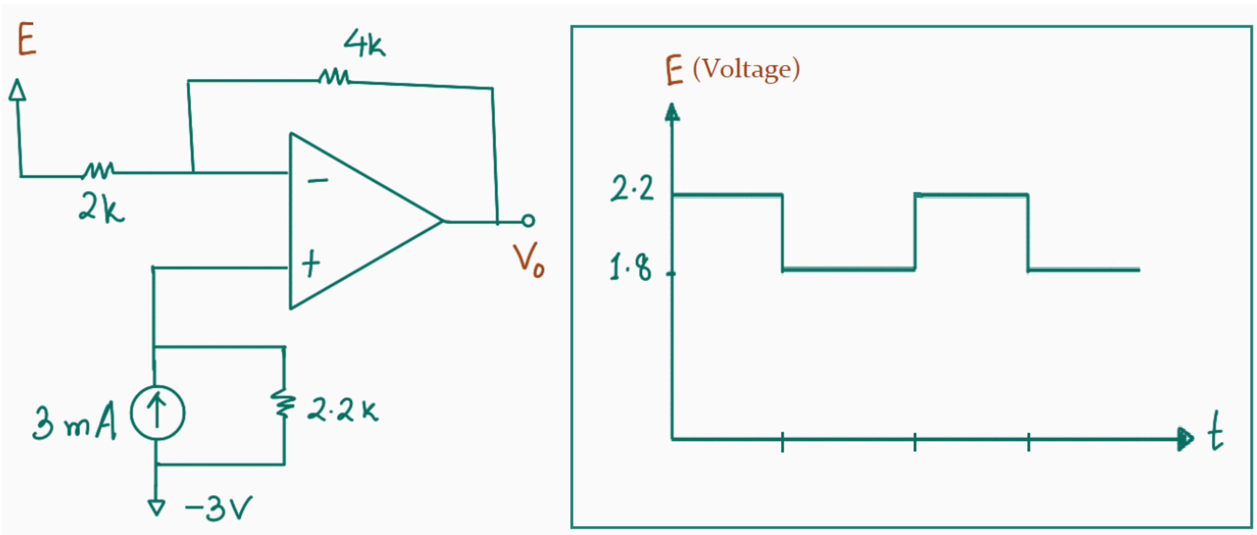
* For the comparator : $V_a < V_b$

$\Rightarrow V^+ < V^-$

$\therefore V_o = -5V$

24. Miscellaneous

Draw the correct waveform of V_0 (with voltage labels) alongside the input waveform of E .



$V^{+} = -3 + (2.2 * 3) = 3.6V$ [you may use source transformation here too]

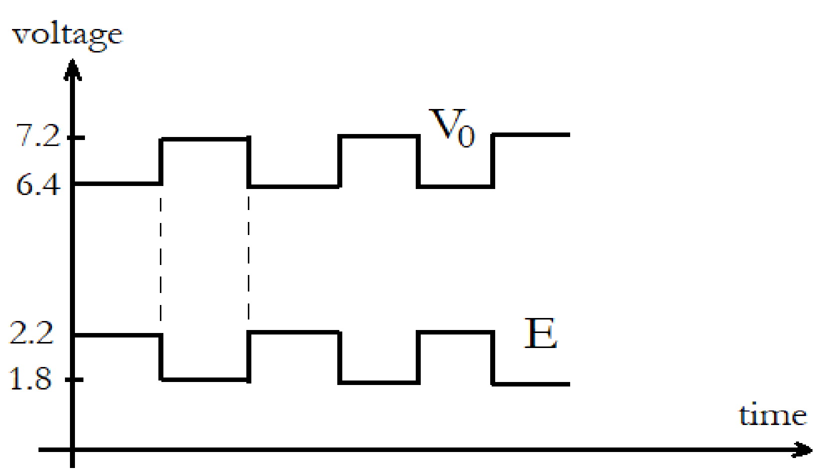
$V^{+} = V^{-}$ = 3.6V

When E= 2.2V => Nodal Analysis at V^{-} :

$(V^{-} - 2.2)/2 + (V^{-} - V_0)/4 = 0 \quad => \quad V_0 =$ 6.4V

When E= 1.8V => Nodal Analysis at V^{-} :

$(V^{-} - 1.8)/2 + (V^{-} - V_0)/4 = 0 \quad => \quad V_0 =$ 7.2V



25. Miscellaneous

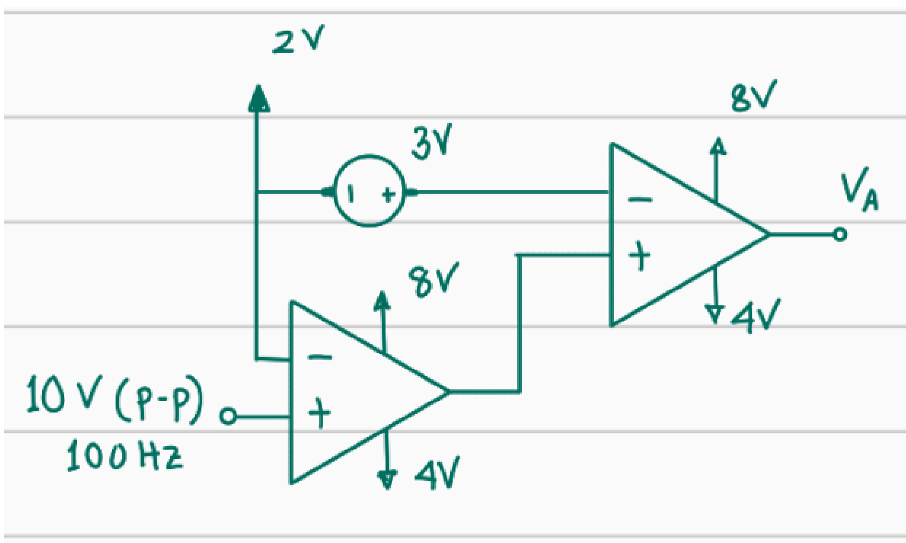
We know that the input-output relationship of an ideal inverting amplifier with op-amp is given by:

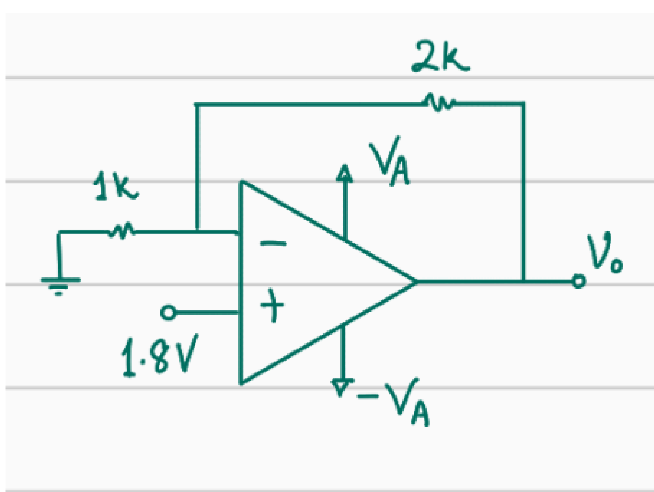
$$V_0 = -\frac{R_F}{R_1} V_{in}$$

However, realistic op-amps are non-ideal. Determine the input-output relationship of a non-ideal inverting amplifier. Use the equivalent circuit of an op-amp which contains A, R_i, R_0.

26. Miscellaneous

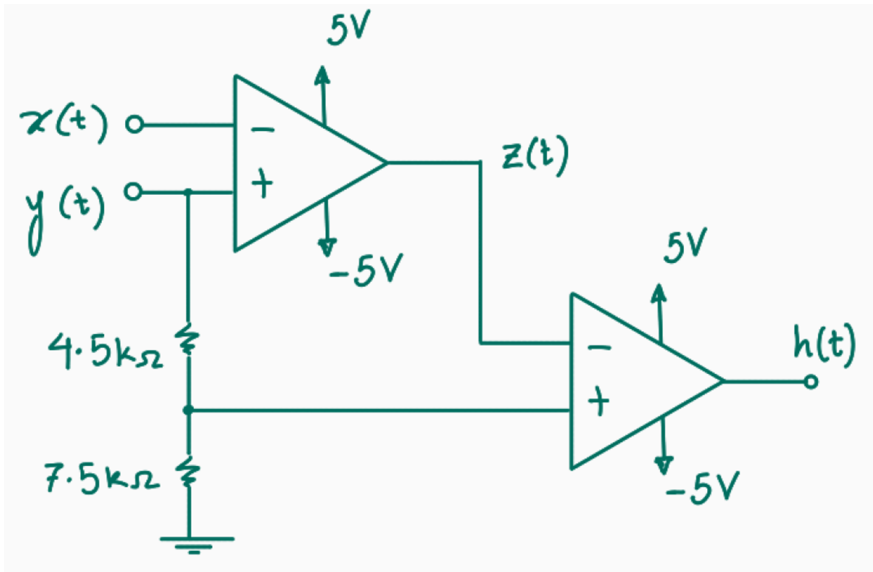
Draw the approximate waveforms of both V_A **and** v_0 **from the circuit below.**

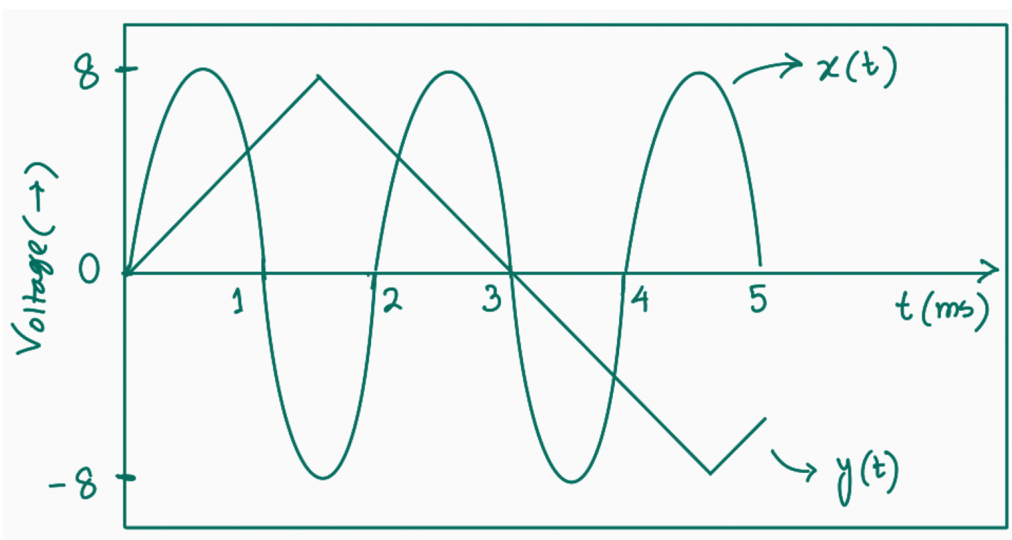




27. Miscellaneous

After drawing both $z(t)$ and $h(t)$, determine the relation between them.





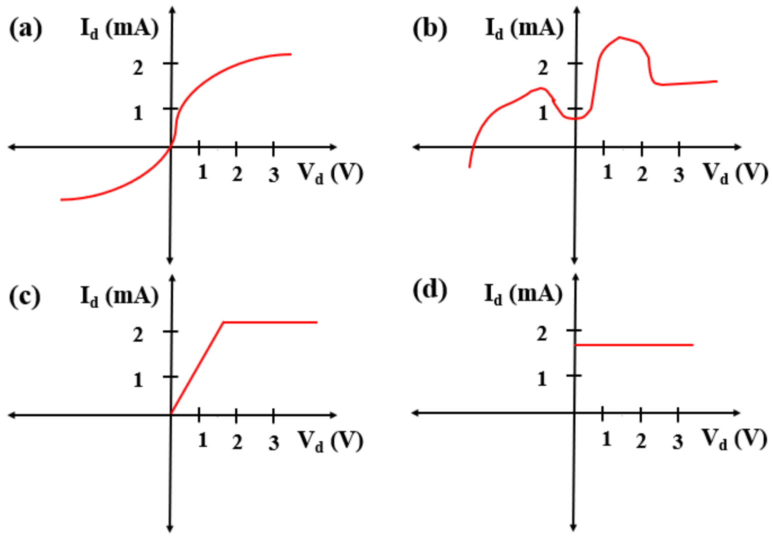
28. Miscellaneous

Draw the VTC of both an inverting and a non-inverting amplifier. The following information are known:

(i) $2R_1 = R_F$ **(ii)** $V_{sat}^{+} = +10V,\ V_{sat}^{-} = -10V$

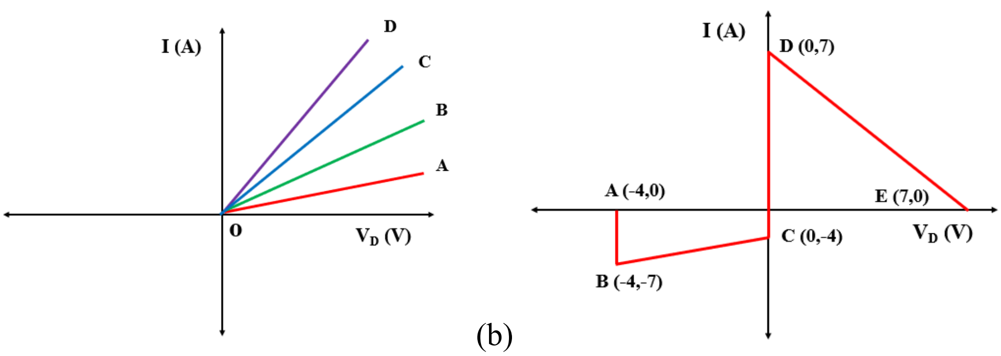
I-V

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



Ans: Linear: (d)

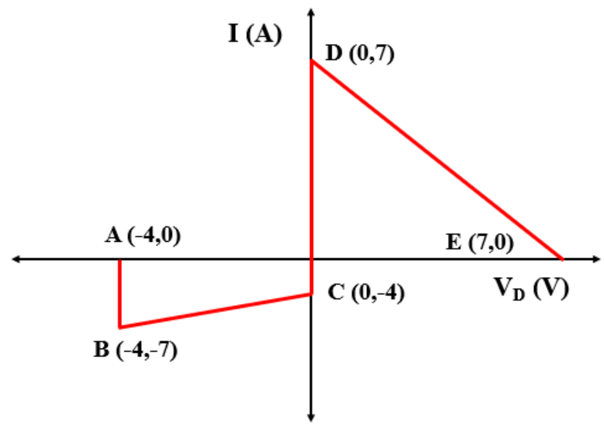
- Write down the slopes of these following regions in ascending order (you do not need to calculate the slopes)



(a) (b)

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

- Find out the slope of the following curves



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

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

$|DE| = \left|\frac{y_2-y_1}{x_2-x_1}\right| = \left|\frac{0-7}{7-0}\right| = 1$ **[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 $-\frac{Vo}{R} = Io$**=c]**

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

i. Vo= 5V, m= 2 $/k\Omega$
ii. Vo= 3.5 V, m= -2.5$/k\Omega$
iii. Vo= -5V, m= 5$/k\Omega$

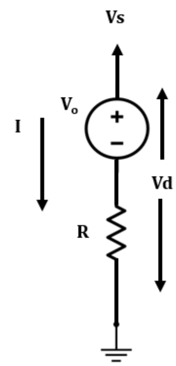
Solution:

i. $|R| = |\frac{1}{m}|$ i.e. $\frac{1}{2}\,k\Omega,\ c = -\frac{Vo}{R} = -\frac{5}{0.5}mA = -\ 2.5\ mA$

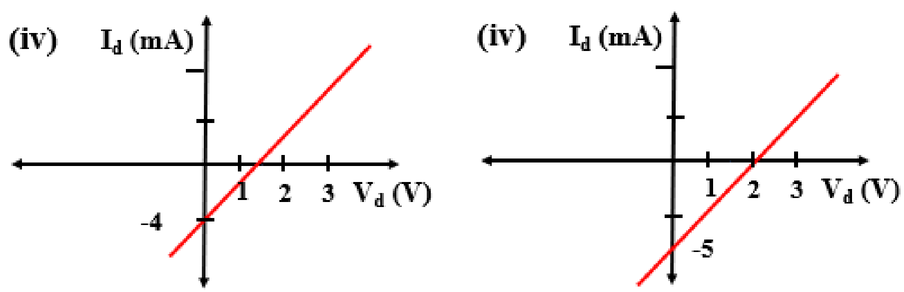
ii. $|R| = |\frac{1}{m}|$ i.e. $\frac{1}{2.5}\,k\Omega,\ \ c = -\frac{3.5}{0.4}mA = -\ 8.75\ mA$

iii. $|R| = |\frac{1}{m}|$ i.e. $\frac{1}{5}\,k\Omega,\ c = -\frac{-5}{0.2}mA\ =\ 25\ mA$

Alternative Diagram:

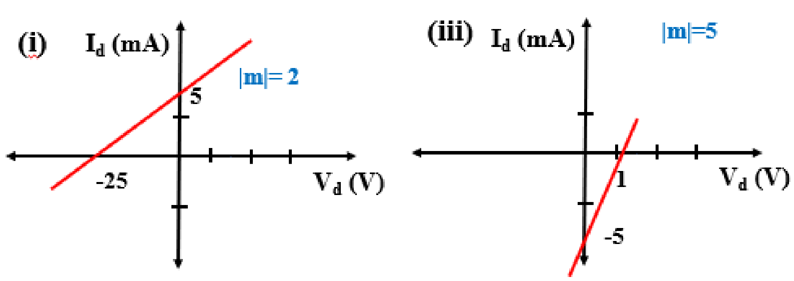


I-V curve:



- Calculate and Show ‘C’ and ‘Vo’ in the figures

  [Hint: Use $IoR\ =-\ Vo$]



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

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

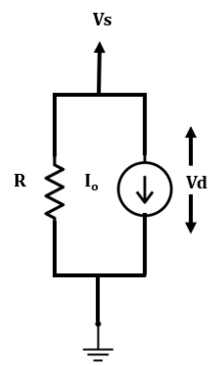
Solution:

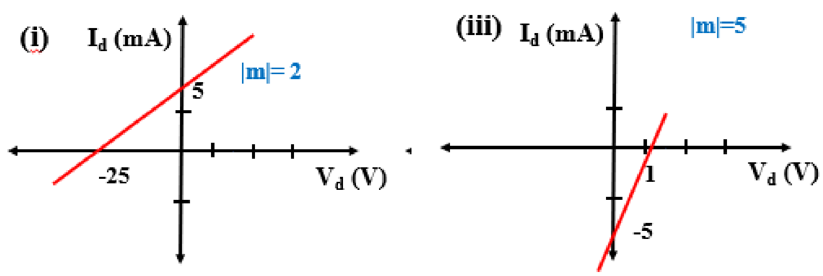
i. $|R|=|\frac{1}{m}|$ i.e. $\frac{1}{2}\ k\Omega,\ c\ =\ Io= 5\ mA, Vo\ =-\ IoR\ =-\ 2.5\ V$

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

iii. $|R|=|\frac{1}{m}|$ i.e. $\frac{1}{5}\ k\Omega,\ c\ =\ Io\ =-\ 5\ mA, Vo\ =-\ IoR\ =\ 1\ V$

Alternative diagram:

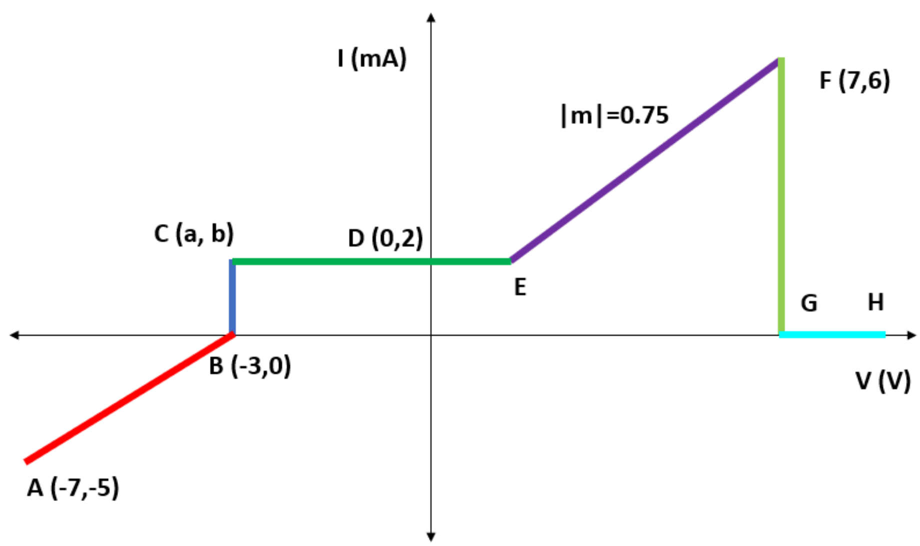




I-V:

- From the I-V curve-

  i. State the device model for each region,



<u>**Solution:**</u>

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, Vo= 10 V in series with a resistor of R= 3 $k\Omega$.

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= m. Vs$-\frac{Vo}{R}$

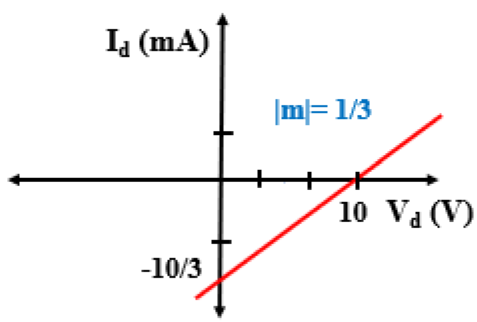
ii. Vo= 10 V, R=3 $k\Omega$

$|\mathbf{m}| = |\frac{1}{R}| = \frac{1}{3}$

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

X axis intersection: Vo= 10 V

iii.



- A Voltage Source, Vo= -10 V in series with a resistor of R= 3 $k\Omega$.

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= m. Vs$-\frac{Vo}{R}$

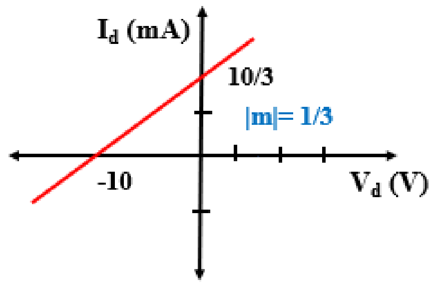
ii. Vo= 10 V, R=3 $k\Omega$

$|\mathbf{m}| = |\frac{1}{R}| = \frac{1}{3}$

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

X axis intersection: Vo= -10 V

Iii.



- A Current Source, Io= 5 mA in parallel with a resistor of R= 5 $k\Omega$.

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, $Is = \frac{Vs}{R} + Io$

ii. Vo= 10 V, R=5 $k\Omega$

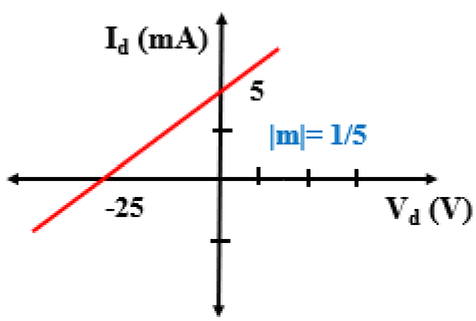
|m| $= |\frac{1}{R}| = \frac{1}{5}$

Y axis intersection : c= Io= 5 mA

X axis intersection: $IoR = - Vo$

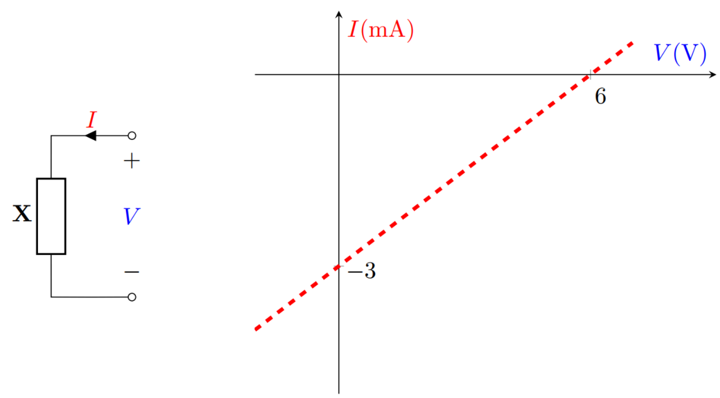
Or, Vo= -5*5 V= -25V

iii.



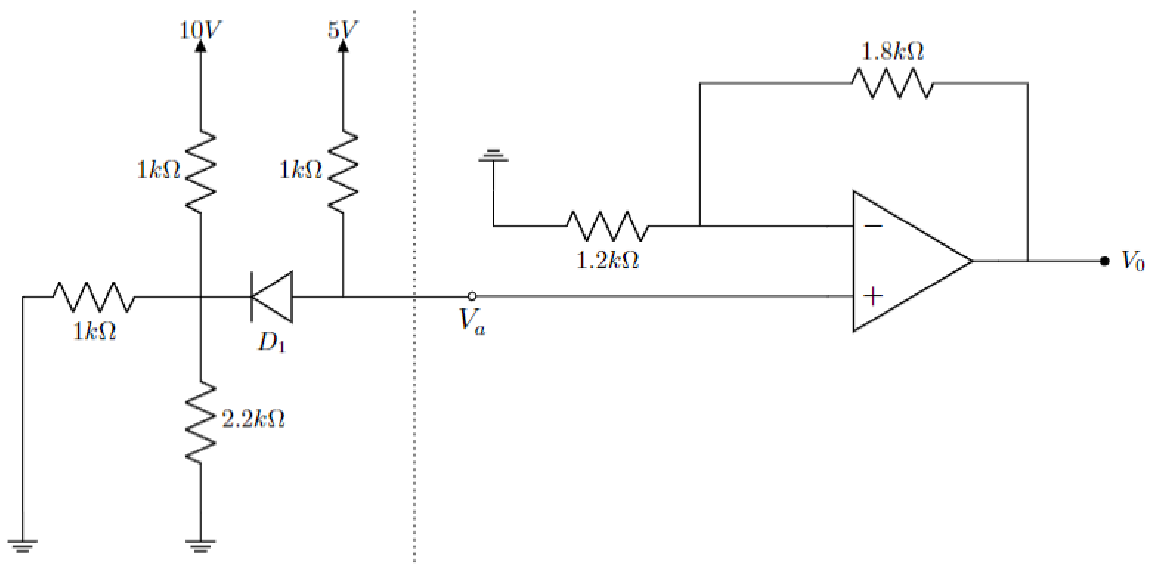
- You are provided with the following circuit elements:
    - Two 1 kΩ resistors
    - A 4 V voltage source
    - A 2 V voltage source

  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.



Hybrid Problems

1.



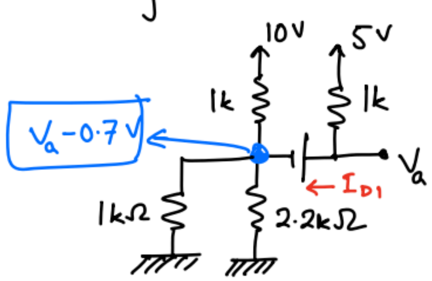
The saturation voltages of the Op-Amp are given as- $V^{+}_{sat} = +10V$ and $V^{-}_{sat} = -10V$. The forward voltage drop of the diode, V_D is $0.7V$.

(a) **Determine** the operating mode diode, D_1. Verify your assumption with 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, Vo of the Op-Amp.

ⓐ Assuming D_1 to be ON:



Node equation at supernode (V_a)

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

$\Downarrow$

$\boxed{V_a = 4.84\ V}$

$\boxed{V_a = 4.84\ V}$

$\Downarrow$

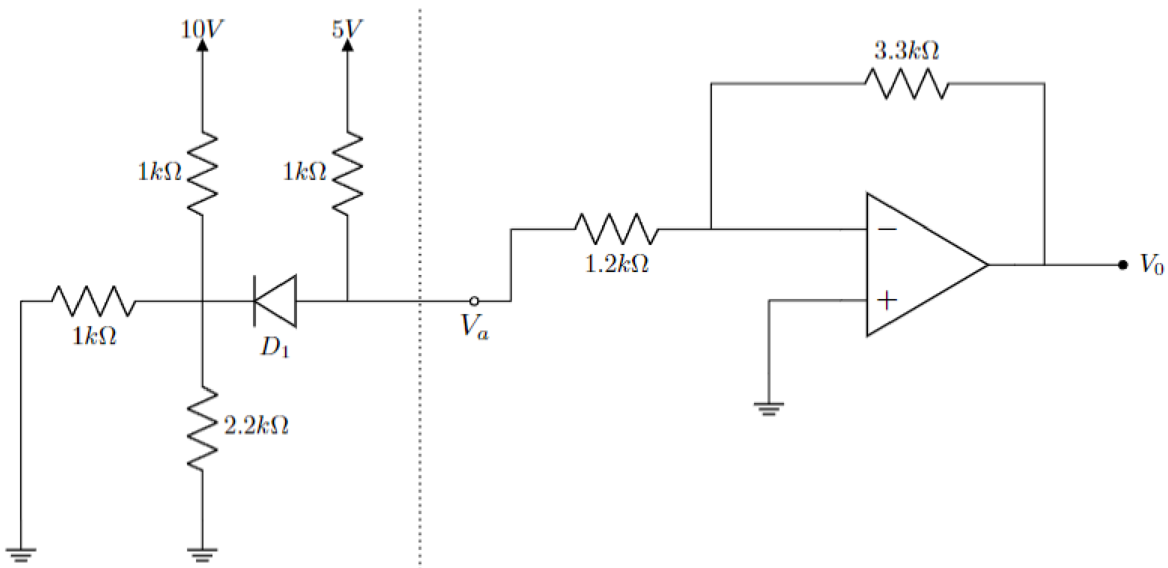
$I_{D1} =$

$= 0.16\ mA > 0$ (no current flows into op-amp terminals)

∴ Assumption true.

V0 = (1+1.8/1.2)*Va

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 $0.7V$.

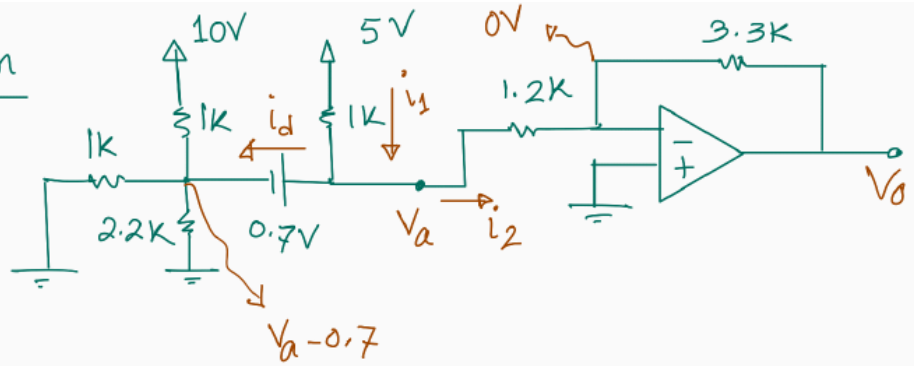
(a) **Determine** the operating mode diode, D_1. Verify your assumption with necessary calculations.

(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, Vo of the Op-Amp.

Soln:

Assume D_1 on



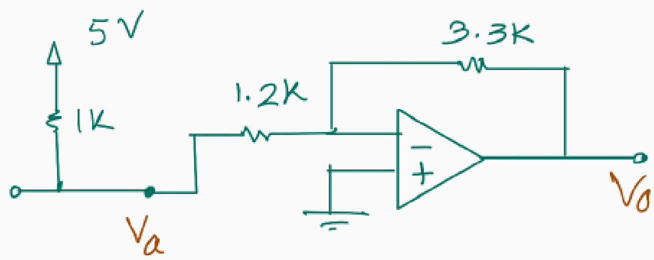
Nodal: $(V_a-0.7)\left(1+2.2^{-1}+1\right)+V_a\left(1+1.2^{-1}\right)=10+5$

$$\Rightarrow V_a = 3.898\ V$$

$$\therefore i_d = i_1 - i_2 = \frac{5-V_a}{1} - \frac{V_a-0}{1.2} = -2.15\,mA < 0\,mA$$

$\boxed{\therefore D_1 \text{ "cannot" be ON}}$

$\therefore$ D1 is OFF $\rightarrow$ Left side Open $\rightarrow$ Equivalent ckt:

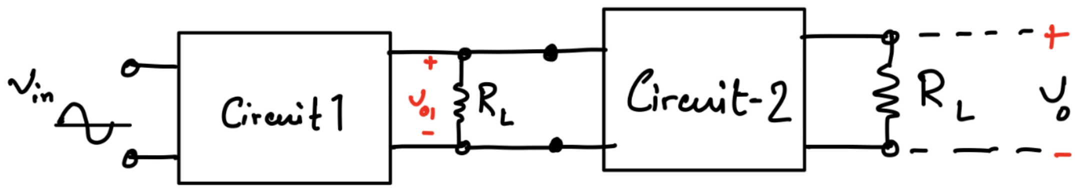


$\Rightarrow$ This is an invterting amplifier with 5V and (1k + 1.2k) at the inverting terminal

$$\therefore V_o = -\frac{3.3}{1+1.2}\times 5V = -6.82\,V$$

3.

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



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

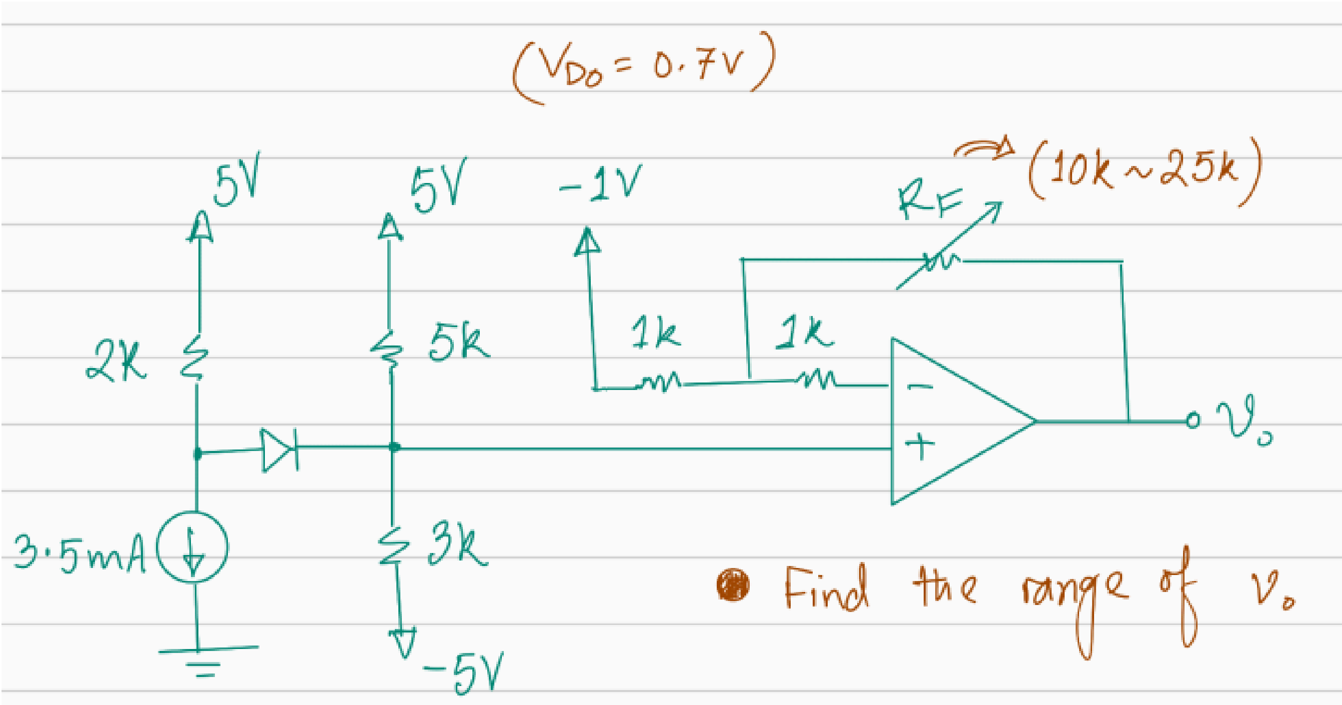
(a) Design **circuit-1** with the single diode and $R_L = 10\ k\Omega$ (R_L is already provided in the diagram as output terminals of **circuit-1**) to get a rectified voltage and determine the DC value of the output voltage (v_{o1}) of the circuit. [1+2]

(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]

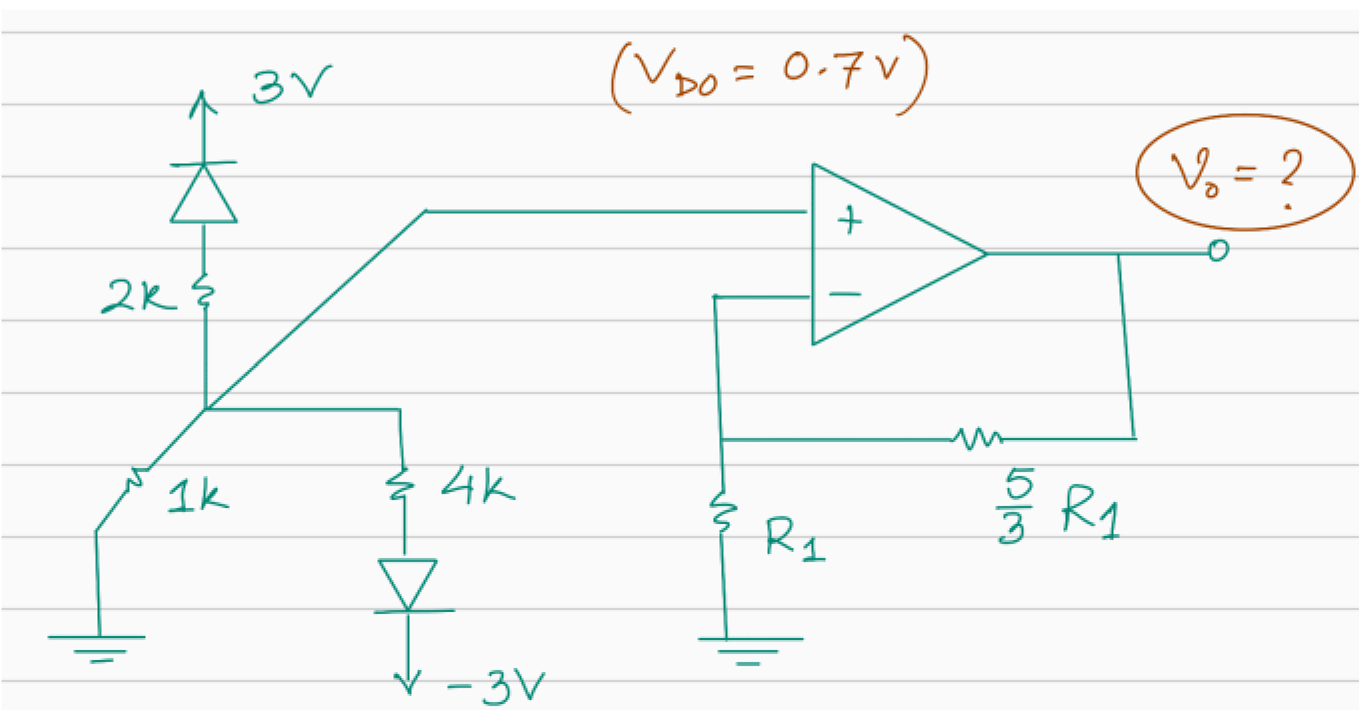
(c) What should be the value of a capacitor used at the output end of **circuit-1** with R_L to reduce the ripple voltage of v_{o1} to $0.1\ V$. How should the capacitor be connected with R_L in the diagram? [4+1]

(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]

4.


(V_{DO} = 0.7V)
5V
5V
−1V
RF
(10k ~ 25k)
2K
5k
1k
1k
3.5mA
3k
−5V
v_o
Find the range of v_o

5.


3V
(V_{DO} = 0.7V)
V_o = ?
2k
1k
4k
−3V
R_1
$\frac{5}{3}R_1$