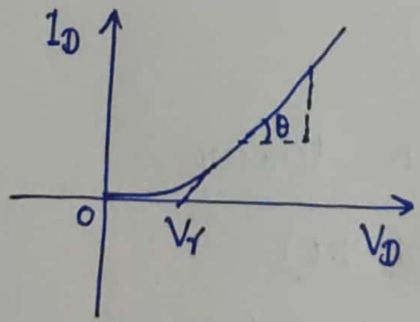
Diode Equivalent Circuit

An equivalent circuit is a combination of elements (e.g. R, L, C, etc.) properly chosen to best represent the actual characteristics of device in a particular operating region.

<u>Why we need equivalent circuit?</u> we can not use traditional circuit analysis techniques (like, KVL, KCL, network theorems, etc.) with actual device.

1. <u>Piecewise linear model:</u>

<u>Assumption:</u> I-V characteristics is linear in forward wise (with small linearity)

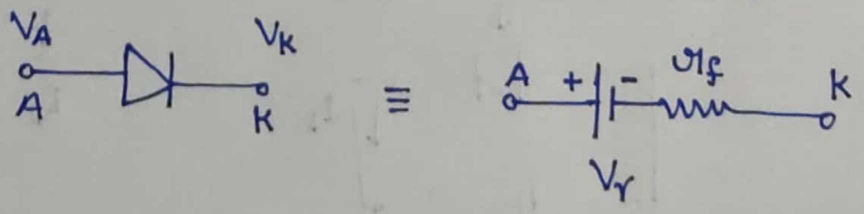


Forward resistance,

$$r_f = \frac{1}{\text{Slope}} = \frac{1}{\tan\theta}$$

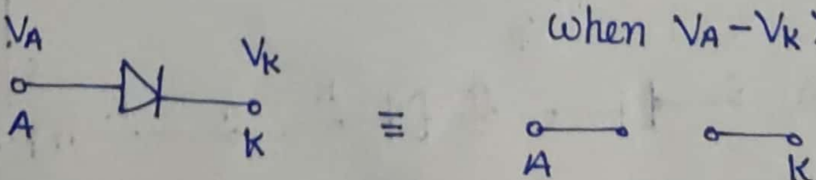
$$\tan\theta = \frac{\Delta I_D}{\Delta V_D}$$

(a)



when $V_A - V_K > V_\gamma$

(b)



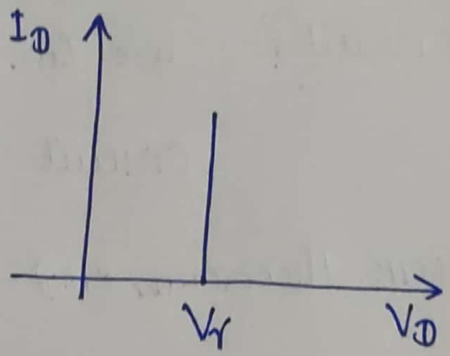
when $V_A - V_K \leq V_\gamma$

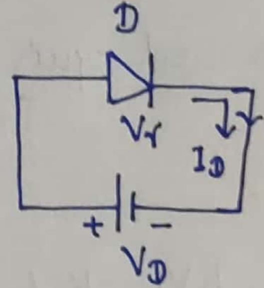
2. Constant Voltage Drop / Simplified Equivalent Ckt.

1 Assumptions: (i) I-V curve is piece-wise linear

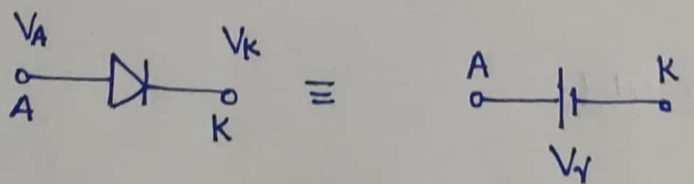
(ii) r_f is very small ($r_f \simeq 0$)

I-V characteristics



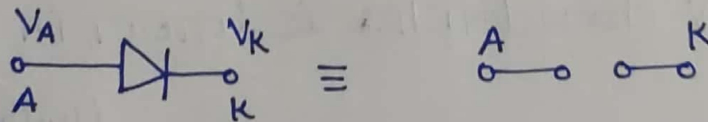


(a)



when $V_A - V_K > V_\gamma$

(b)



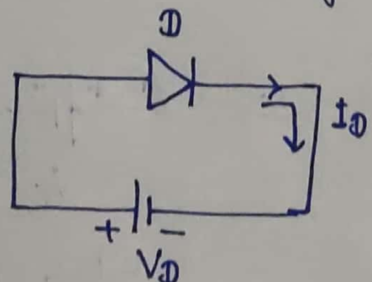
when $V_A - V_K \leq V_\gamma$

3. Ideal model

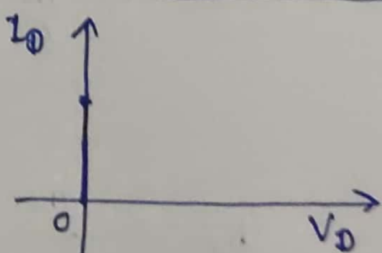
Assumptions: (i) I-V curve is piece-wise linear

(ii) r_f is very small ($r_f \simeq 0$)

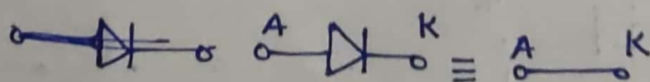
(iii) Cut-in voltage is very small ($V_\gamma \simeq 0$)



I-V curve / characteristics

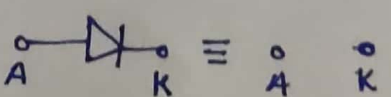


(a)



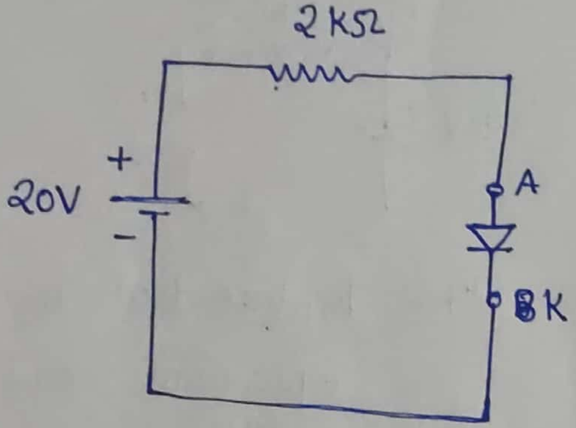
if F.B.

(b)

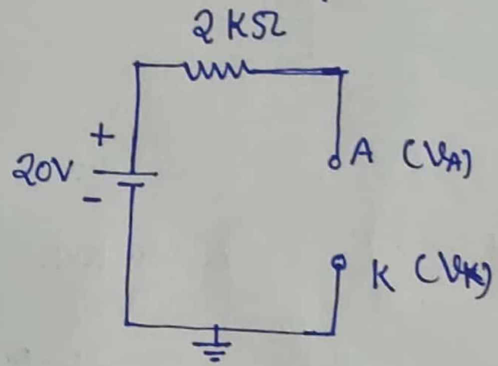


if R.B.

Q. 1: Find the current I in the given circuit? Given that $V_\gamma = 0.7$ and $r_f = 200\,\Omega$.



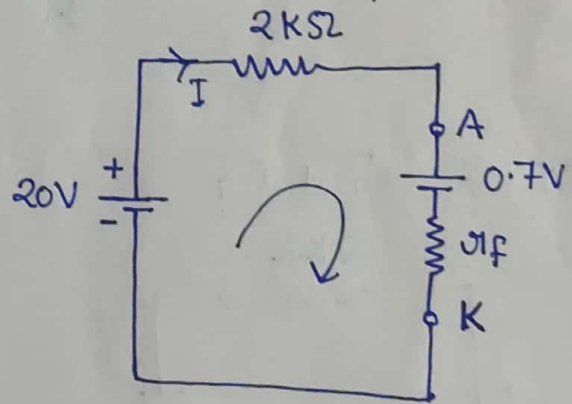
Sol: Step 1: Determine the state of Diode



$\cancel{V_A - V_K > V_\gamma} \Rightarrow V_{AK} = 20V$

$V_{AK} > V_\gamma$

Step 2: Replace diode by equivalent ckt model



Apply KVL

$\cancel{2I + 0.7I}$

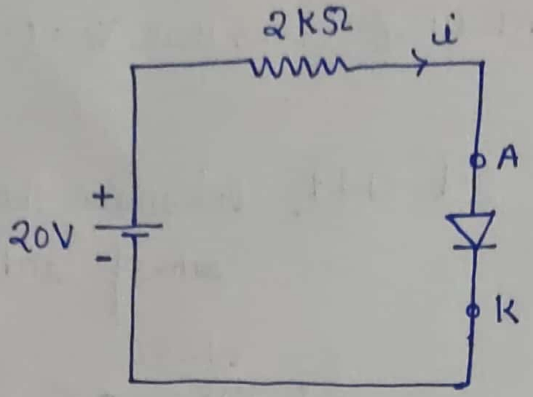
$2000I + 0.7I + r_f I = 20$

$$I = \frac{20 - 0.7}{2000 + 200}$$

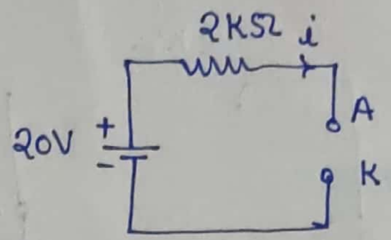
$$= \frac{19.3}{2200} = 8.73\ mA$$

A

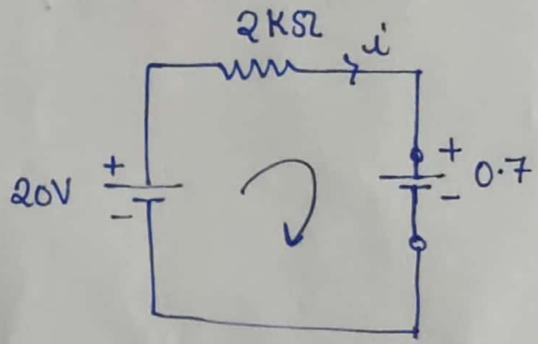
Example 2:- Find current i if $V_\gamma = 0.7V$.



Step 1: Determine the state of diode



Step 2: Replace diode by the equivalent model



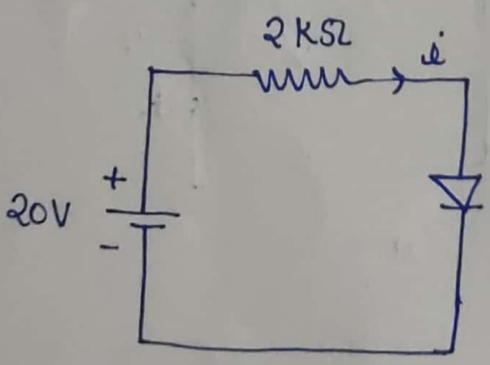
Apply KVL

$$i = \frac{20-0.7}{20000}$$

$$= \frac{19.3}{20000}$$

$$= 9.65\ mA$$

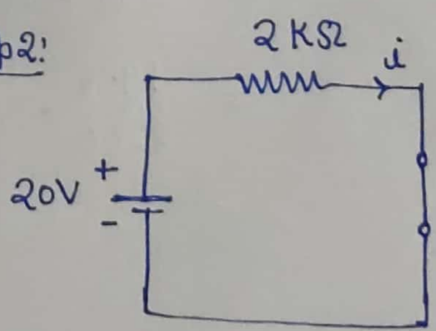
Example 3:- Find i ?



Step 1: Determine the state of diode

Diode is in F.B.

Step 2:

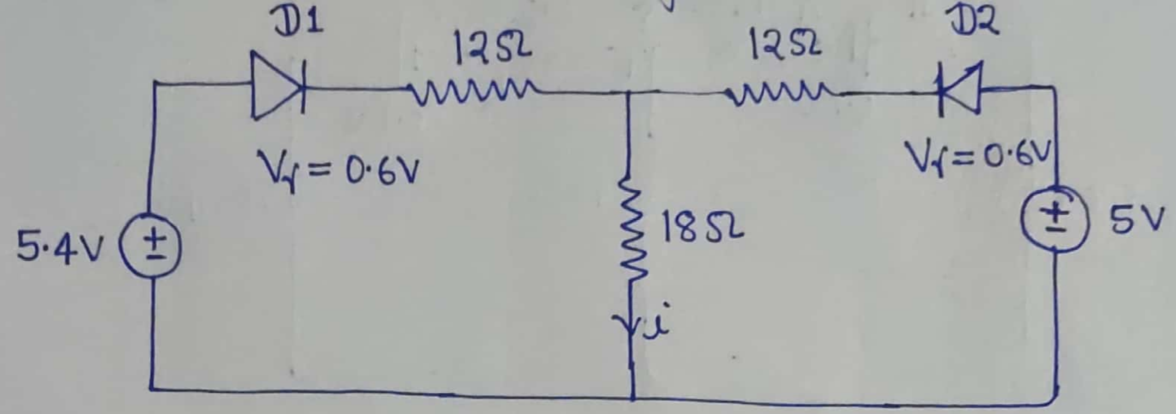


$$i = \frac{20}{2000}$$

~~= 10mA~~

$= 10\ mA$

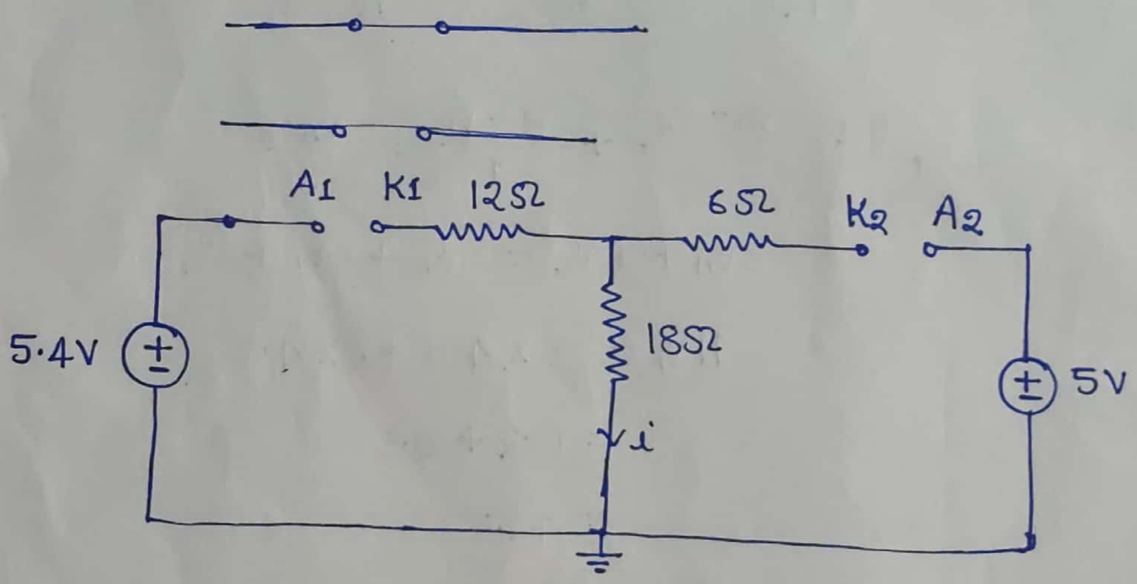
Ex:- Determine the current i in the given Circuit?



Sol:-

Step 1: Determine the state of diodes

(i) Assume that all diodes are in reverse bias



$V_{A1} = 5.4V$; $V_{A2} = 5V$

$V_{K1} = 0V$; $V_{K2} = 0V$

~~$V_{A1} =$~~

$V_{A1} - V_{K1} = 5.4 - 0$; $V_{A2} - V_{K2} = 5 - 0$

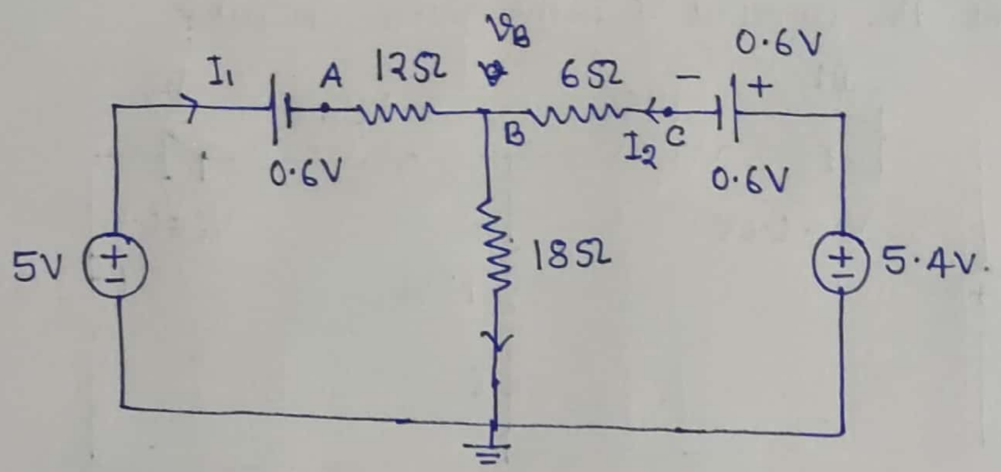
$= 5.4V$ $\quad V_{A2K2} = 5.0 > V_\gamma$

$> V_\gamma$

D2 is F.B.

D1 is F.B.

Step2:



$$V_A = 5 - 0.6 \quad ; \quad V_C = 5.4 - 0.6$$
$$= 4.4V \quad ; \quad = 4.8V$$

$$\frac{V_A - V_B}{12} + \frac{V_C - V_B}{6} = \frac{V_B - 0}{18}$$

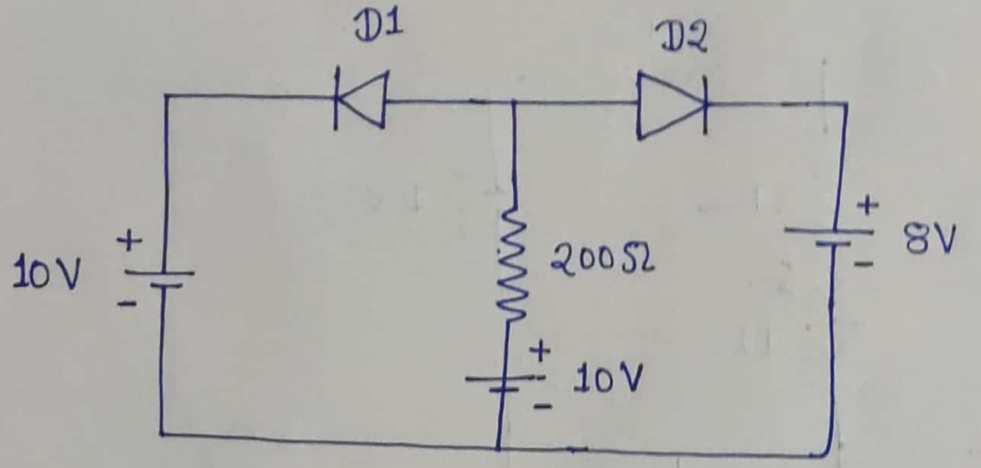
Or $$\frac{V_A - V_B}{2} + \frac{V_C - V_B}{1} = \frac{V_B}{3}$$

$$3V_A + 6V_C = 2V_B + 6V_B + 3V_B$$

$$11V_B = 3 \times 4.4 + 6 \times 4.8$$
$$= 13.2 + 28.8$$
$$= 42.0$$
$$V_B = \frac{42}{11}$$

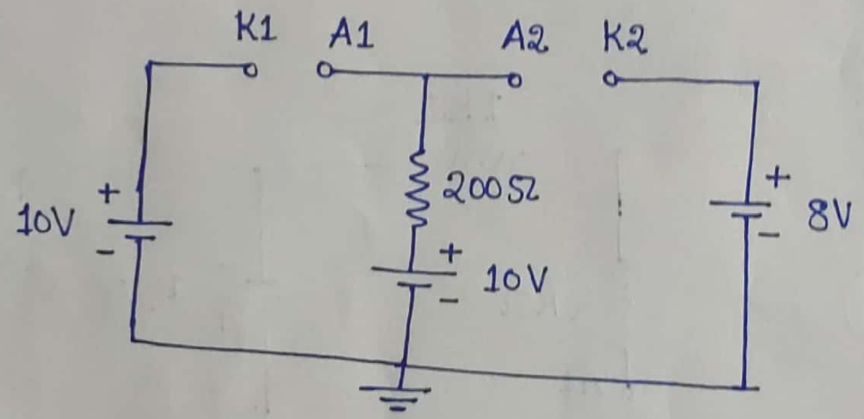
$$i = \frac{\frac{42}{11} - 0}{18} = \frac{42^{7}}{18_{3} \times 11}$$
$$= 7/33\,A$$

Ex: Determine the current I ?



Sol:

Step 1:



For D1

$V_{K1} = 10V$

$V_{A1} = 10V$

$V_{A1} - V_{K1} = 0V$

D1 R.B.

For D2

$V_{K2} = 8V$

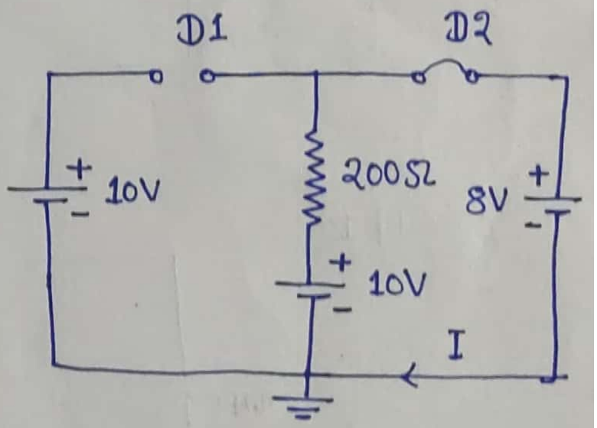
$V_{A2} = 10V$

$V_{A2K2} = V_{A2} - V_{K2}$

$= 10 - 8$

$= 2V$

D2 F.B.

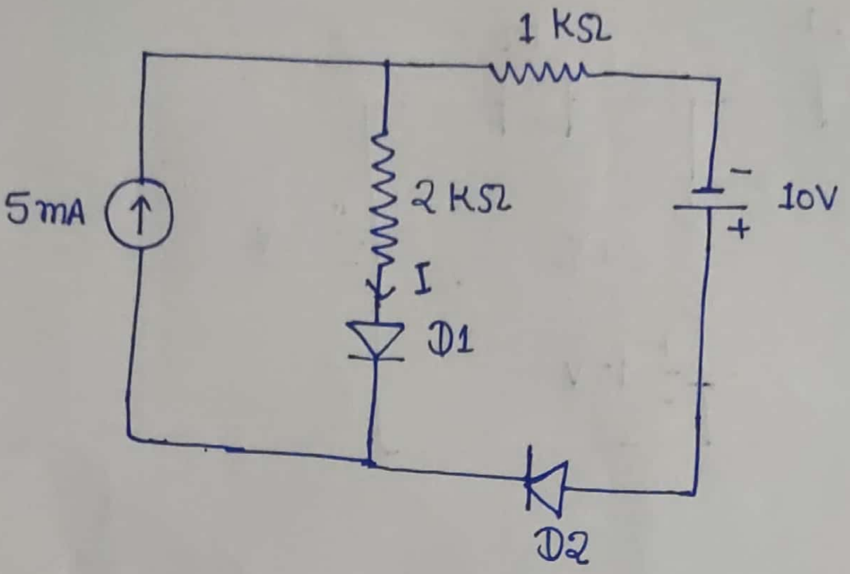


$8 - 10 + 200I = 0$

or $I = \frac{2}{200}$

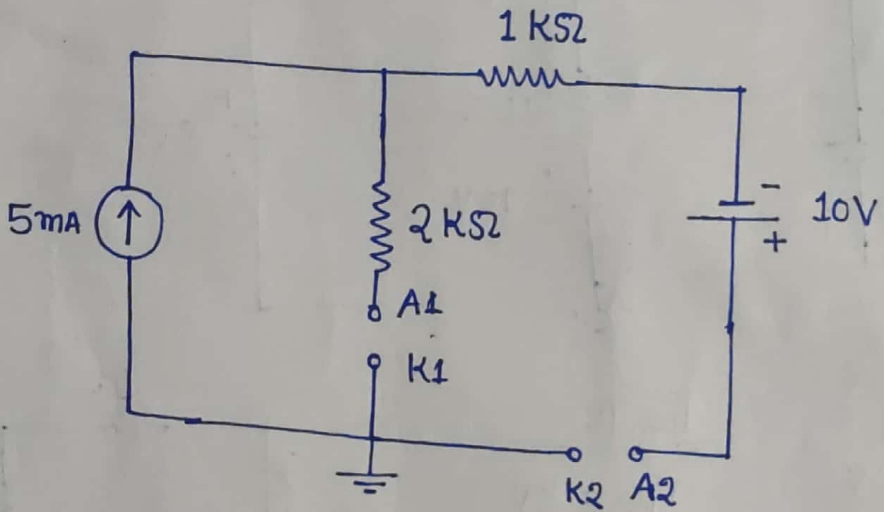
$= 10mA$

Ex:- Determine the current I? (Both diodes are ideal.)



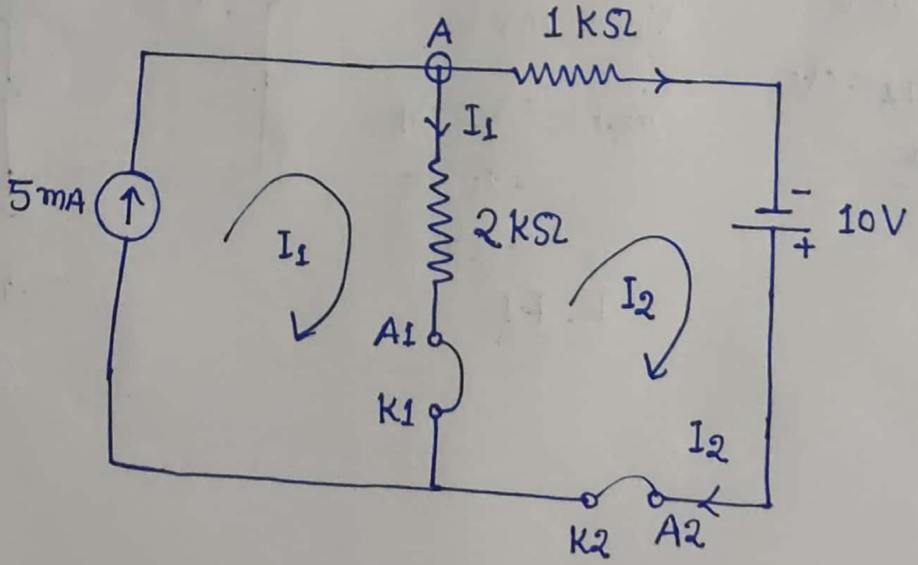
Sol:

Step 1:



KCL is Violated

Step 1:



For L2

$-10 - 2000I_1 + 1000I_2 = 0$ —(1)

Apply KCL at A

$I = I_1 + I_2$

$5\text{ mA} = I_1 + I_2$

or $I_1 = 5 - I_2$

$-10 - 2I_1 + I_2 = 0$

$I_2 - 2I_1 = 10$

$I_2 - 2(5 - I_2) = 10 \Rightarrow I_2 - 10 + 2I_2 = 10$

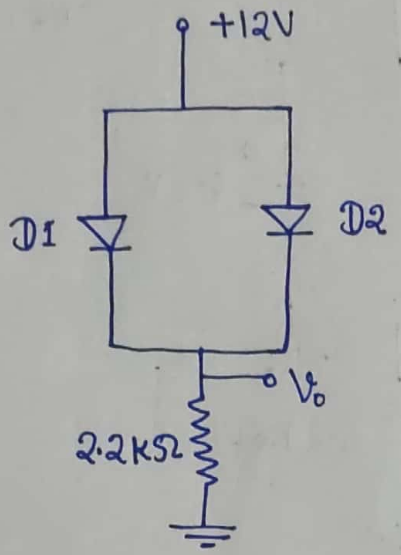
$\Rightarrow I_2 = 20/3\text{ A}$ D2 : FB

$I_1 = 5 - I_2$

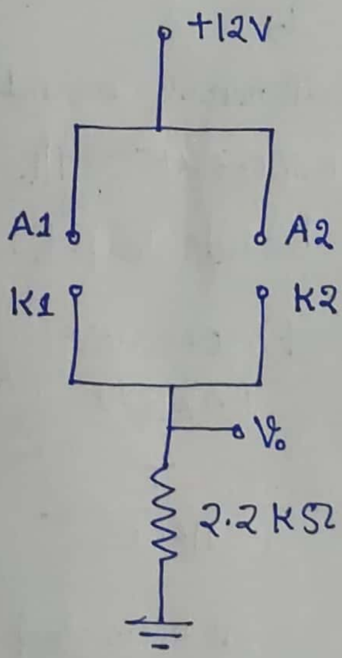
$= 5 - \frac{20}{3} = -\frac{5}{3}\text{ A}$

D1 : R.B.

Ex:- Find V_o ? Given that $(V_\gamma)_{D1} = 0.7V$ and $(V_\gamma)_{D2} = 0.3V$.



Sol: Step 1: Determine state of diodes



For D1

$V_{A1} = 12V$

$V_{K1} = 0V$

$V_{A1} - V_{K1} = 12 - 0 = 12V$

$D1 \rightarrow$ F.B.

For D2

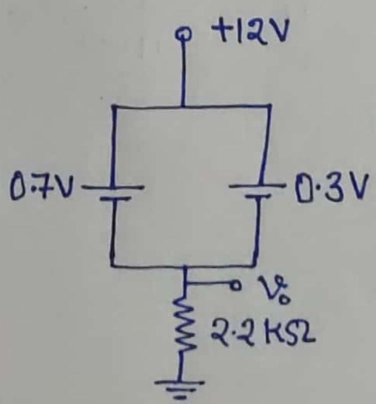
$V_{A2} = 12V$

$V_{K2} = 0V$

$V_{A2} - V_{K2} = 12 - 0 = 12V$

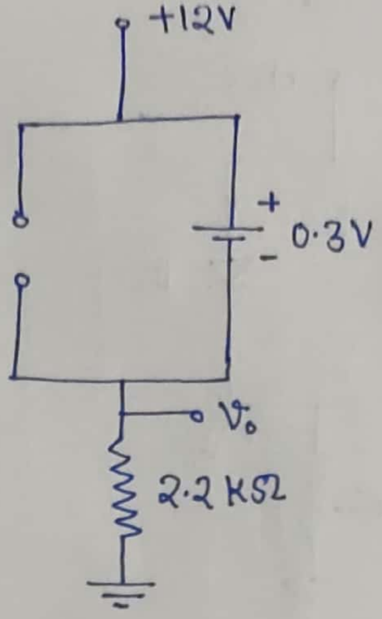
$D2 \rightarrow$ F.B.

Step 2:



Not Possible

Sol:



$$-12 + 0.3V + 2.2i = 0$$

$$2.2i = 12 - 0.3$$

$$i = \frac{11.7}{2.2}\ mA$$

Thermal Valtage

$$V_T = \frac{KT}{q} =$$

K = Baltzmann's constant ; $\bar{e} = 1.6 \times 10^{-19} C$

$= 1.38066 \times 10^{-23}\ J/K$

T = absolute temp. [$T = 273 + T'(^\circ C)$]

$$V_T = \frac{1.38066 \times 10^{-23}}{1.6 \times 10^{-19}} \times T$$

$$= \frac{T}{11600}$$

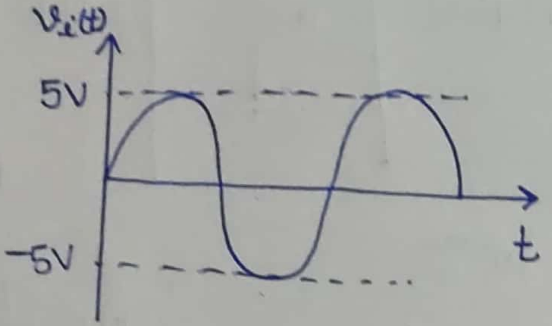
At Room temp.

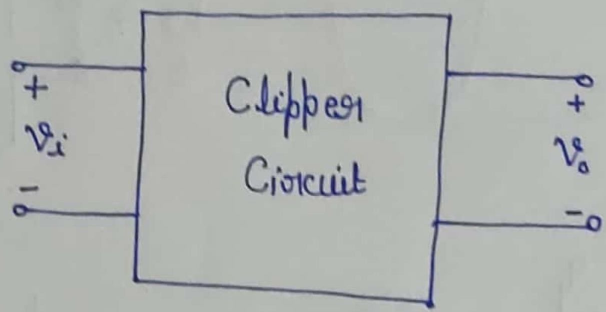
$T = 27^\circ C = 27 + 273 = 300\ K$

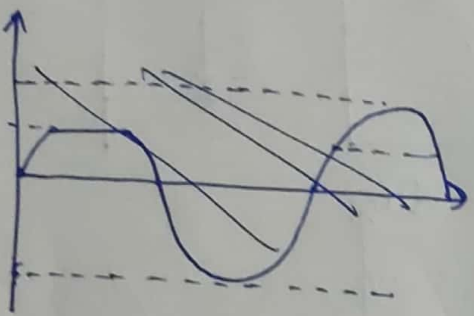
$$V_T = \frac{300}{11600} = \frac{3}{116} = \underline{0.029\ V}$$

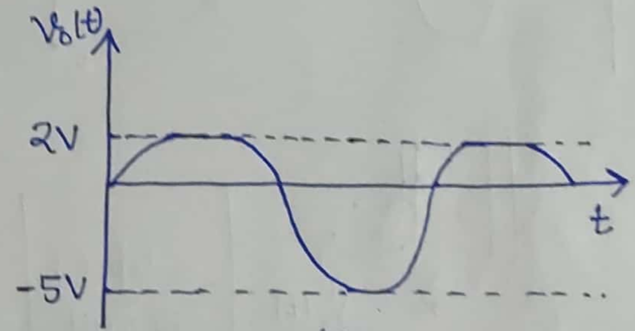
Clipper Circuits (Limiting Circuits)

Function: To limit the minimum and/ or maximum value of the input voltage.



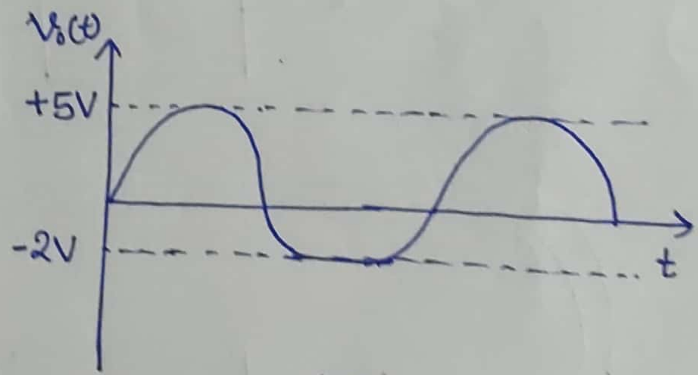




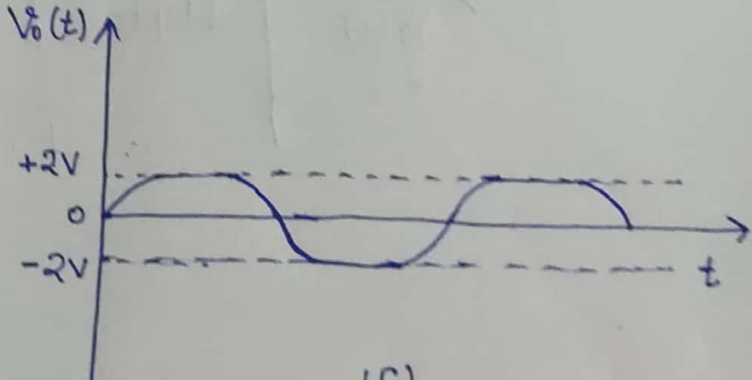


(a)

Possible outputs of a Clipper circuit

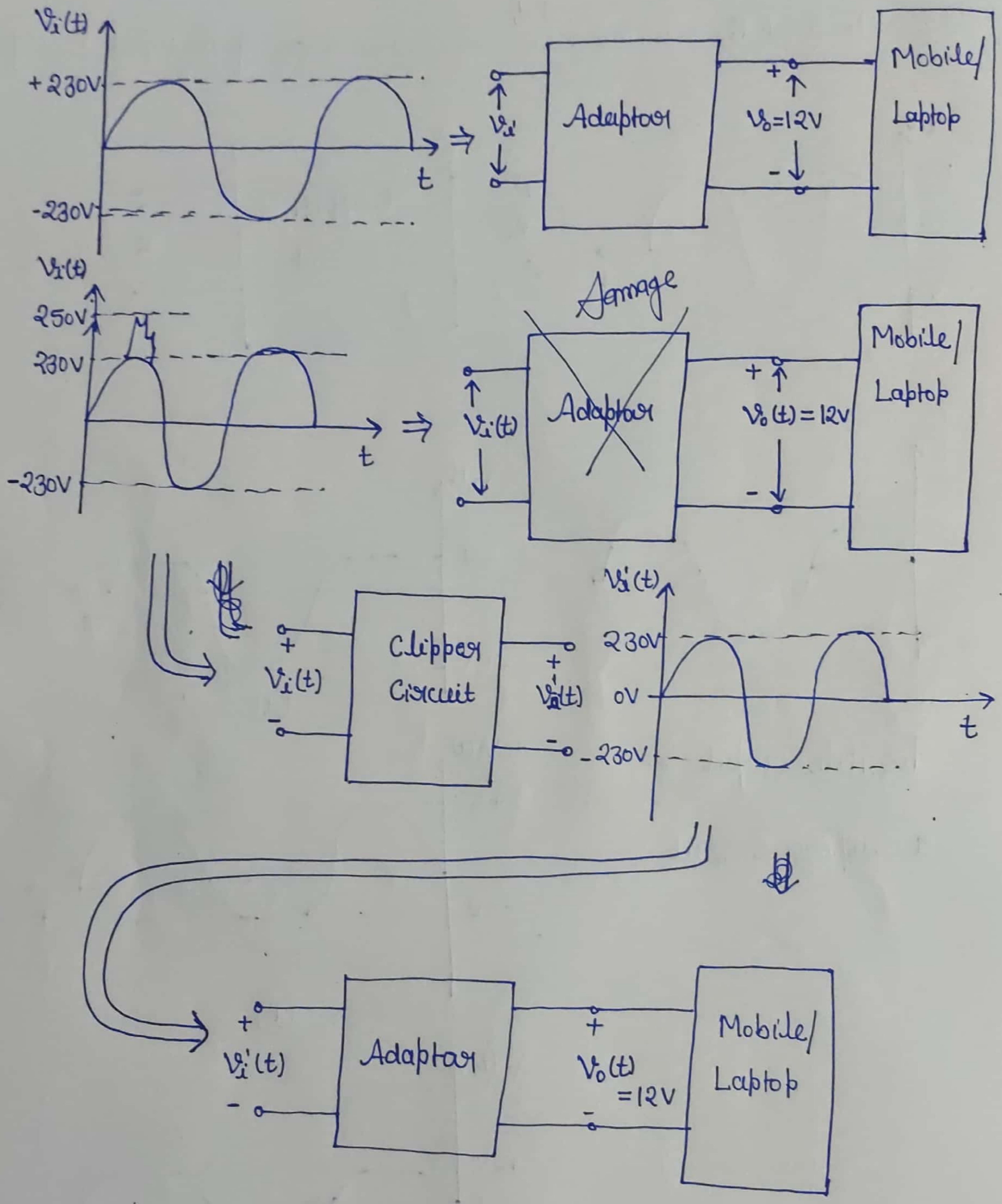


(b)

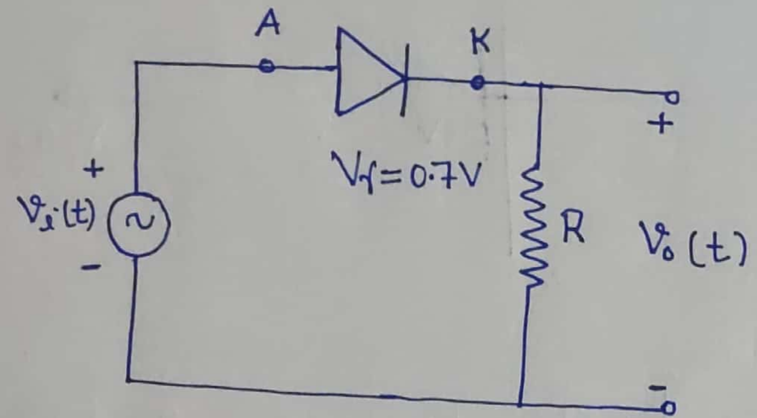


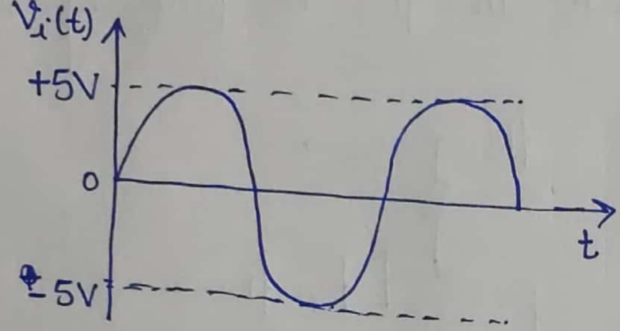
(c)

Application of Clipper Circuit



Example-1: Determine V_o and transfer characteristics for the given circuit?

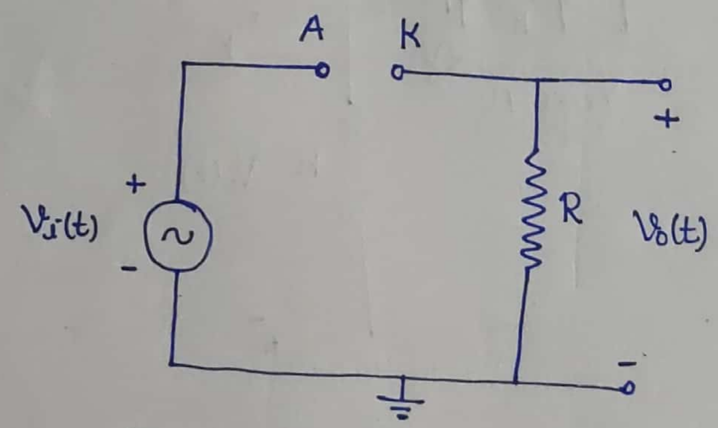




$V_i(t) = 5 \sin \omega t$

Sol:-

Step 1: Determine the condition for F.B. and R.B.

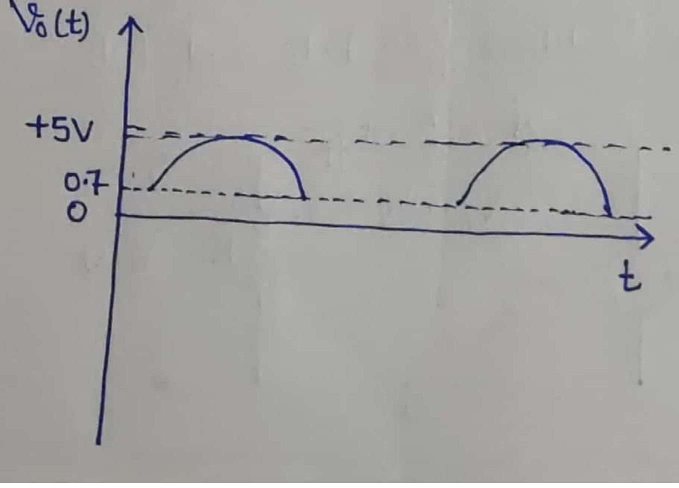


D is F.B. if

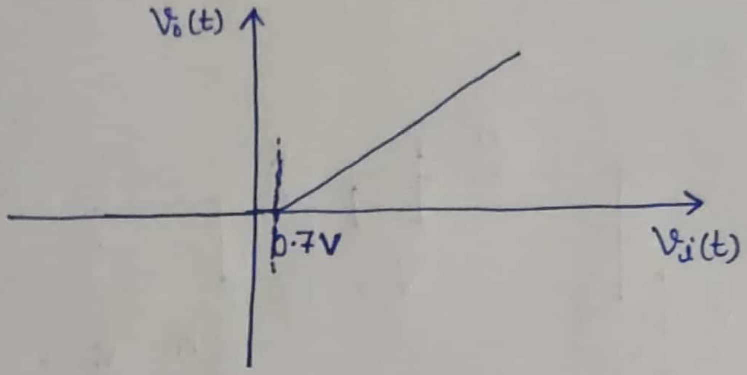
$V_A - V_K > 0.7V$

D is R.B. if

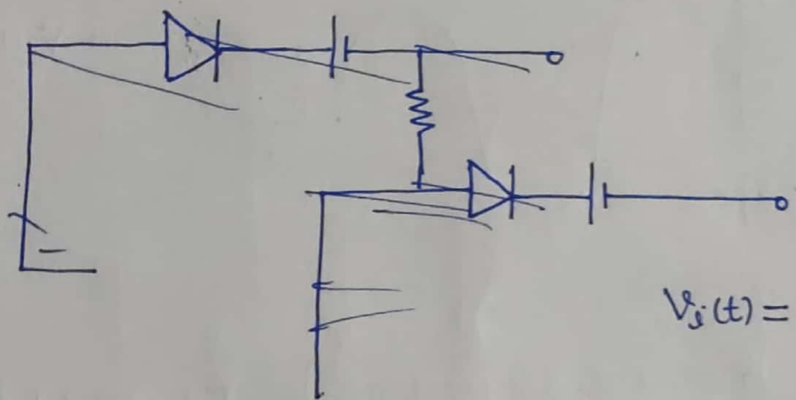
$V_A - V_K \leq 0.7V$



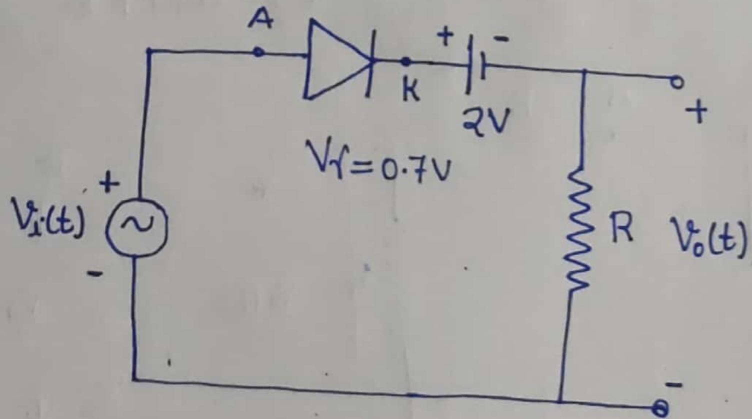
Transfer characteristics



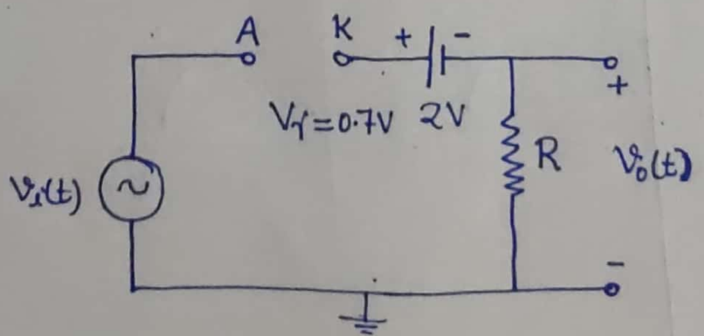
Ex:- Find V_o and transfer characteristics for the following circuit?



$V_i(t) = 10 \sin\omega t$



Sol: Determine the condition for F.B. and R.B.



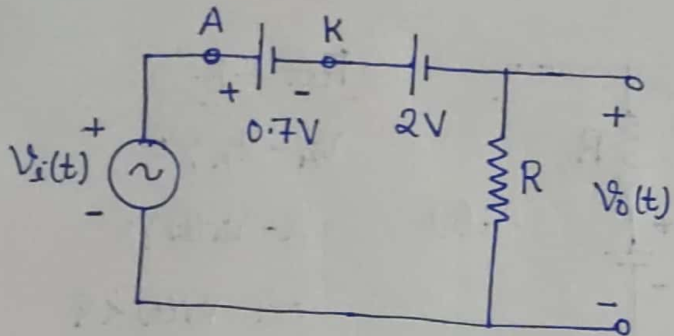
For F.B.

$V_A - V_K > 0.7$

$V_i(t) - 2 > 0.7$

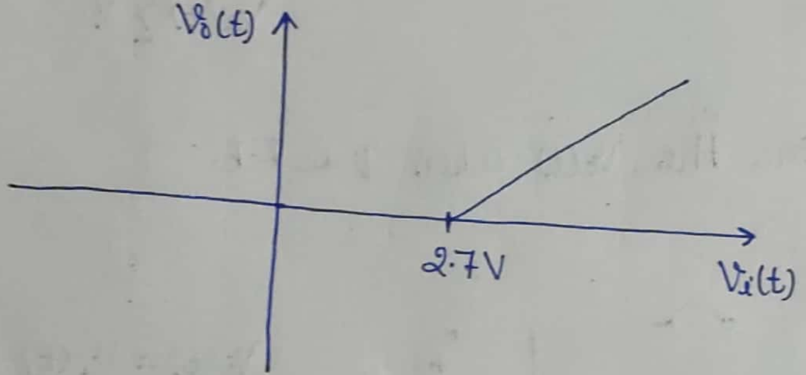
$V_i(t) > 2.7V$

Step 2: Determine $V_o(t)$

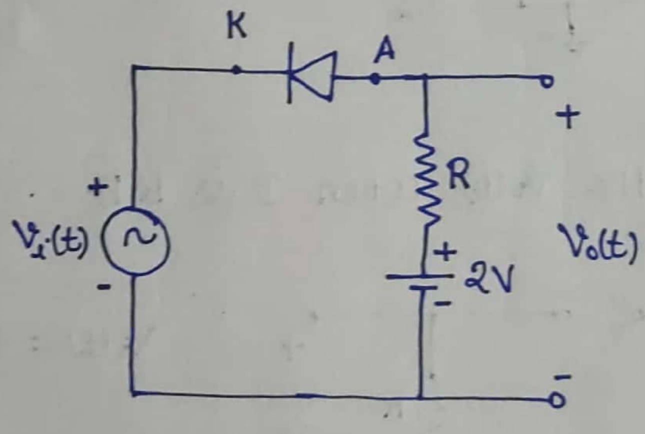


$$V_o(t) = \begin{cases} V_i(t) - 2.7 \; ; & \text{if } V_i(t) > 2.7V \\ 0 \; ; & \text{if } V_i(t) \leq 0 \end{cases}$$

Step 3: Transfer characteristics



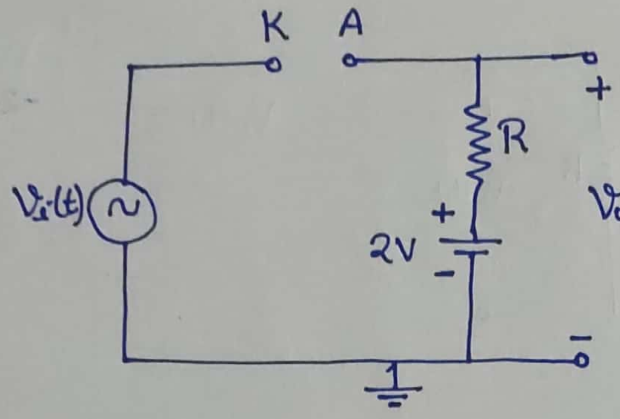
Example 4: Find V_o and transfer characteristics for the given circuit?



Given that

$V_i(t) = 10 \sin \omega t$

Sol: **Step 1:** Determine the condition for F.B. and R.B.



For F.B.

$V_A - V_K > 0$

$2 - V_i(t) > 0$

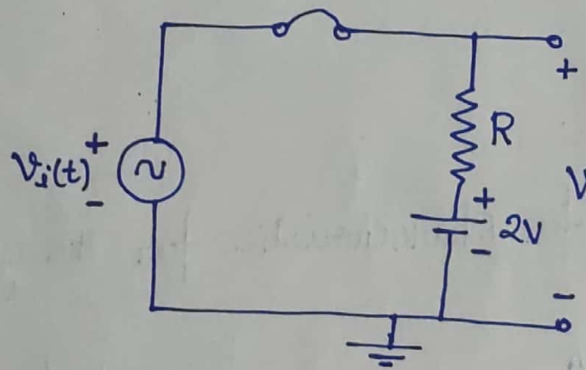
or $V_i(t) < 2$

For R.B.

$V_A - V_K \leq 0$

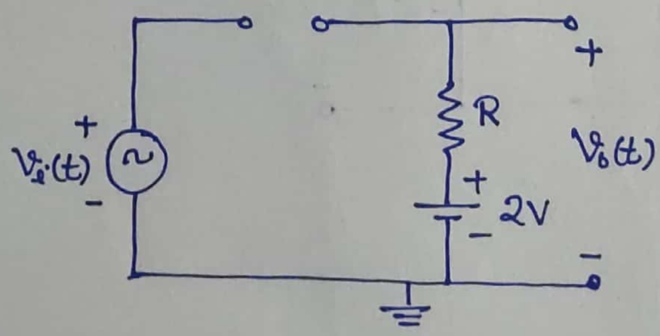
$V_i(t) \geq 2$

Step 2: Determine the $V_o(t)$ when D is F.B.



$V_o(t) = V_i(t)$

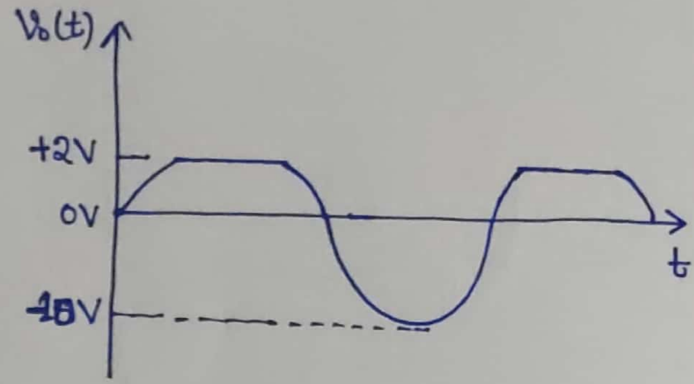
Step 3: Determine the $V_o(t)$ when D is R.B.



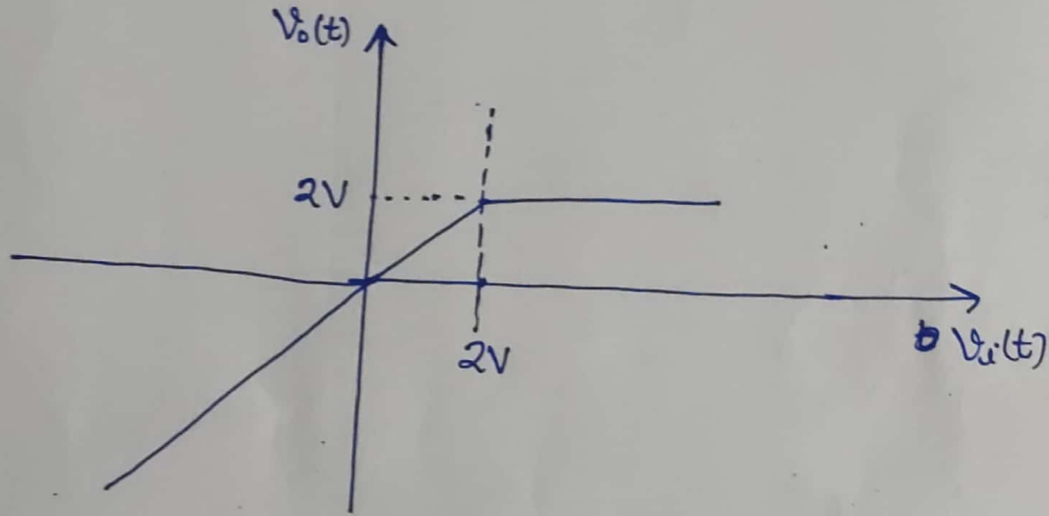
$V_o(t) = 2V$

Step 4: Plot $V_o(t)$

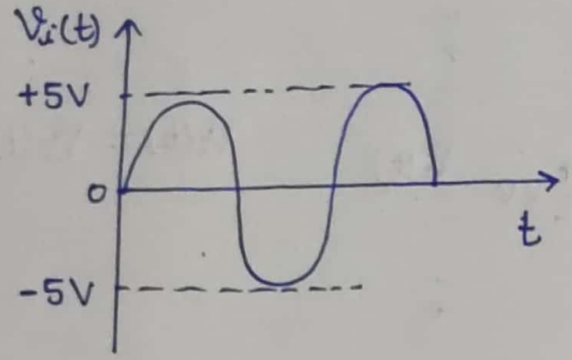
$$V_o(t) = \begin{cases} V_i(t) \, ; & \text{if } V_i(t) < 2V \\ 2V \, ; & \text{if } V_i(t) \geq 2V \end{cases}$$

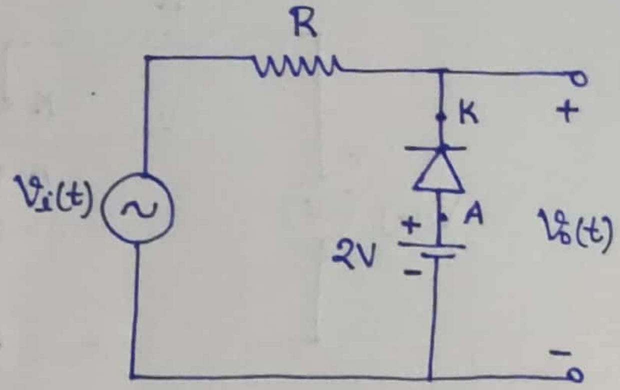


Step 5: Transfer characteristics

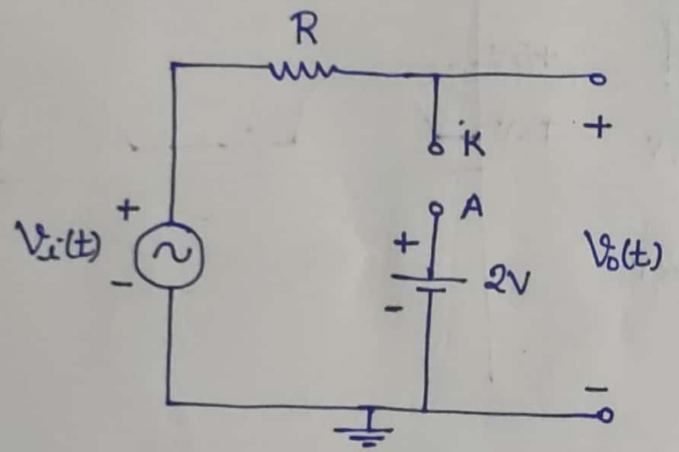


Example: Determine $V_o(t)$ and transfer characteristics for the given Circuit?





Sol: **Step 1:** Determine Condition for F.B. and R.B.



For F.B.

$V_A - V_K > 0$

$2 - V_i(t) > 0$

$V_i(t) < 2V$

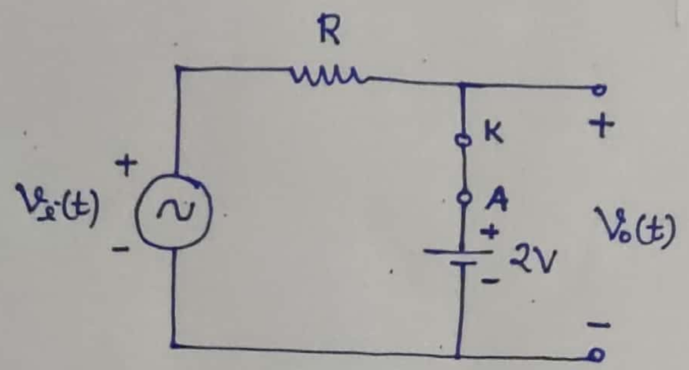
For R.B.

$V_A - V_K \leq 0$

$2 - V_i(t) \leq 0$

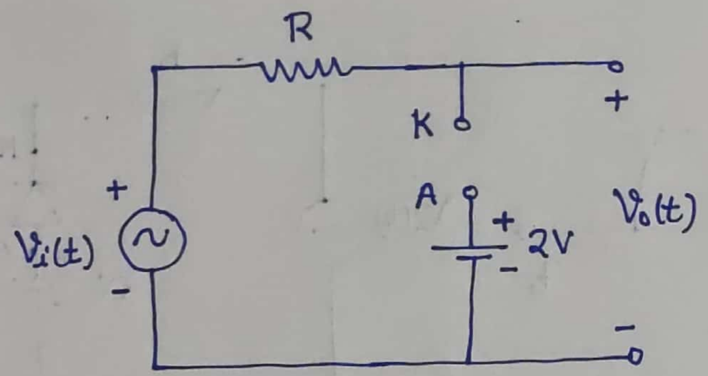
$V_i(t) \leq 2V$

Step 2: Determine V_o when D is in F.B.



$V_o(t) = 2V$; if $V_i(t) < 2V$

Step 3: Determine $V_o(t)$ when D is R.B.

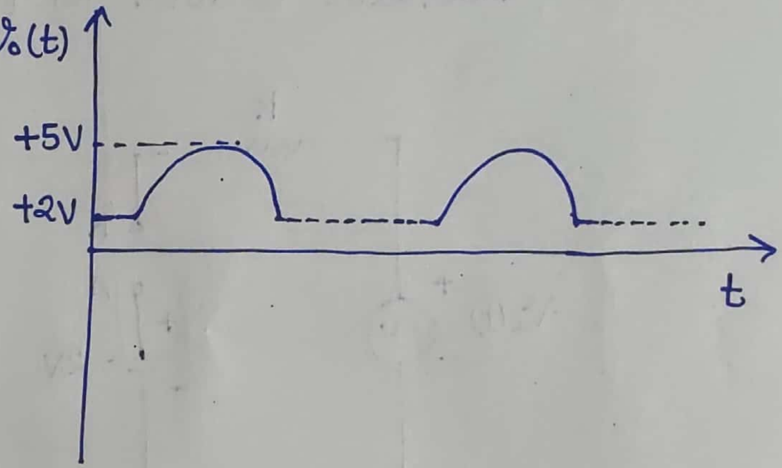


$V_o(t) = V_i(t)\ ;\ V_i(t) \geq 2V$

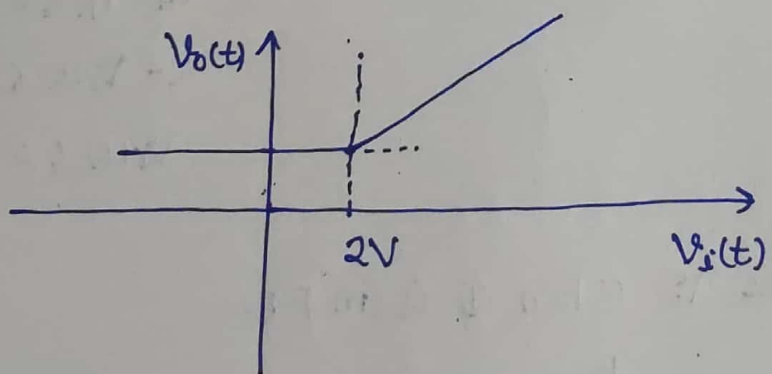
Step 4: Plot $V_o(t)$

~~$V_o(t) = 2V$~~

$$V_o(t) = \begin{cases} 2V\ ; \text{ if } V_i(t) < 2V \\ V_i(t)\ ; \text{ if } V_i(t) \geq 2V \end{cases}$$



Step 5: Plot Transfer characteristics



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