Helwan University - Faculty of Engineering (Helwan)
Electronics and Communications Engineering Department

Lec-3 Diodes: Applications

Presented By:

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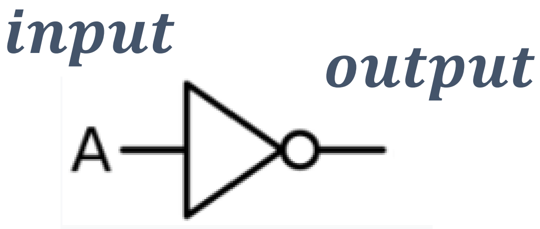
Diode Applications

Diodes are used in many types of circuits such as:

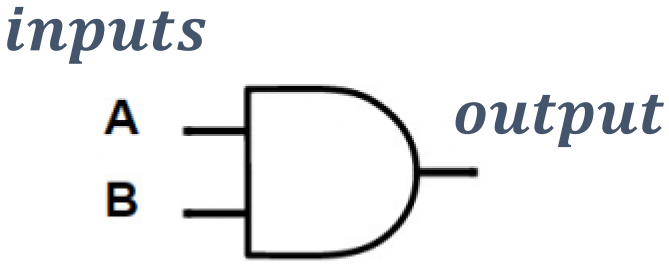
- Digital Circuits (**Logic Gates**).
- Clipping Circuits.
- Clamping Circuits.
- Rectifier Circuits.

❑ Digital Circuits

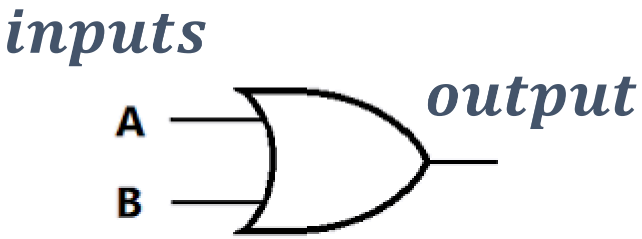
All digital circuits (such as microprocessor, memory, ...) contain hardware elements called **logic gates** that perform the logical operations on binary numbers (0 and 1).



NOT Gate



AND Gate



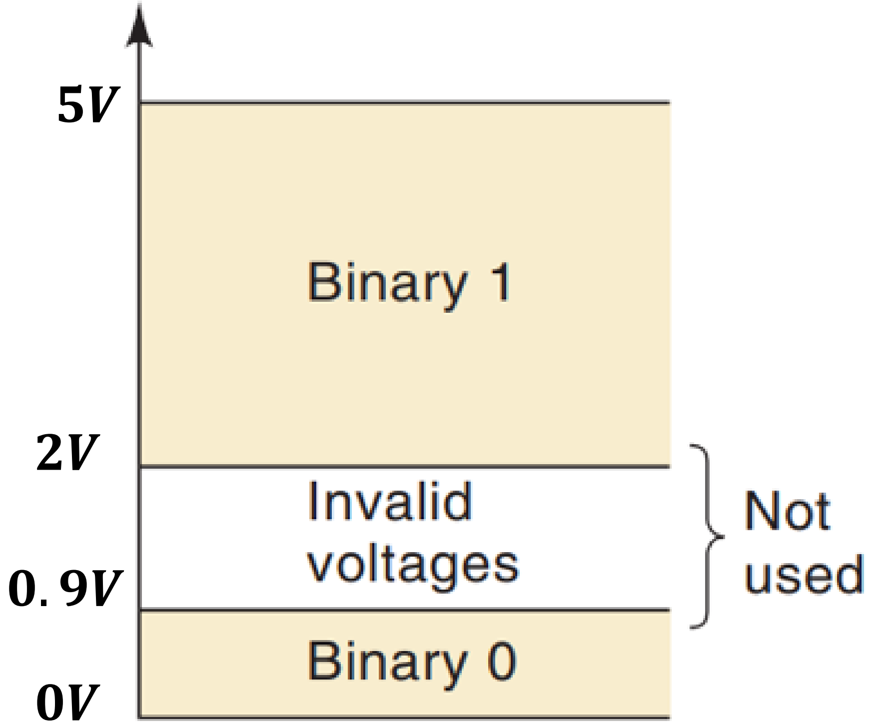
OR Gate

In digital circuits, binary 0 and 1 are represented by two voltage levels.

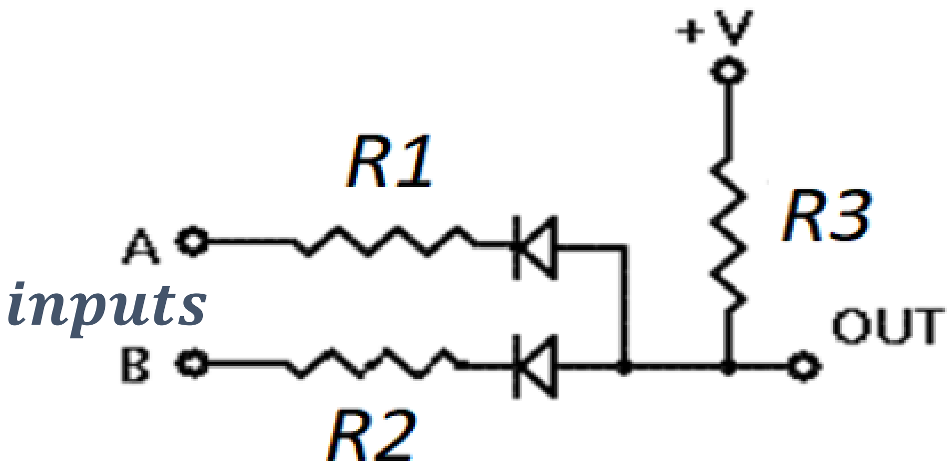
For example, zero volts (0V) represents binary 0, and +5V represents binary 1.

In actuality, because of circuit variations, binary 0 and 1 are represented by voltage ranges.

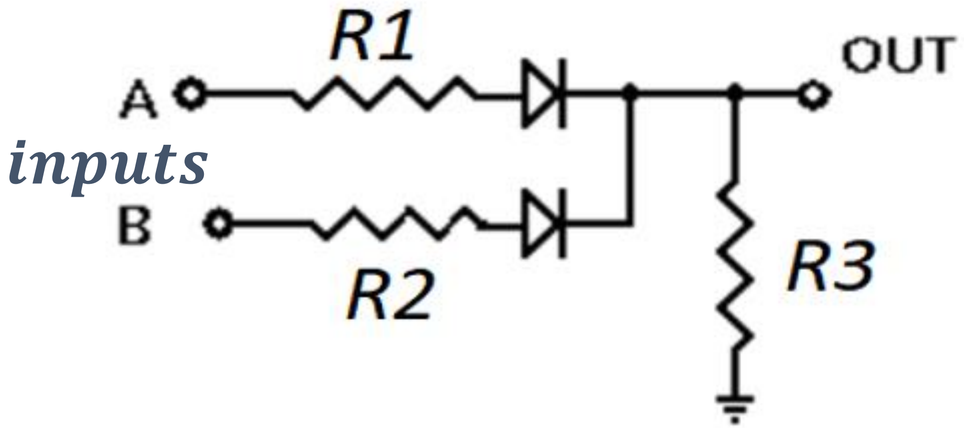
For example, any voltage between 0 and 0.9V represents binary 0 and any voltage between 2 and 5V represents binary 1.



Logic gates (AND, OR) can be made by combining diodes and resistors.

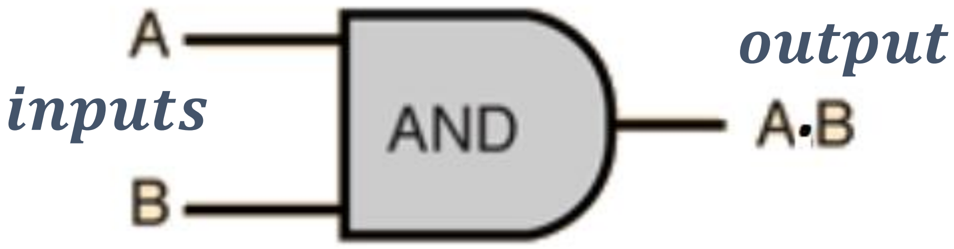


$Two - Inputs\ AND\ Gate$



$Two - Inputs\ OR\ Gate$

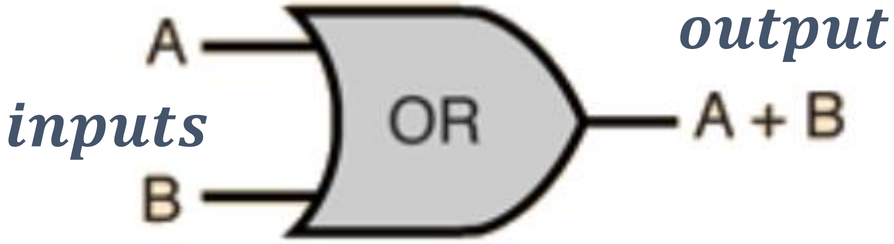
AND gate performs AND function, its output is 1 if both inputs are 1 and its output is 0 otherwise.



A	B	Out
0	0	0
0	1	0
1	0	0
1	1	1

Truth Table of AND Gate

OR gate performs OR function, its output is 1 if either or both inputs is 1 and its output is 0 otherwise.



A	B	Out
0	0	0
0	1	1
1	0	1
1	1	1

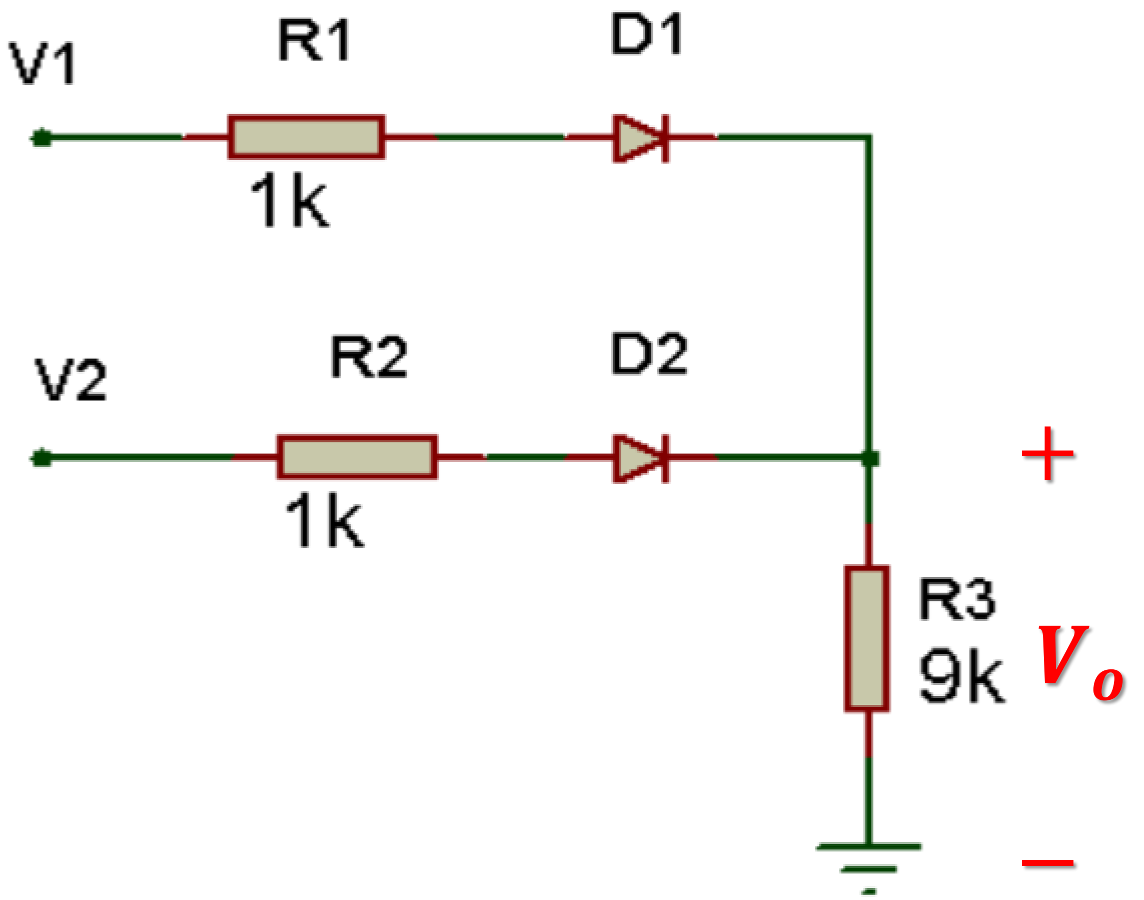
Truth Table of OR Gate

Example-1

For the circuit shown, the cut in voltage of a diode is 0.6V and the voltage drop across a conducting (forward) diode is 0.7V.

Calculate V_o for the following input voltages:

(a) V_1=5V and V_2=5V
(b) V_1=5V and V_2=0V
(c) V_1=0V and V_2=0V



Solution:

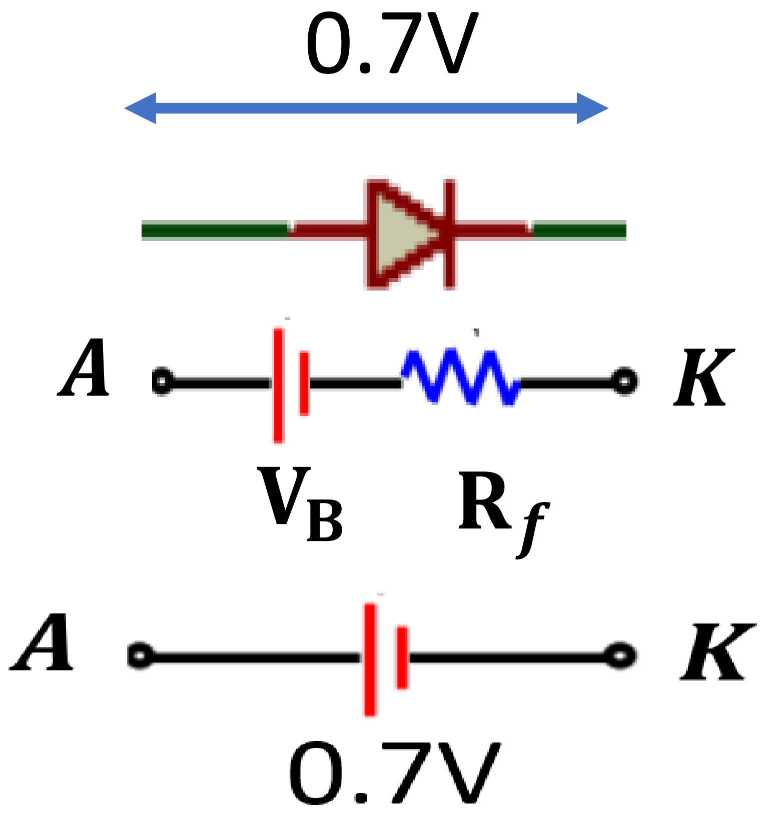
Cut in voltage = barrier voltage = V_B= 0.6V

means

Voltage drop across conducting (forward) diode is 0.7V.

=

Voltage across forward resistance plus barrier voltage is 0.7V.



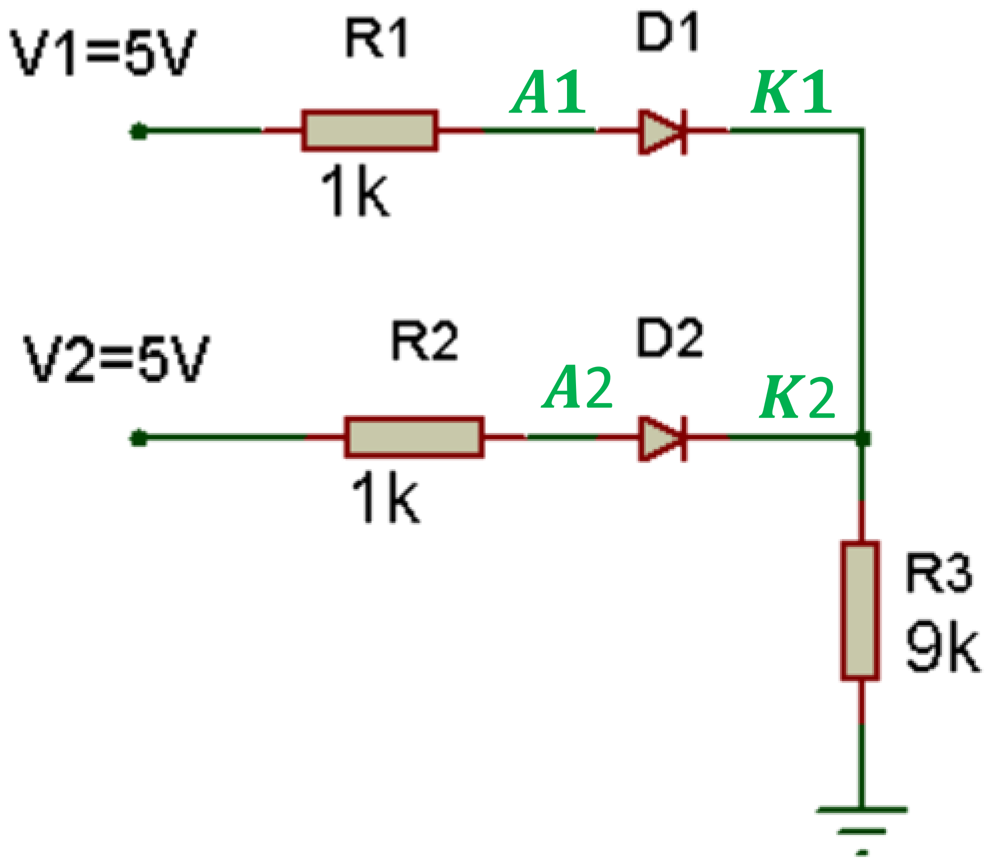
(a) V_1=5V and V_2=5V

Assume:

$$(V_{A1}=4) > (V_{K1}=0) + (V_B=0.6)$$

$$(V_{A2}=4) > (V_{K2}=0) + (V_B=0.6)$$

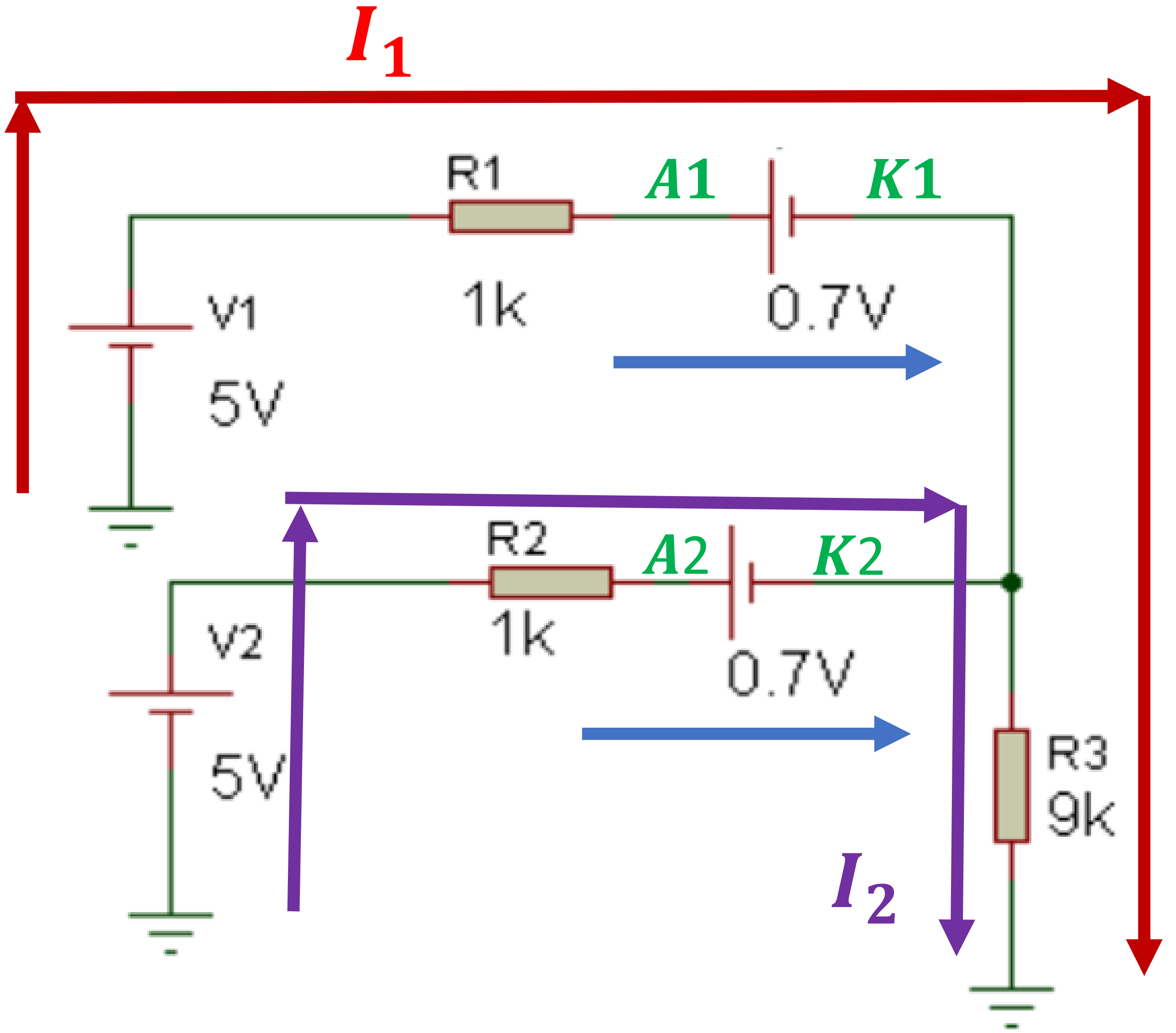
$\therefore$ *Assume* D_1 *and* D_2 *are forward*



$$\sum V\ in\ any\ closed\ loop = 0$$

$$5-(1k)I_1-0.7-(9k)(I_1+I_2)=0$$

$$5-(1k)I_2-0.7-(9k)(I_1+I_2)=0$$



$$I_1 = 0.23mA$$
$$I_2 = 0.23mA$$

$\because I_1 = I_{D1} =$ *positive value*

$\because I_2 = I_{D2} =$ *positive value*

$\therefore I_{D1}$ *and* I_{D2} *are in the correct direction*

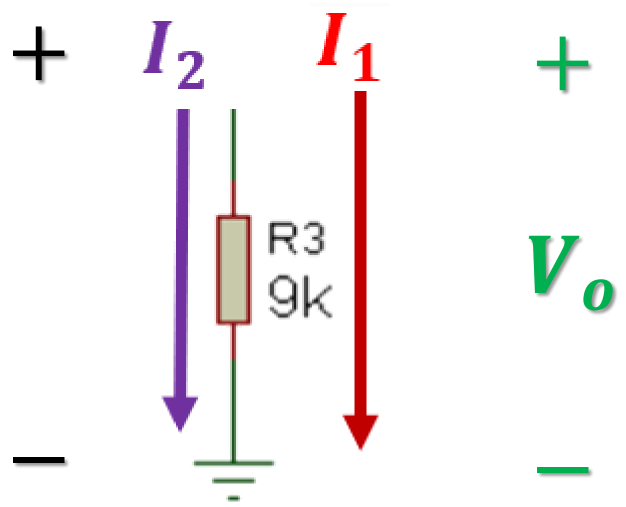
$\therefore$ *our assumption is true (D_1 and D_2 are forward)*

To find $\boldsymbol{V_o}$, write KVL between $\boldsymbol{V_o}$ and **the branch** (that you calculate on it the voltage drop):

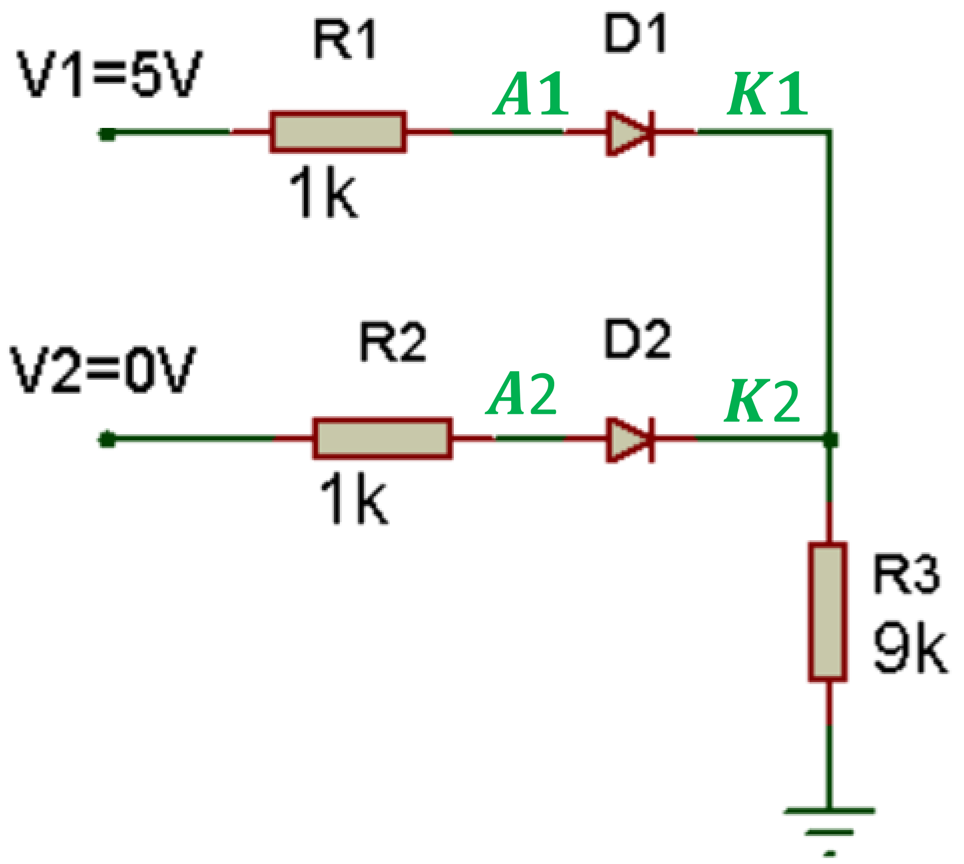
$$Vo - (9k)(I_1+I_2) = 0$$

$$Vo = (9k)(I_1+I_2)$$

$$Vo = 4.07V$$



(b) $V_1=5V$ *and* $V_2=0V$



Assume:

$$(V_{A1} = 4) > (V_{K1} = 0) + (V_B = 0.6)$$

$$(V_{A2} = 0) < (V_{K2} = 0) + (V_B = 0.6)$$

$\therefore$ *Assume* D_1 *is forward and* D_2 *is reverse*

$$\sum \boldsymbol{V\ in\ closed\ loop = 0}$$

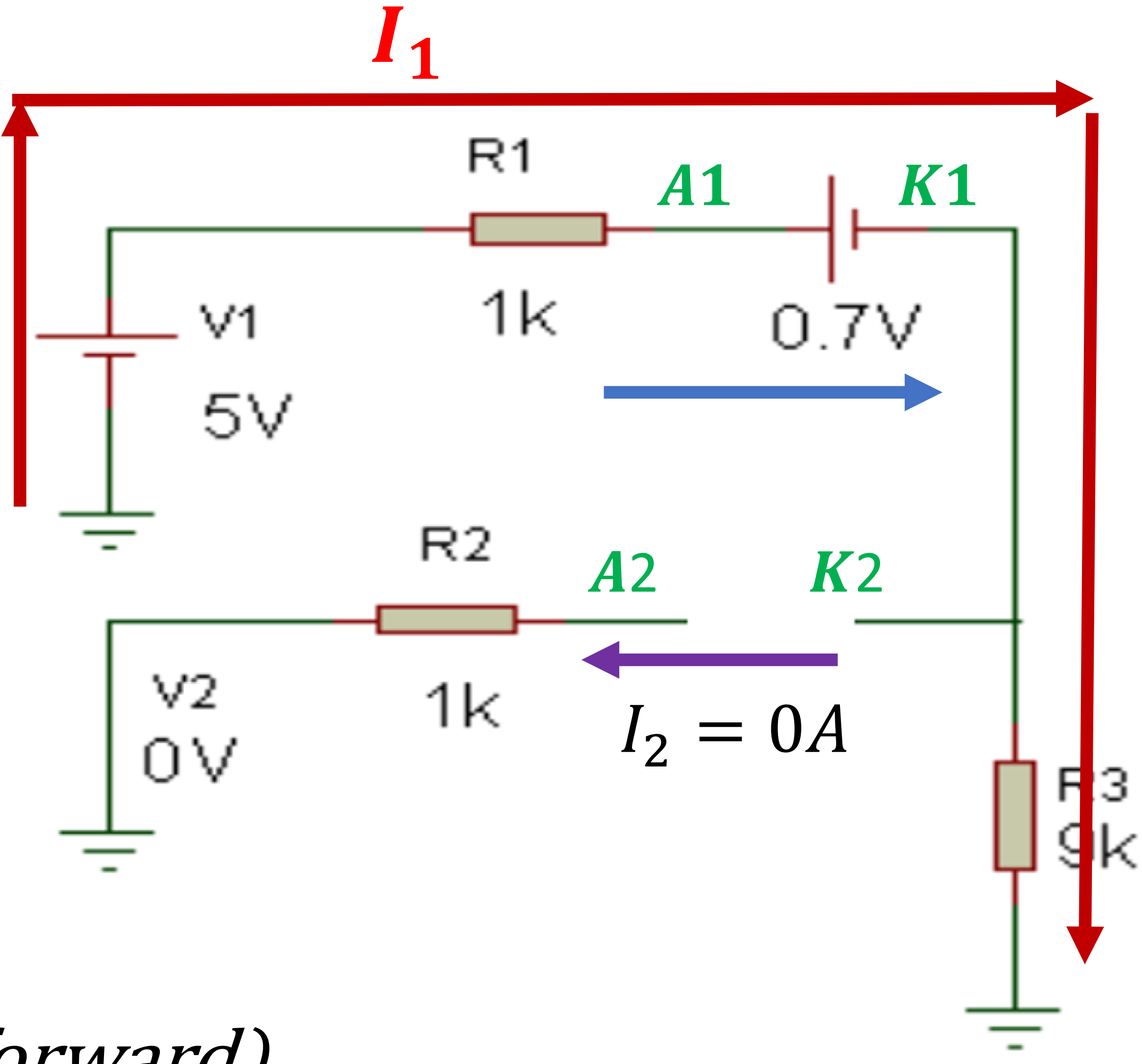
$$5 - (1k)I_1 - 0.7 - (9k)I_1 = 0$$

$$I_1 = 0.43mA$$

$$\because I_1 = I_{D1} = positive\ value$$

$$\therefore I_{D1}\ in\ correct\ direction$$

$$\therefore our\ assumption\ is\ true\ (D_1\ is\ forward)$$

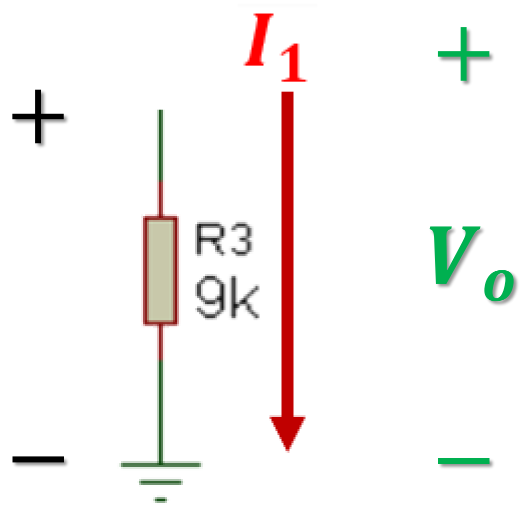


To find $\boldsymbol{V_o}$, write KVL between $\boldsymbol{V_o}$ and **the branch** (that you calculate on it the voltage drop):

$$Vo - (9k)I_1 = 0$$

$$Vo = (9k)I_1$$

$$Vo = 3.87V$$



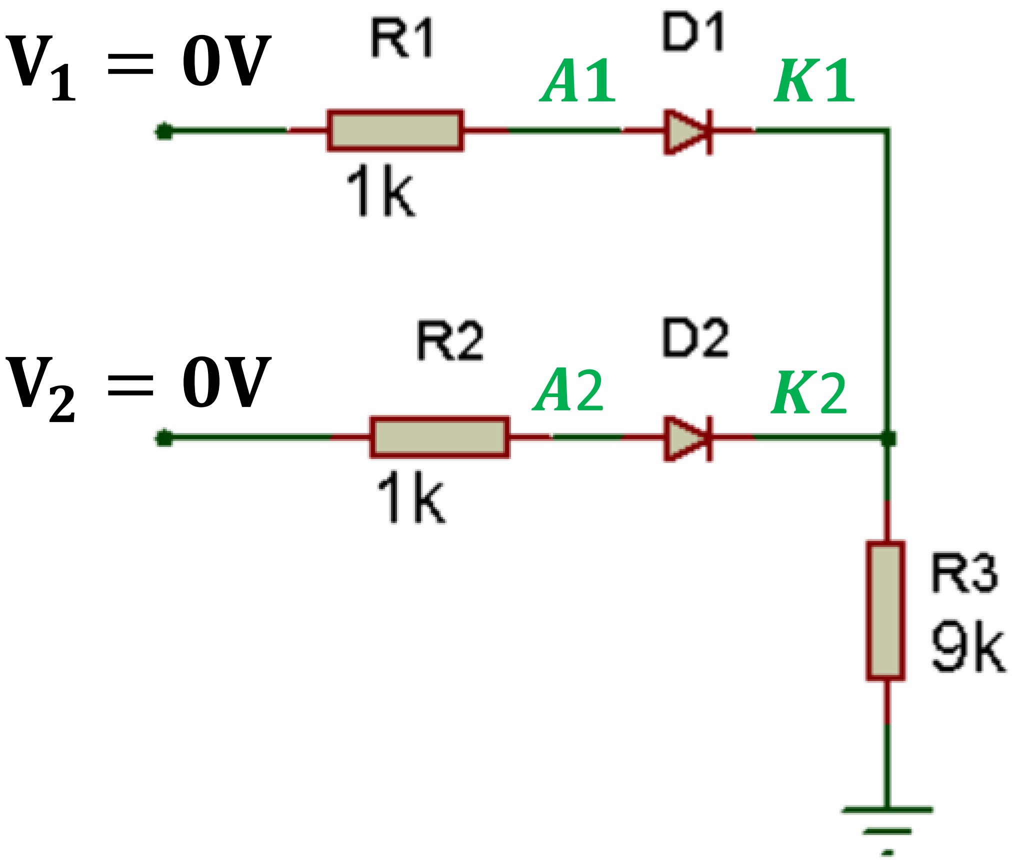
(c) V_1=0V and V_2=0V

Assume:

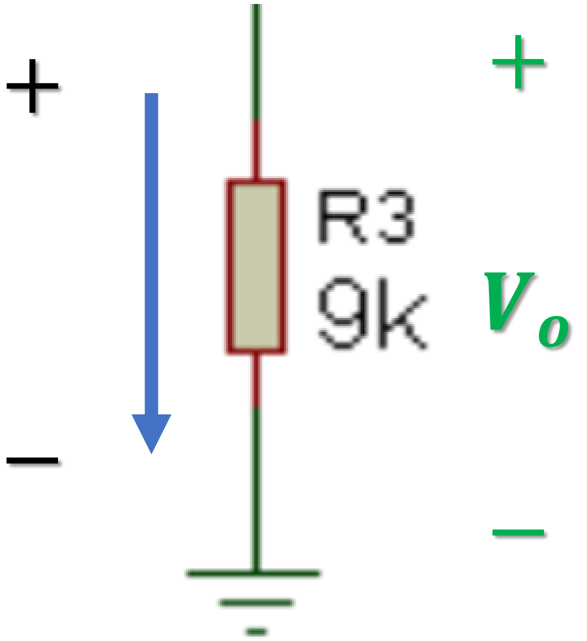
$$(V_{A1} = 0) < (V_{K1} = 0) + (V_B = 0.6)$$

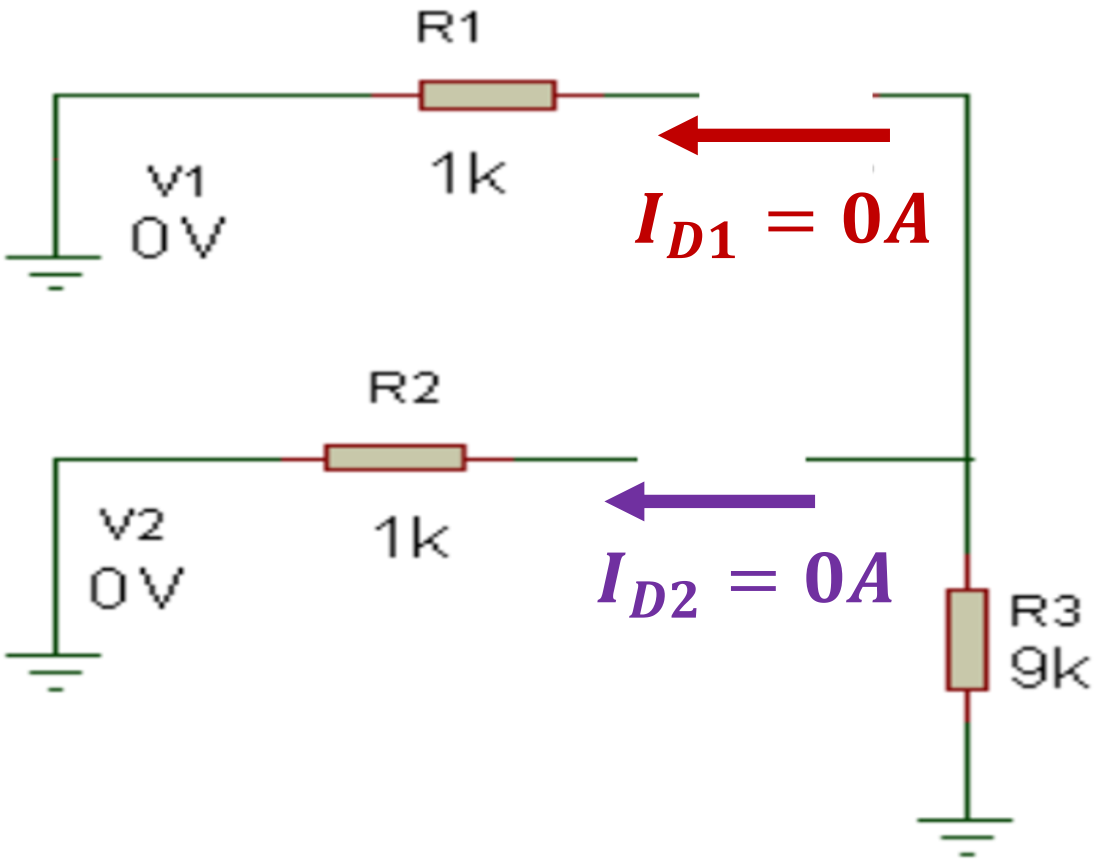
$$(V_{A2} = 0) < (V_{K2} = 0) + (V_B = 0.6)$$

$\therefore$ Assume D_1 and D_2 are reverse



To find $\boldsymbol{V_o}$, write KVL between $\boldsymbol{V_o}$ and **the branch** (that you calculate on it the voltage drop):



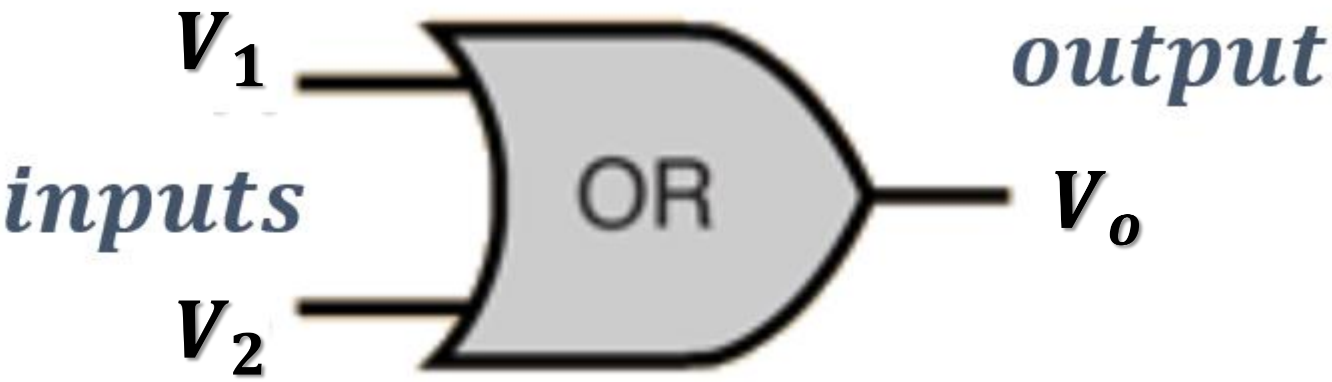


$$Vo - (9k)(0A) = 0$$

$$Vo = (9k)(0A) = 0V$$

Truth Table of OR Gate

Input		*Output*
V_1	V_2	V_o
0V $\equiv$ *Binary 0*	0V $\equiv$ *Binary 0*	0V $\equiv$ *Binary 0*
5V $\equiv$ *Binary 1*	0V $\equiv$ *Binary 0*	3.87V $\equiv$ *Binary 1*
0V $\equiv$ *Binary 0*	5V $\equiv$ *Binary 1*	3.87V $\equiv$ *Binary 1*
5V $\equiv$ *Binary 1*	5V $\equiv$ *Binary 1*	4.07V $\equiv$ *Binary 1*



Example-2

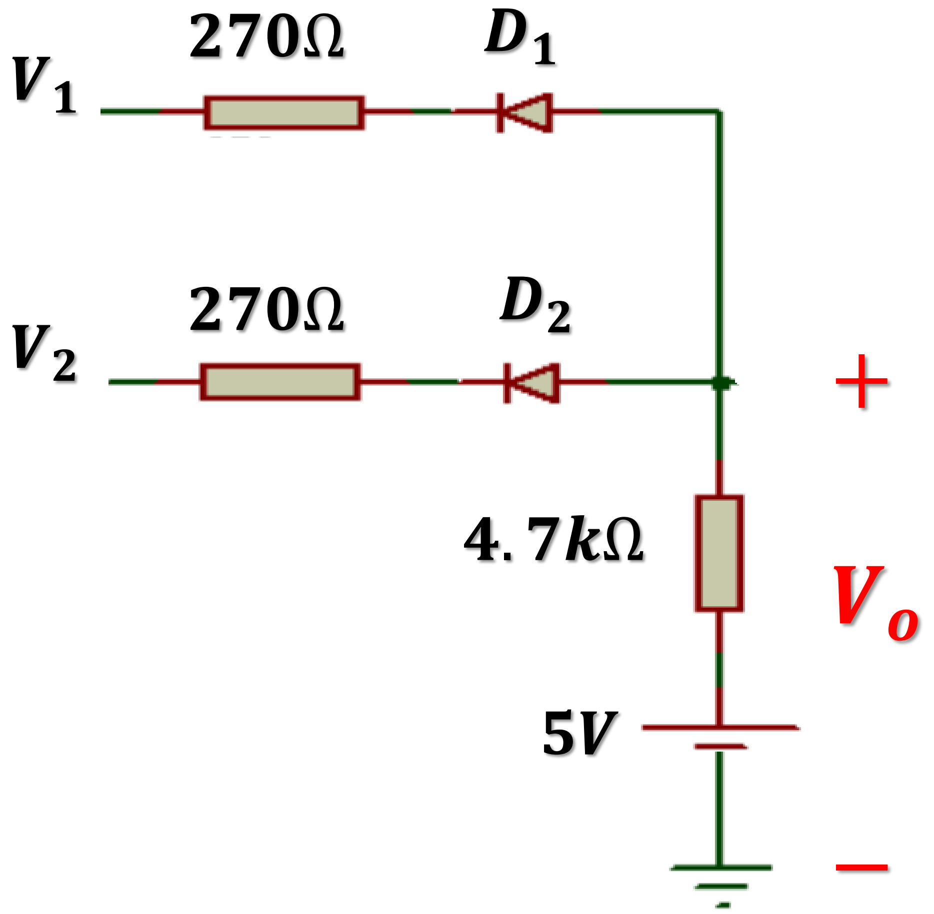
For the circuit shown, assume identical diodes with barrier potential (V_B) of 0.6V and forward resistance (R_f) of 30Ω

Calculate the output voltage (V_o) for the following input voltages:

(a) V_1=0V and V_2=0V.

(b) V_1=5V and V_2=0V.

(c) V_1=5V and V_2=5V.



Solution:

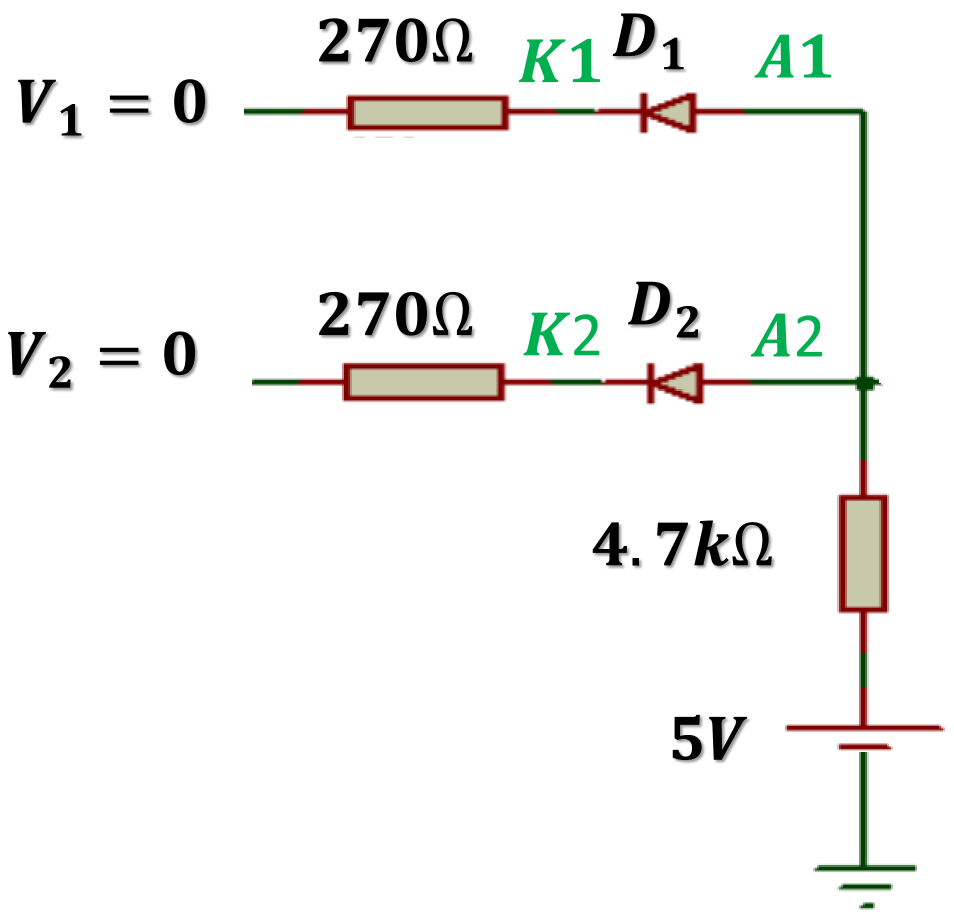
(a) $V_1 = 0V$ *and* $V_2 = 0V$

Assume:

$$(V_{A1} = 4) > (V_{K1} = 0) + (V_B = 0.6)$$

$$(V_{A2} = 4) > (V_{K2} = 0) + (V_B = 0.6)$$

$\therefore$ *Assume* D_1 *and* D_2 *are forward*



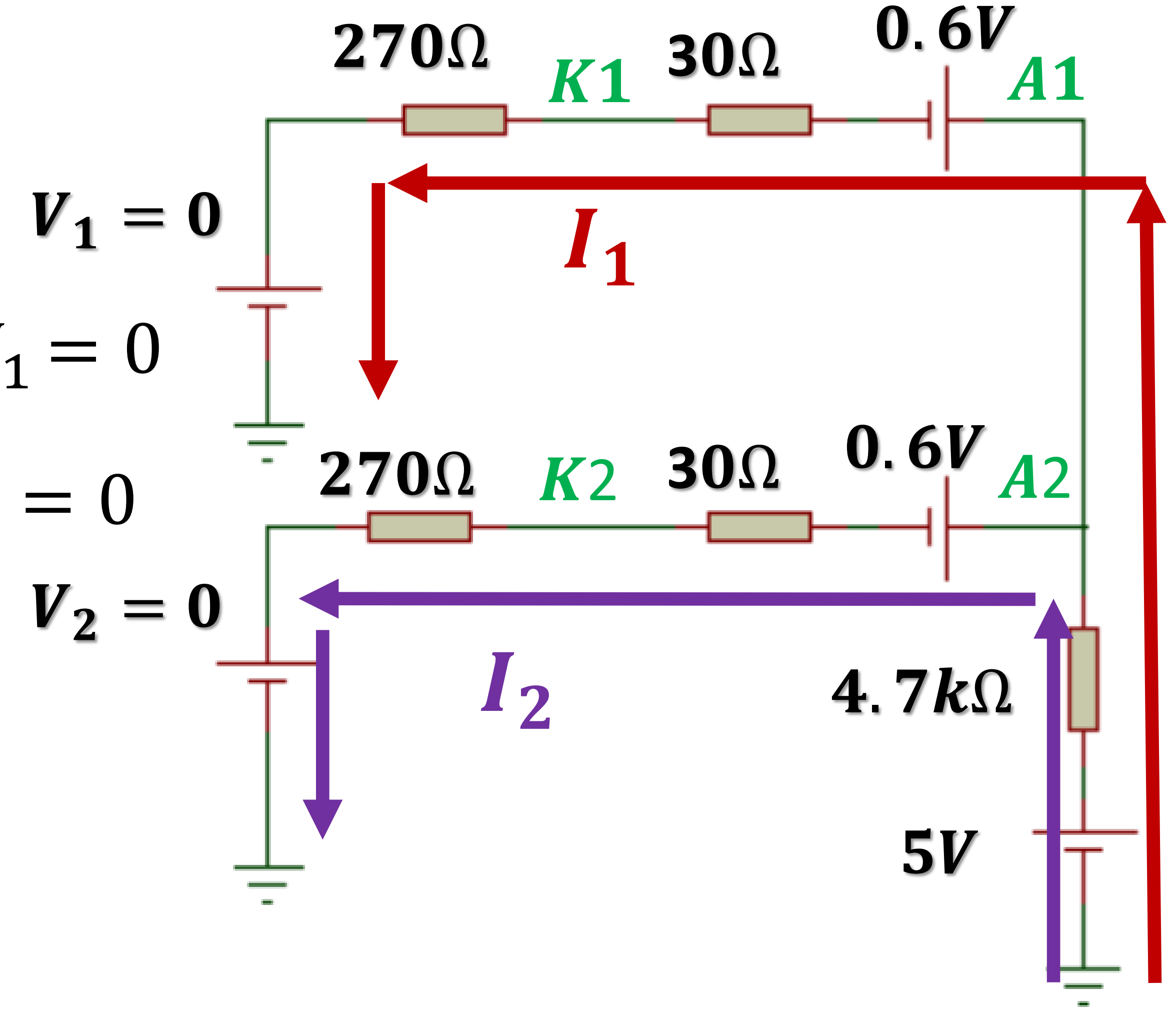
$$\sum V\ in\ closed\ loop = 0$$

$$5 - (4700)(I_1 + I_2) - 0.6 - (30 + 270)\ I_1 = 0$$

$$5 - (4700)(I_1 + I_2) - 0.6 - (30 + 270) I_2 = 0$$

$$I_1 = 0.454mA$$

$$I_2 = 0.454mA$$



The positive value of currents indicates our assumption is true (D_1 and D_2 are forward).

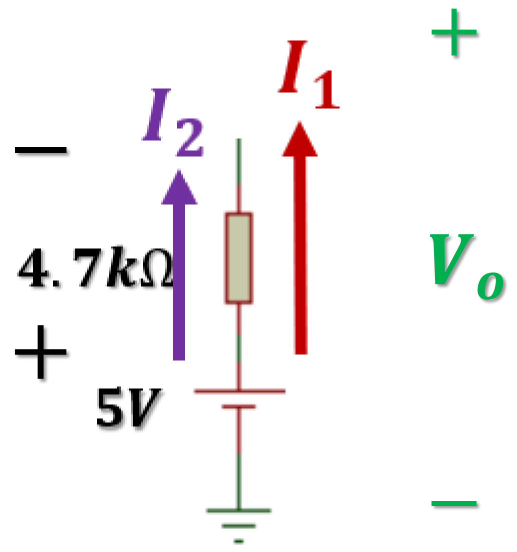
To find $\boldsymbol{V_o}$, write KVL between $\boldsymbol{V_o}$ and **the branch** (that you calculate on it the voltage drop):

$$5 - 4.7k\,(I_1 + I_2) - V_o = 0$$

$$5 - 4.7k\,(0.454mA + 0.454mA) = V_o$$

$$5 - 4.3 = V_o$$

$$V_o = 0.7\text{V}$$



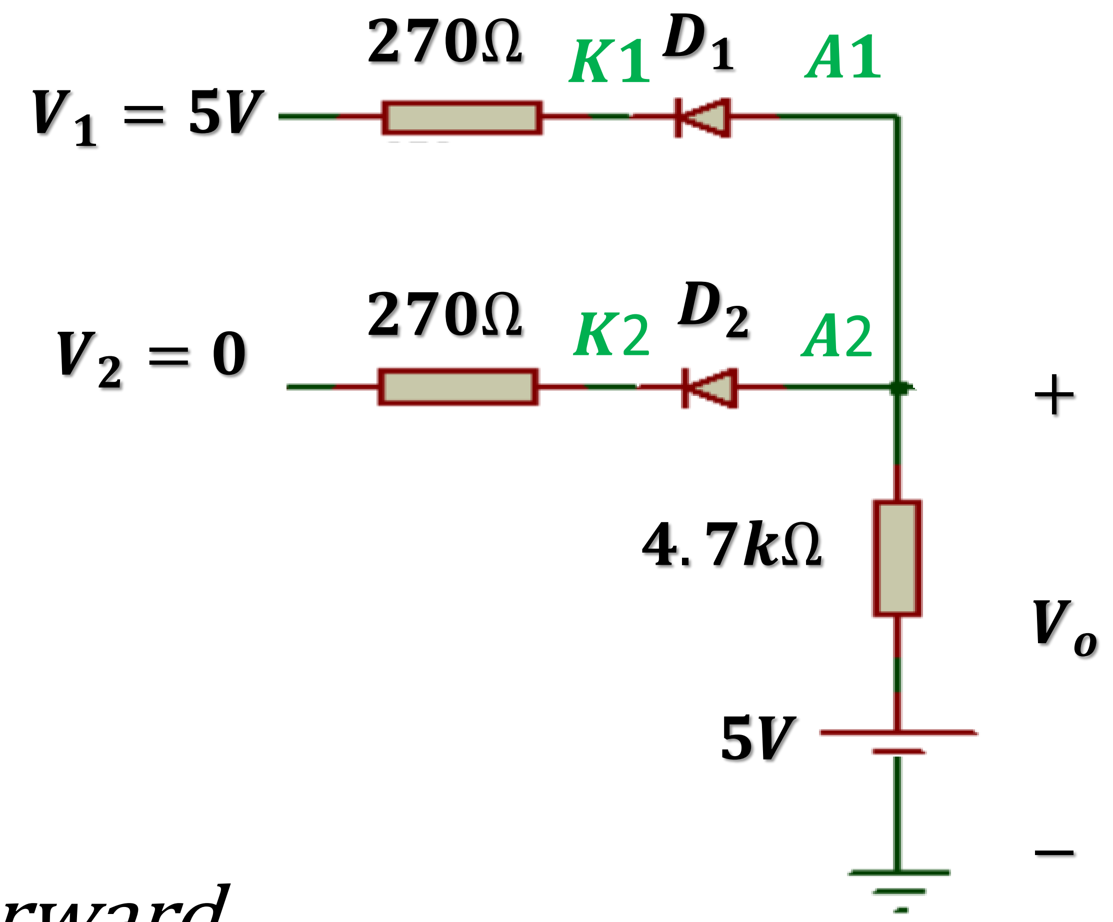
(b) $V_1 = 5V$ *and* $V_2 = 0V$

Assume:

$$(V_{A1} = 4) < (V_{K1} = 4.5) + (V_B = 0.6)$$

$$(V_{A2} = 4) > (V_{K2} = 0) + (V_B = 0.6)$$

$\therefore$ *Assume* D_1 *is reverse and* D_2 *is forward*



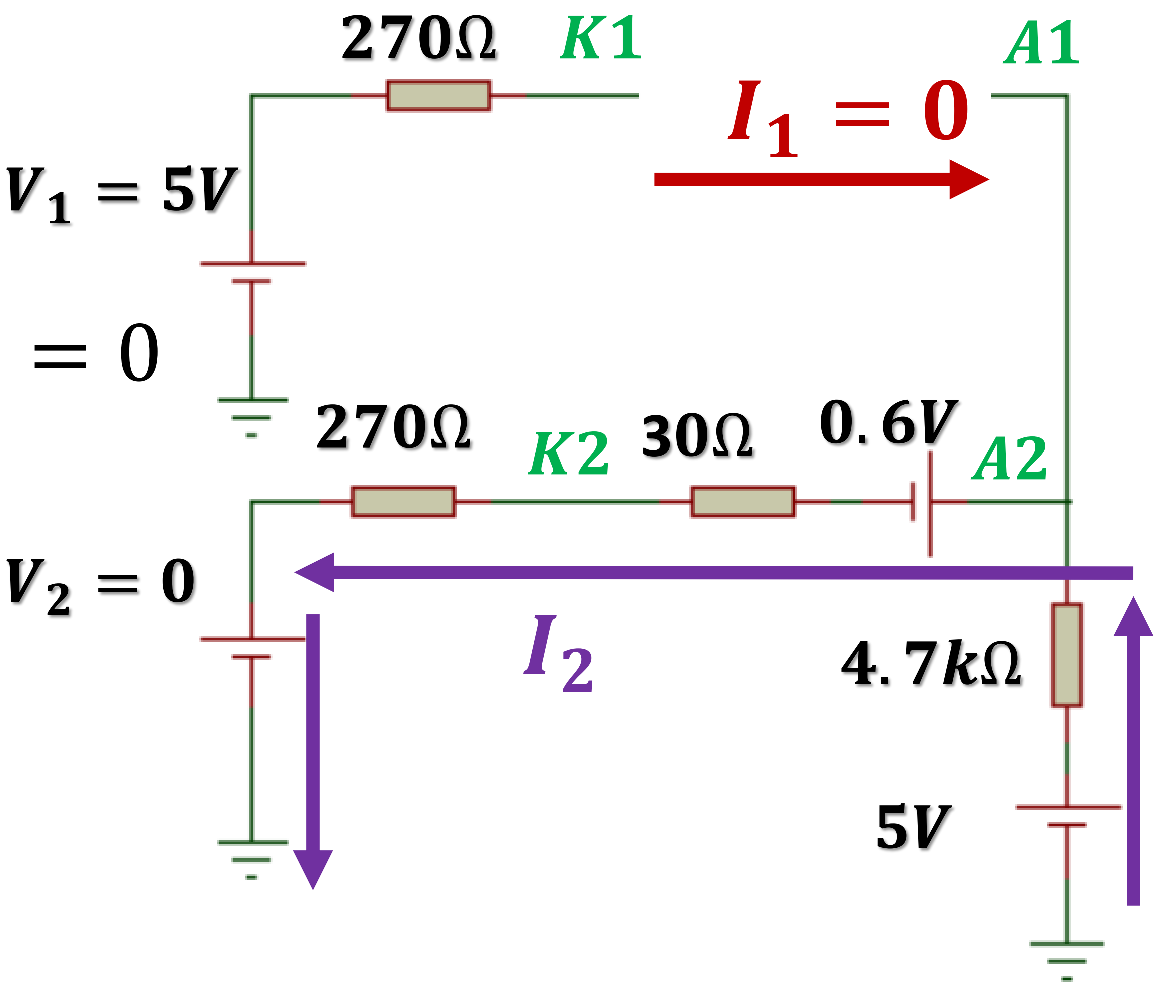
$$\sum \boldsymbol{V\ in\ closed\ loop = 0}$$

$$5 - 4700\,I_2 - 0.6 - (30 + 270)I_2 = 0$$

$$4.4 - 5000I_2 = 0$$

$$4.4 = 5000I_2$$

$$\frac{4.4}{5000} = I_2 = 0.88mA$$



The positive value of current indicates our assumption is true (D_2 is forward).

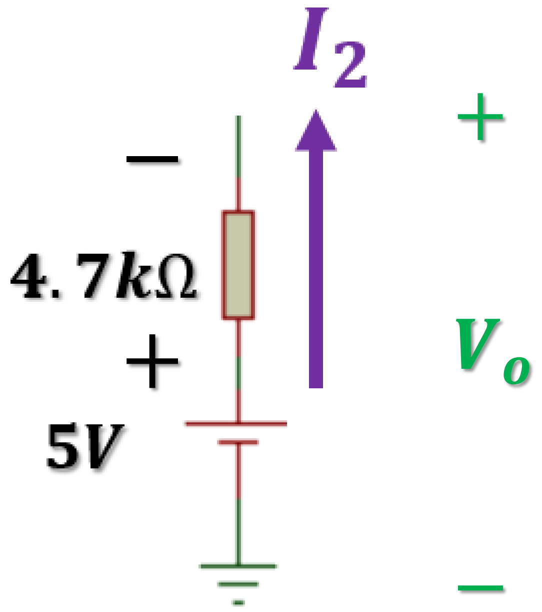
To find $\boldsymbol{V_o}$, write KVL between $\boldsymbol{V_o}$ and **the branch** (that you calculate on it the voltage drop):

$$5 - 4.7k\ xI_2 - V_o = 0$$

$$5 - 4.7k\ x\ 0.88mA = V_o$$

$$5 - 4.1 = V_o$$

$$V_o = 0.9\text{V}$$



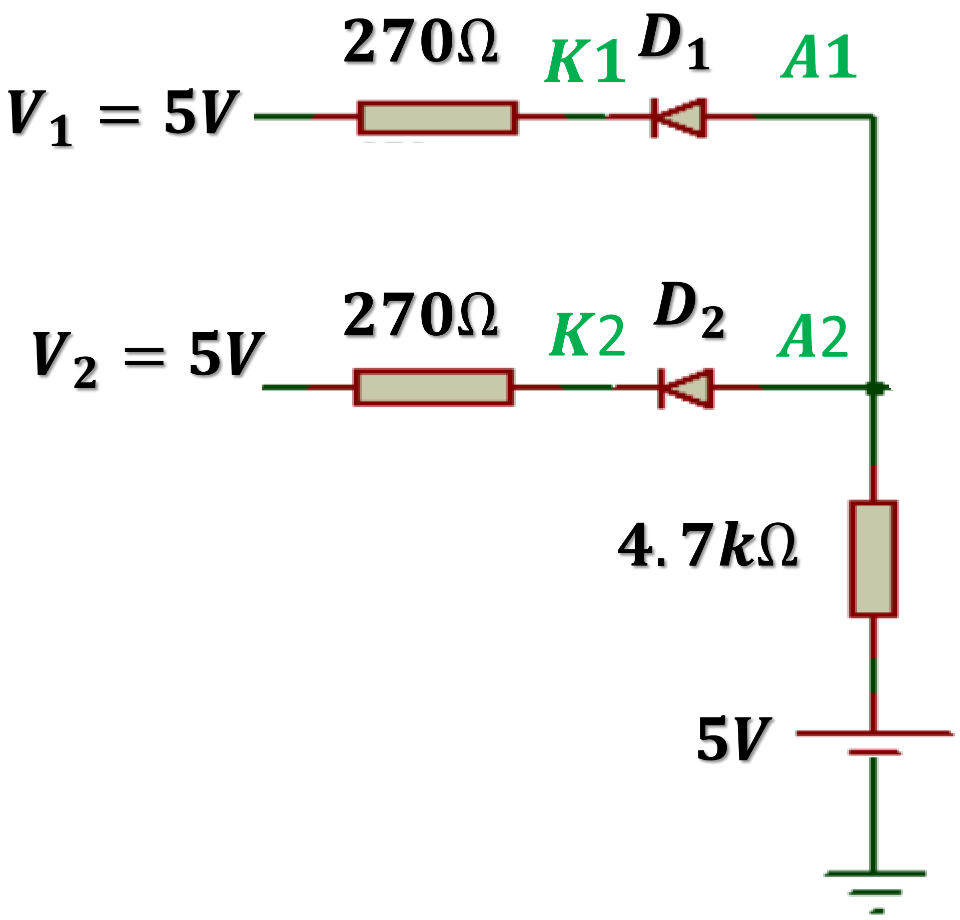
(c) V_1=5V and V_2=5V

Assume:

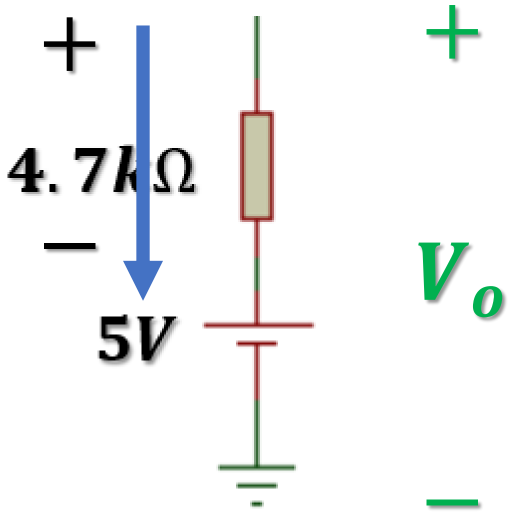
$$(V_{A1} = 4) < (V_{K1} = 4.5) + (V_B = 0.6)$$

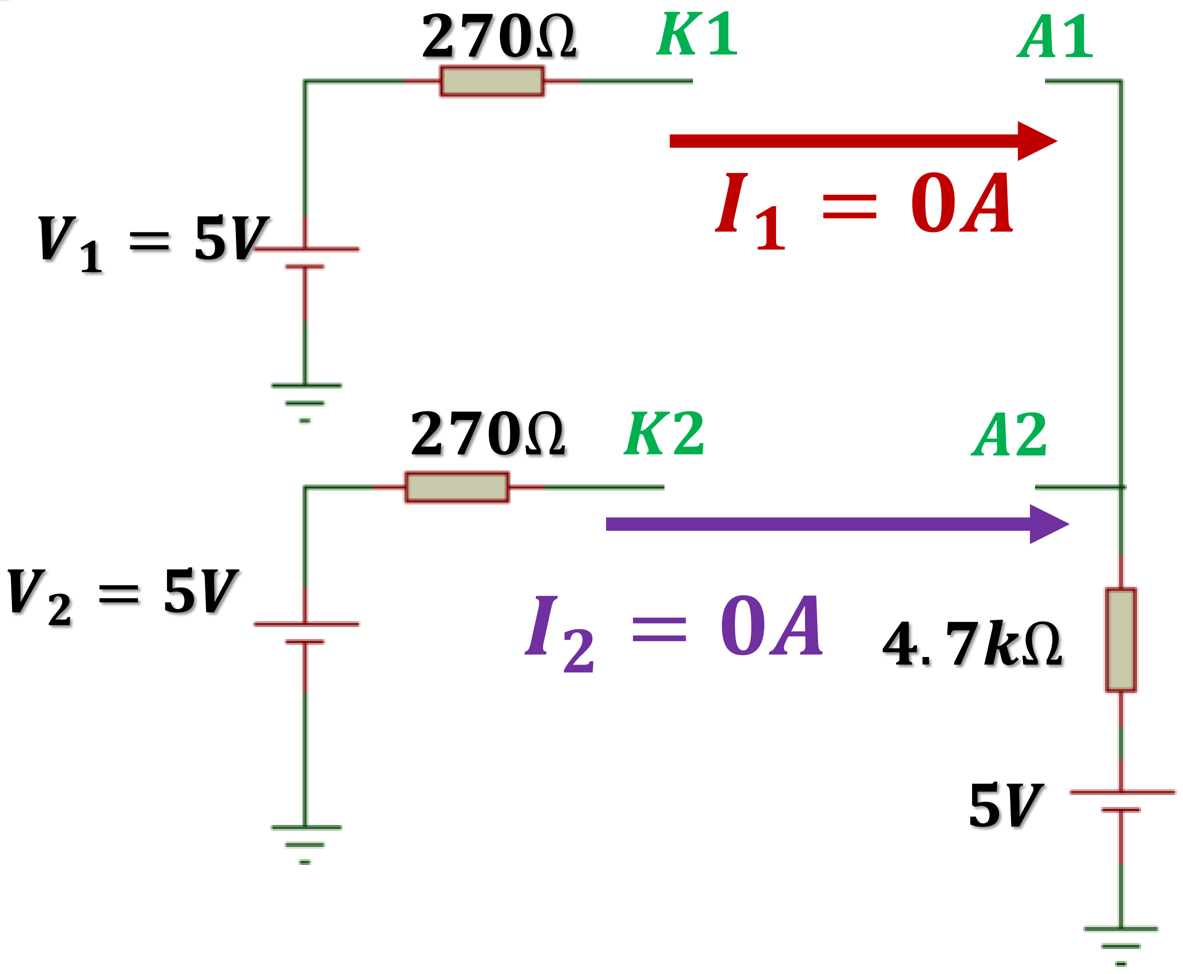
$$(V_{A2} = 4) < (V_{K2} = 4.5) + (V_B = 0.6)$$

$\therefore$ *Assume D_1 and D_2 are reverse*



To find $\boldsymbol{V_o}$, write KVL between $\boldsymbol{V_o}$ and **the branch** (that you calculate on it the voltage drop):





$$5 + 4.7k\ x\ (0A) - V_o = 0$$

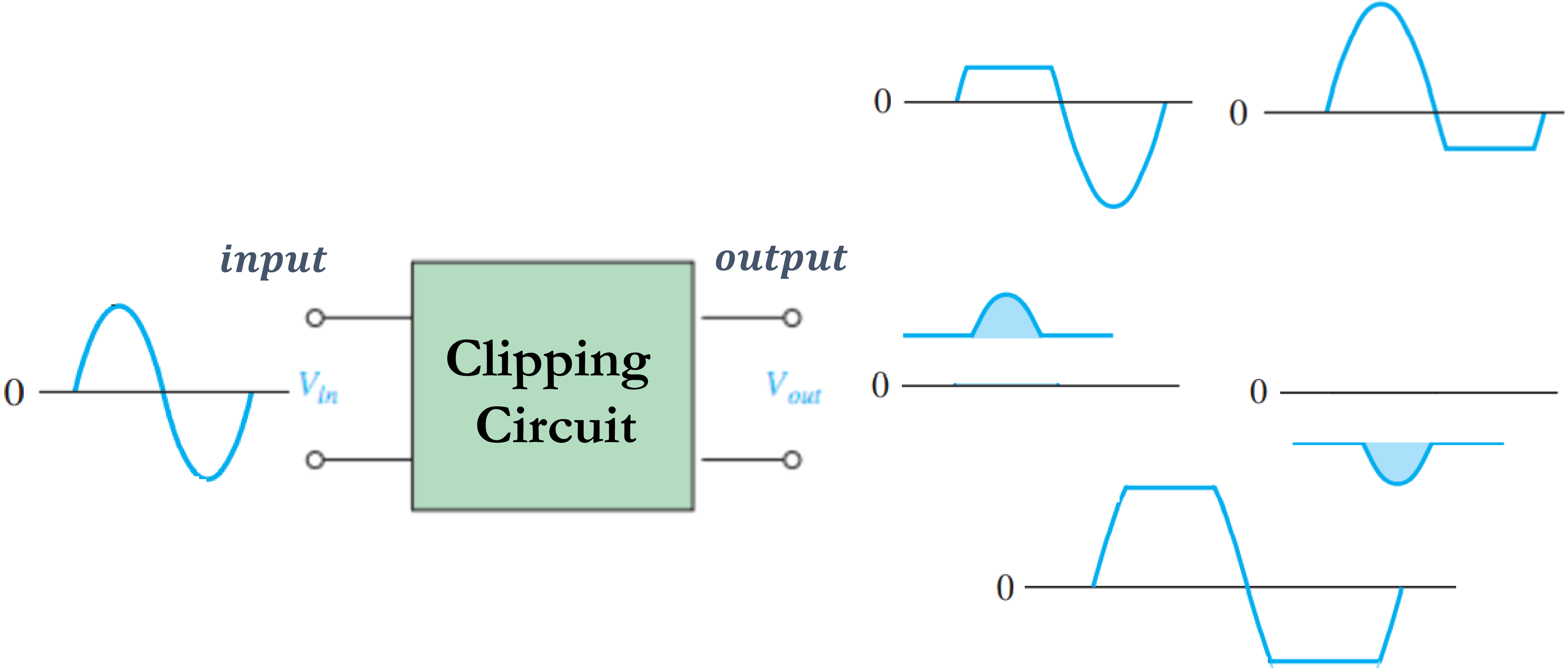
$$V_o = 5\text{V}$$

Truth Table of AND Gate

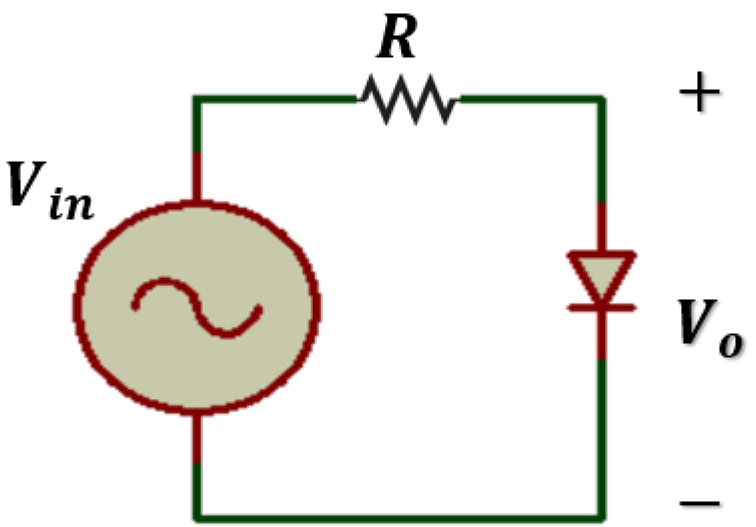
Input		*Output*
V_1	V_2	V_o
0V $\equiv$ *Binary 0*	0V $\equiv$ *Binary 0*	0.7V $\equiv$ *Binary 0*
5V $\equiv$ *Binary 1*	0V $\equiv$ *Binary 0*	0.9V $\equiv$ *Binary 0*
0V $\equiv$ *Binary 0*	5V $\equiv$ *Binary 1*	0.9V $\equiv$ *Binary 0*
5V $\equiv$ *Binary 1*	5V $\equiv$ *Binary 1*	5V $\equiv$ *Binary 1*

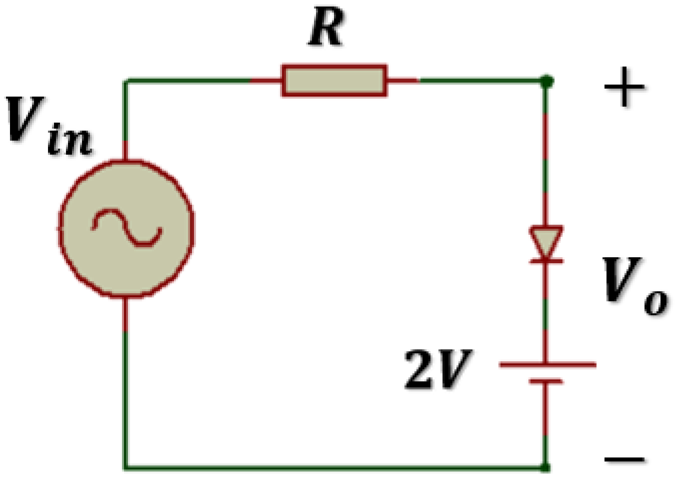
❑ Clipping Circuits

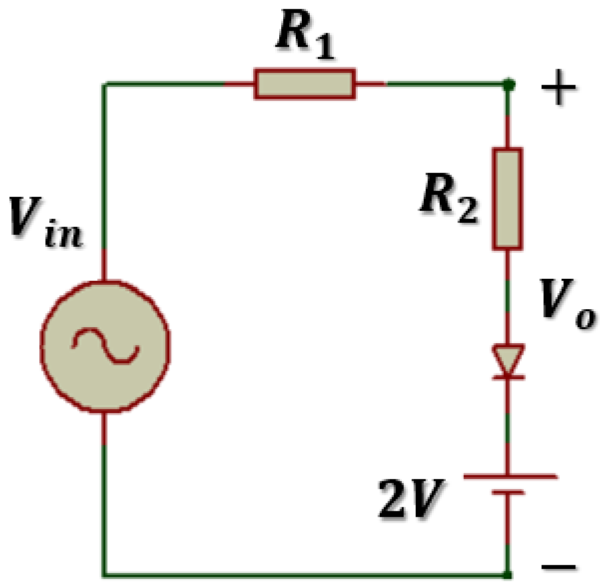
Used to clip off (cut) parts of input signal above or below certain levels.



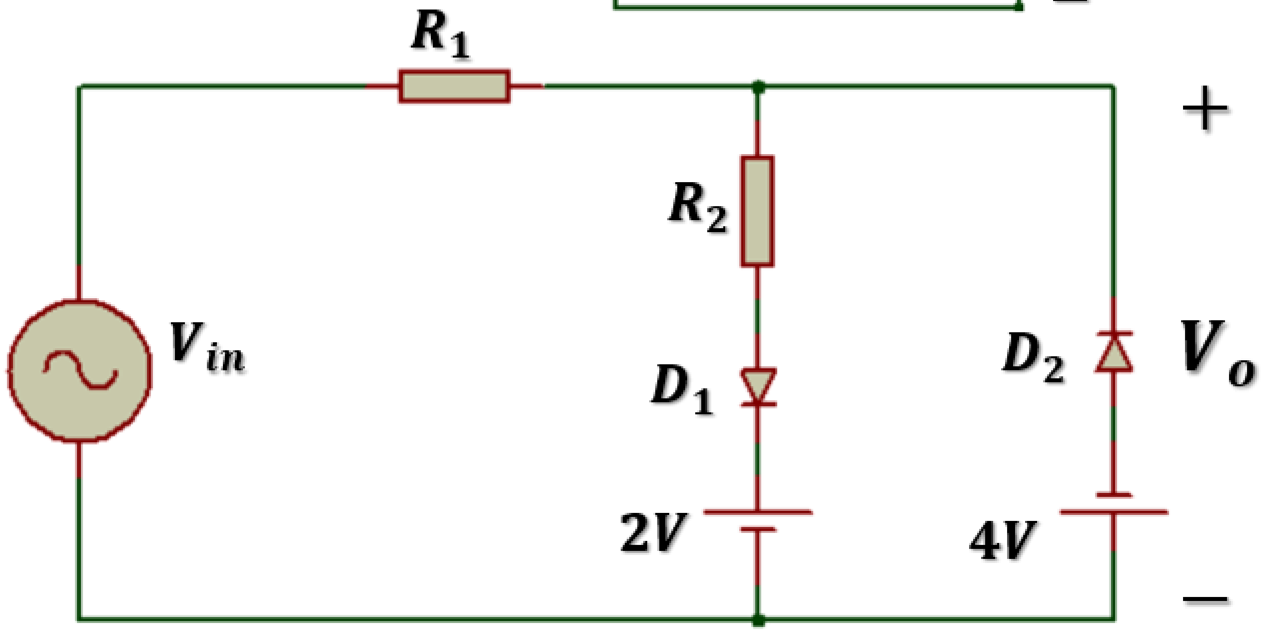
Clipping circuits can be made by combining diodes and resistors.







The **level** to which input signal is clipped can be **adjusted by adding dc voltage** in series with a diode.



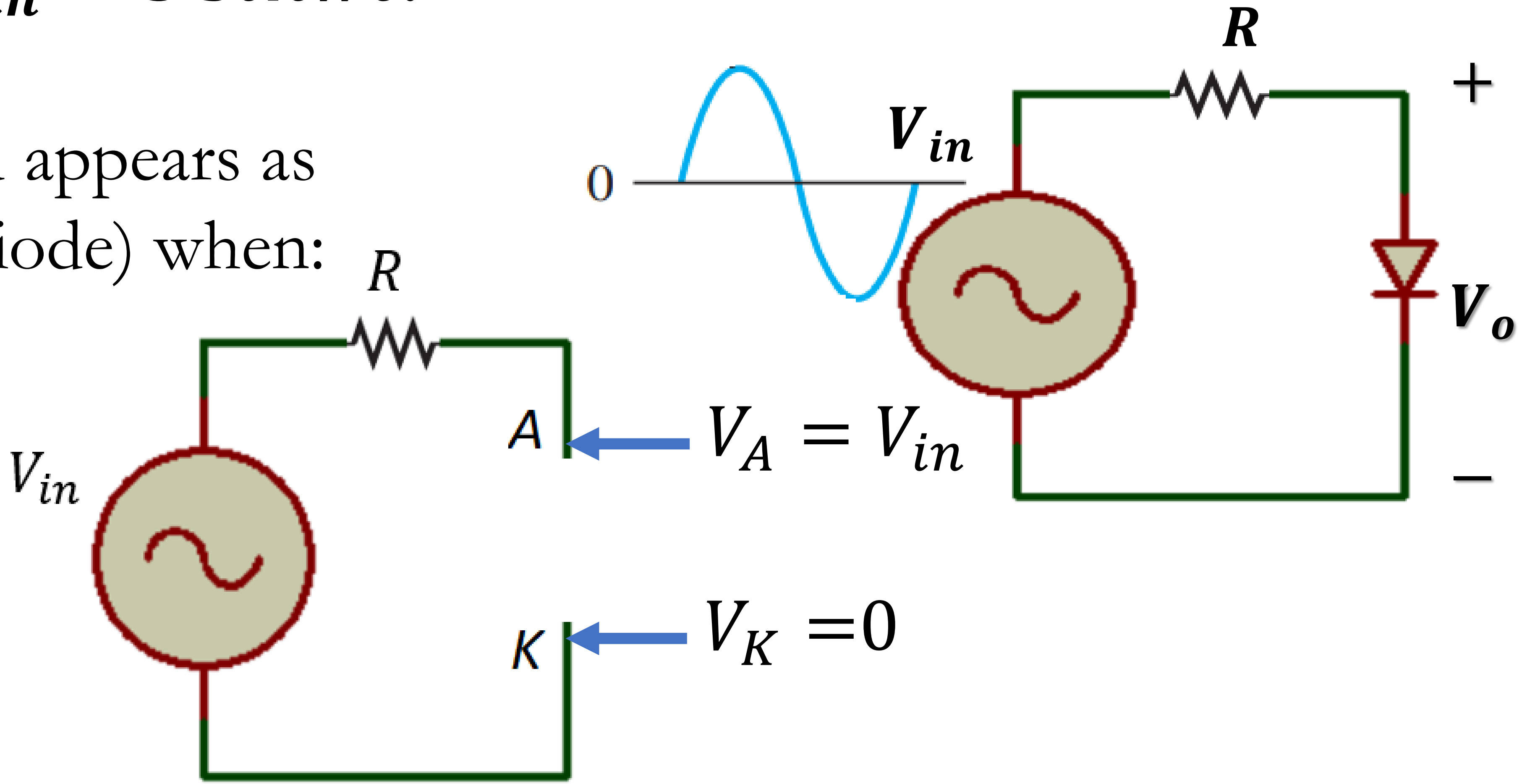
Sketch the output voltage waveform (V_o versus time), assuming ideal diode and $V_{in} = 5\ sinwt$.

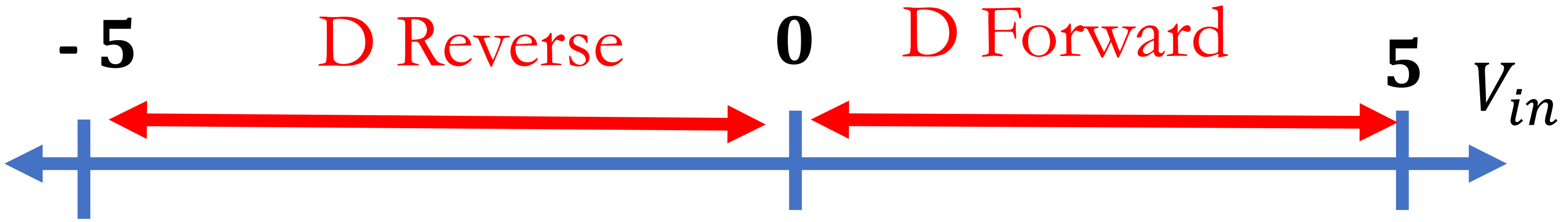
Diode is reverse and appears as open switch (ideal diode) when:

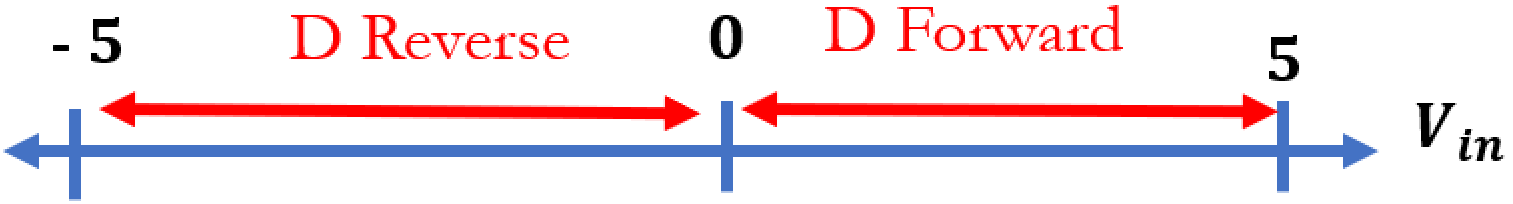
$$V_A \leq V_K + V_B$$

$$V_{in} \leq 0 + 0$$

$$V_{in} \leq 0$$

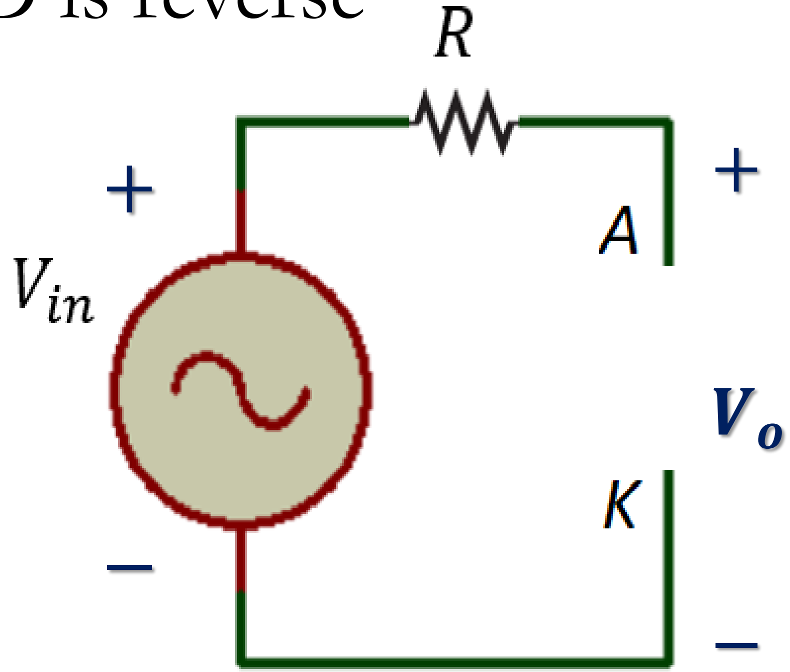






$[1]\ -5 \le V_{in} \le 0$

D is reverse

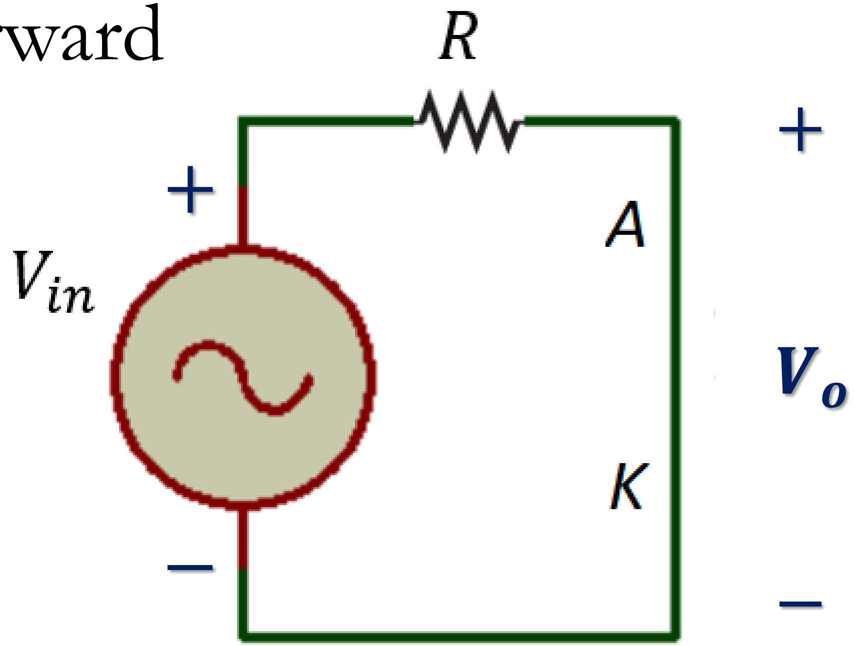


$$V_o - V_{in} = 0$$

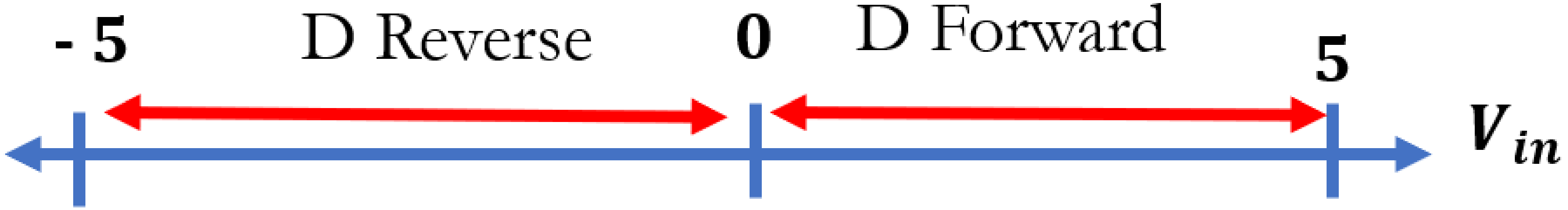
$$V_o = V_{in}$$

$[2]\ 0 < V_{in} \le 5$

D is forward



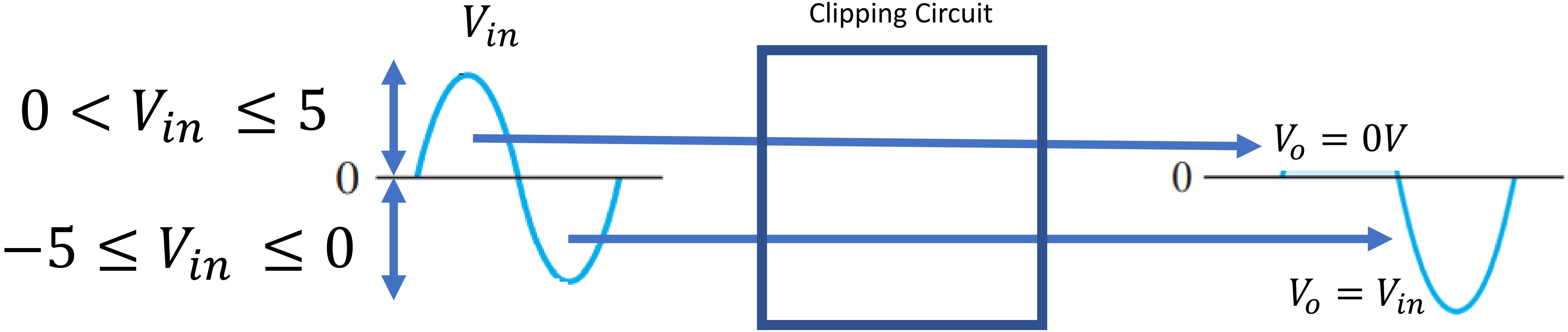
$$V_o = 0V$$



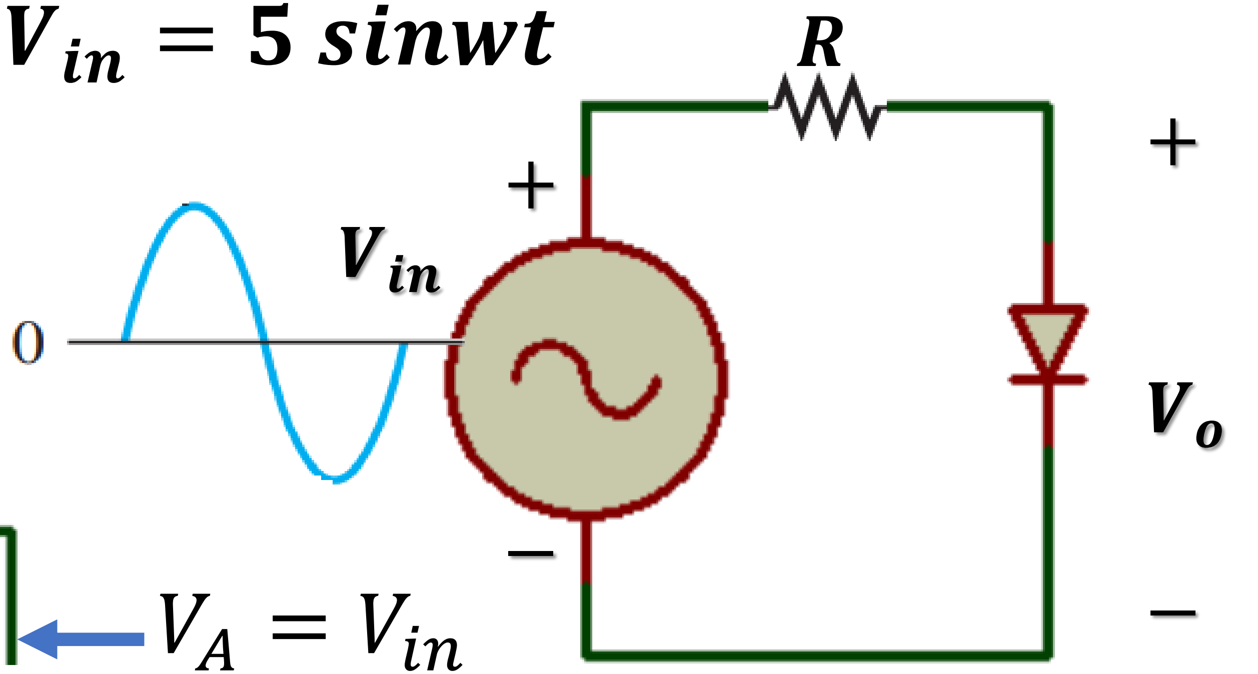
$-5 \le V_{in} \le 0$ $\qquad$ $0 < V_{in} \le 5$

$V_o = V_{in}$ $\qquad$ $V_o = 0V$

The output voltage waveform:



Sketch the output voltage waveform, assuming practical diode with barrier potential $V_B = 0.7V$ and $V_{in} = 5\ sinwt$

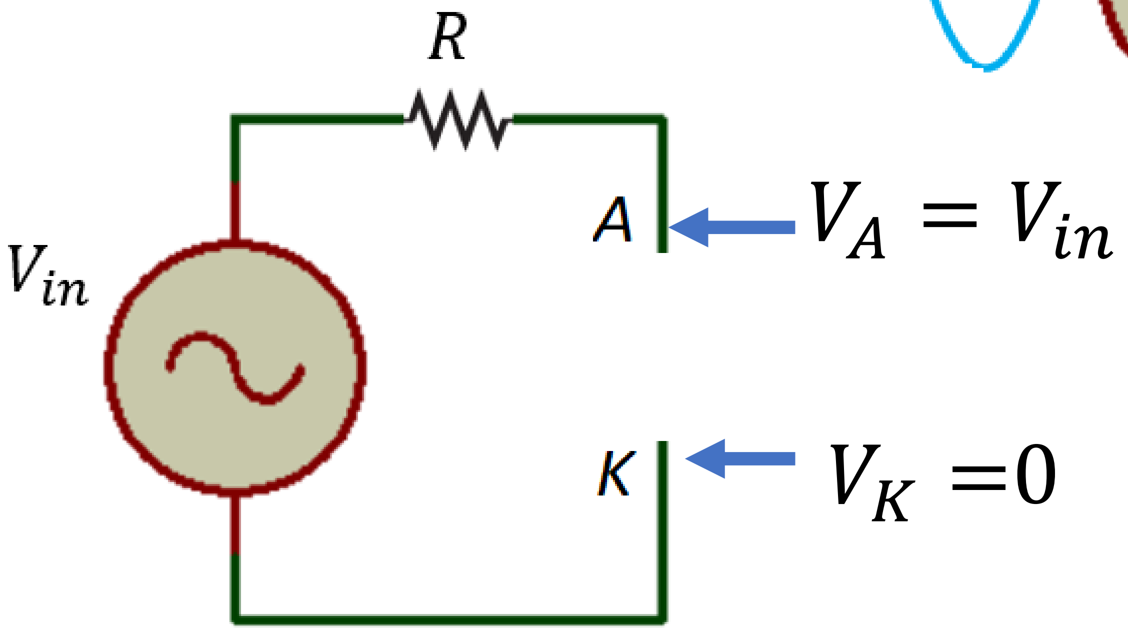


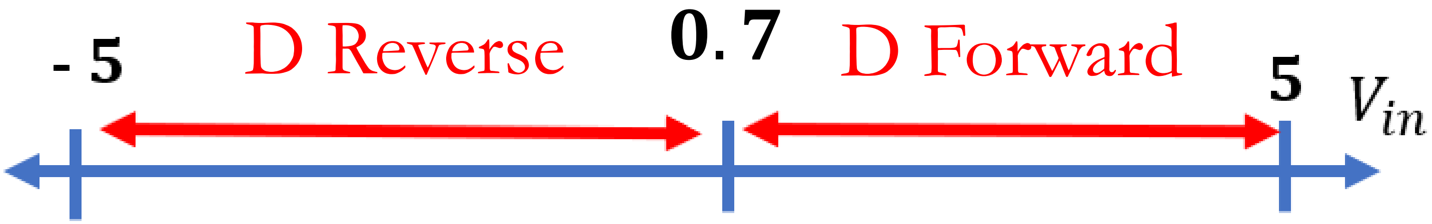
Diode is reverse and appears as open switch ($R_r = \infty$) when:

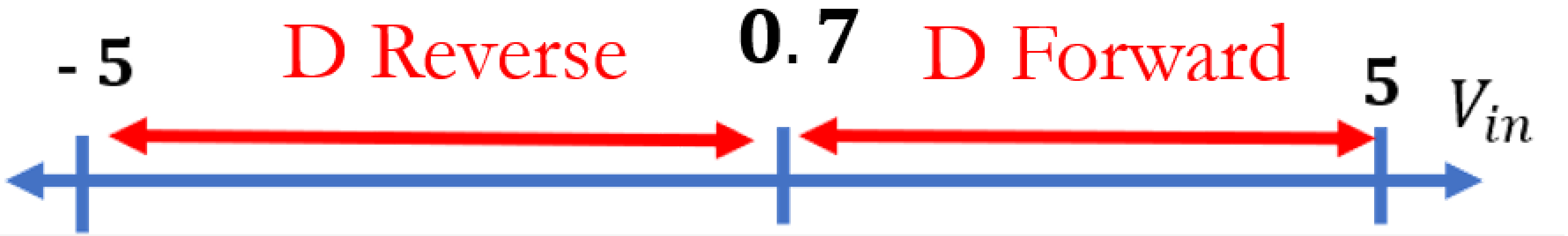
$$V_A \leq V_K + V_B$$

$$V_{in} \leq 0 + 0.7$$

$$V_{in} \leq 0.7$$

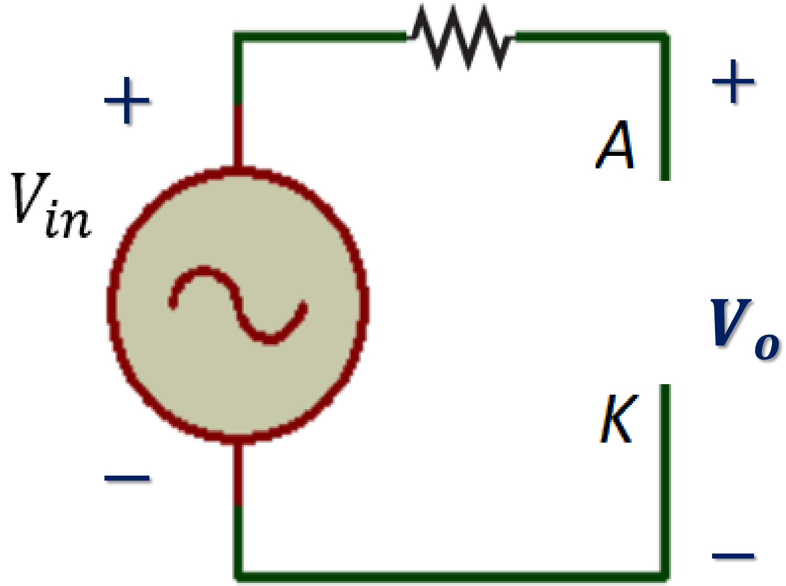






$[1] - 5 \leq V_{in} \leq 0.7$

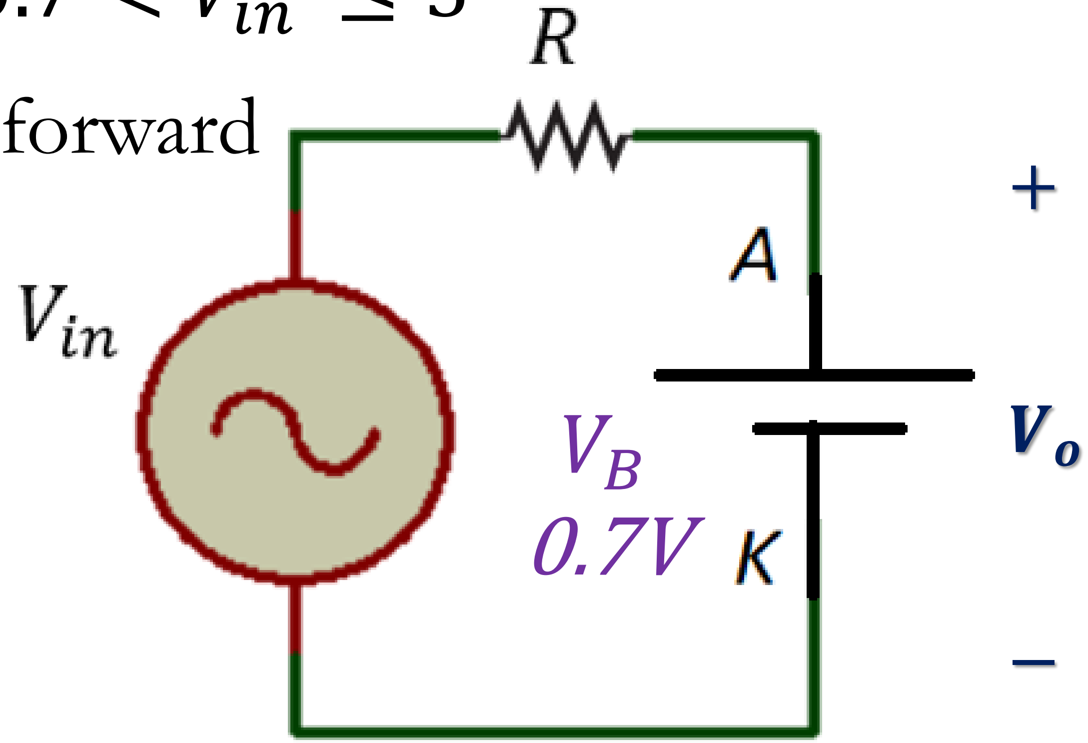
D is reverse



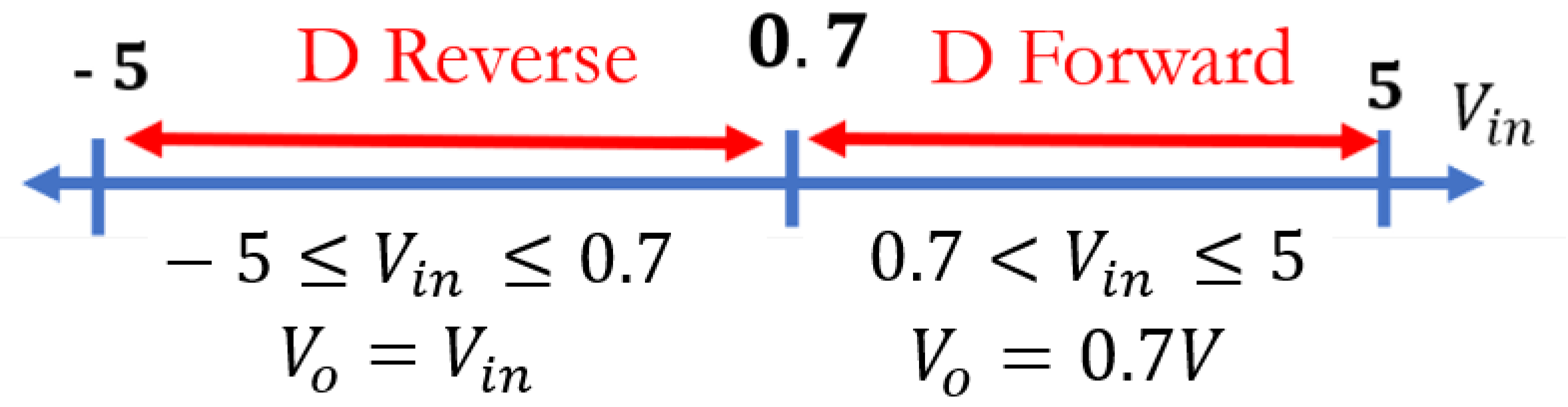
$$V_o - V_{in} = 0$$
$$V_o = V_{in}$$

$[2]\ 0.7 < V_{in} \leq 5$

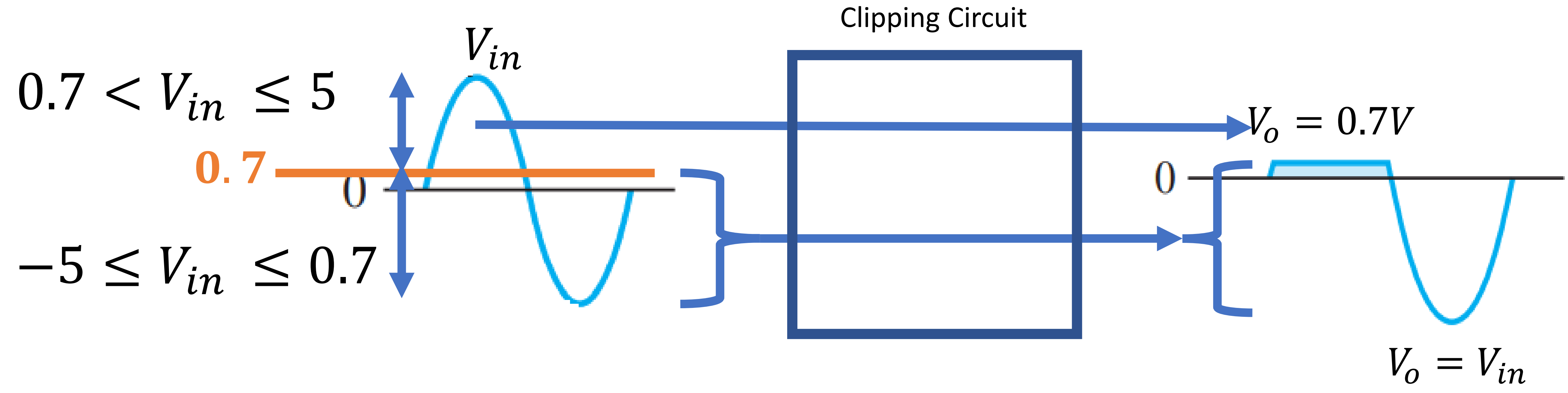
D is forward



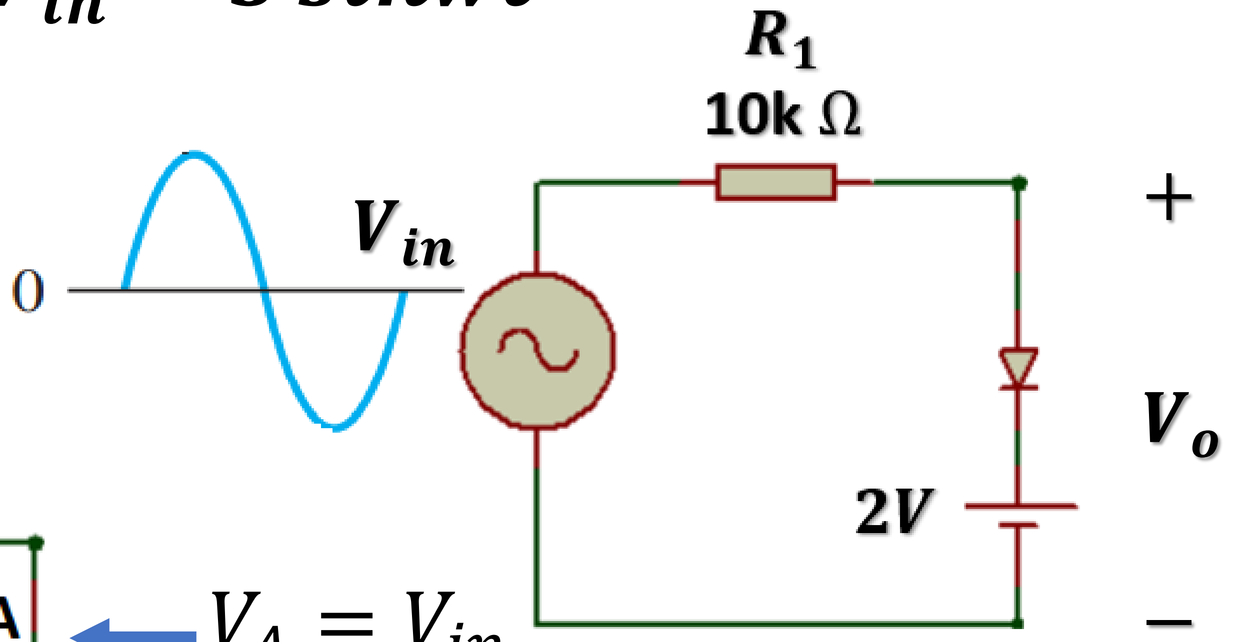
$$V_o - 0.7 = 0$$
$$V_o = 0.7V$$



The output voltage waveform:



Sketch the output voltage waveform, assuming practical diode with barrier potential $V_B = 0.7V$ and $V_{in} = 5\ sinwt$

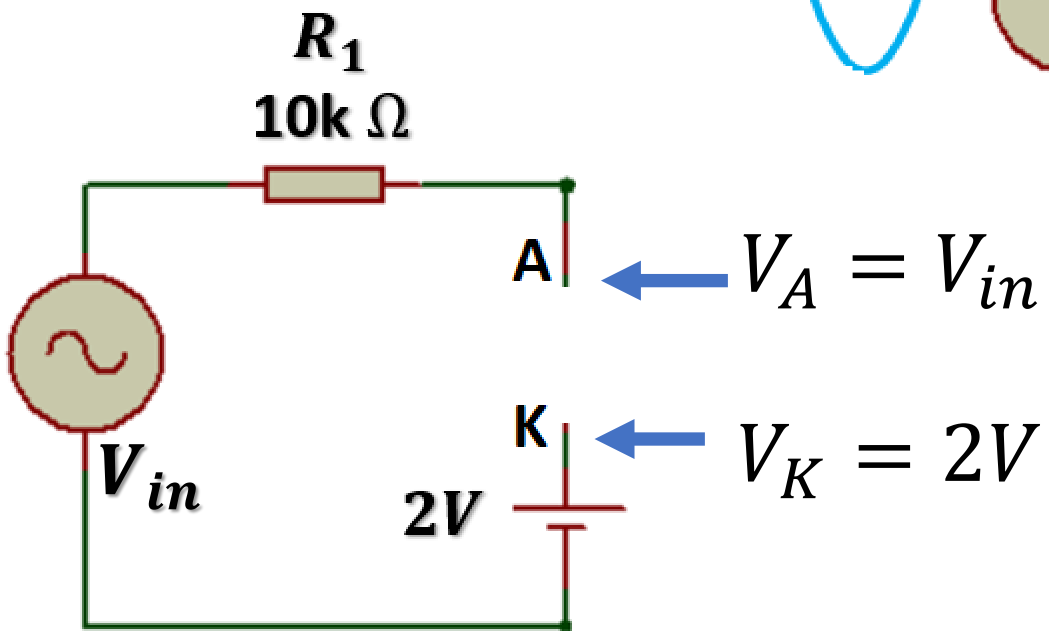


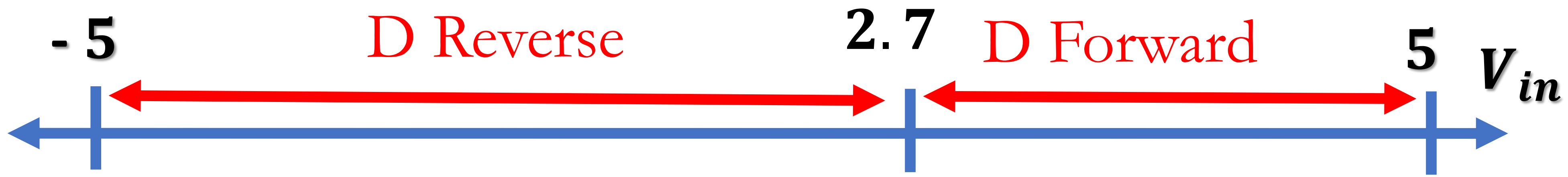
Diode is reverse and appears as open switch ($R_r = \infty$) when:

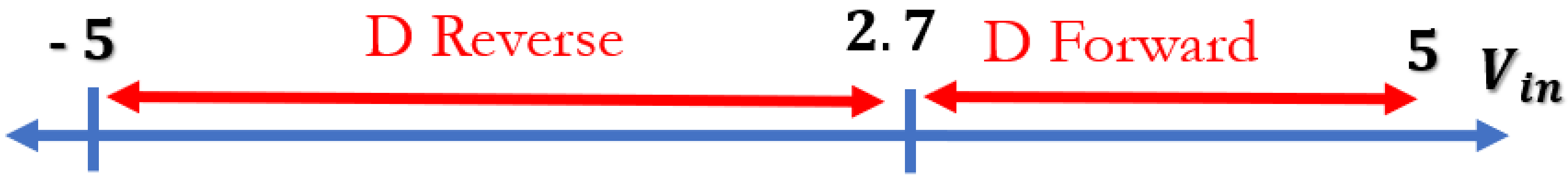
$$V_A \leq V_K + V_B$$

$$V_{in} \leq 2 + 0.7$$

$$V_{in} \leq 2.7$$

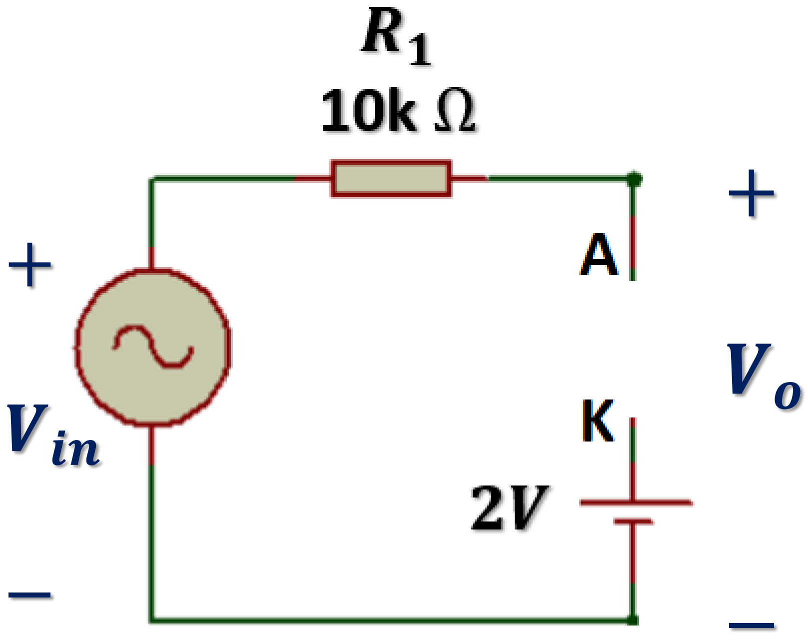






$[1]\ -5 \leq V_{in} \leq 2.7$

D is reverse

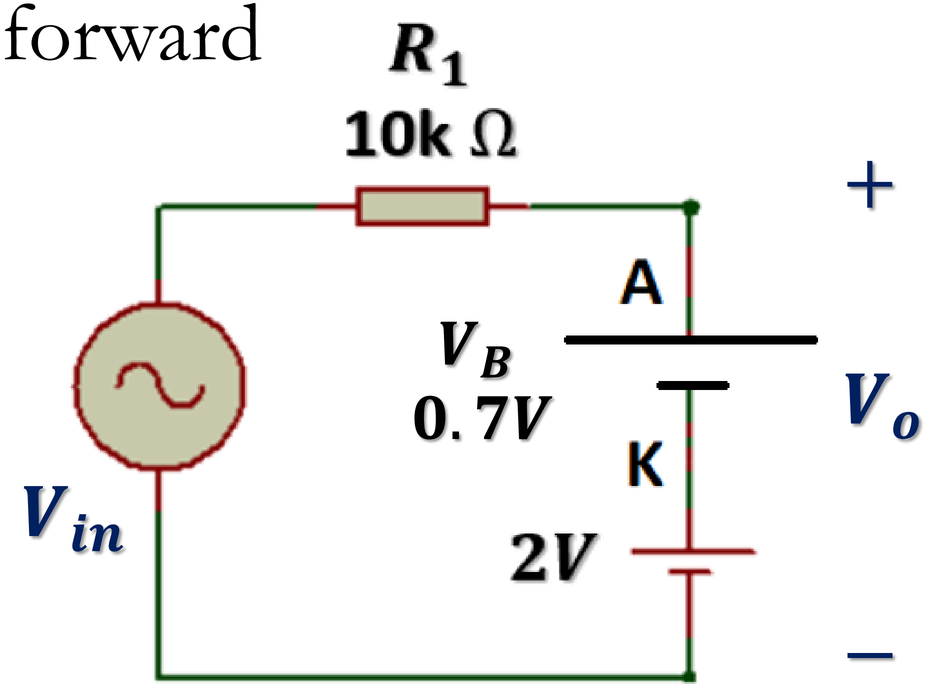


$$V_o - V_{in} = 0$$

$$V_o = V_{in}$$

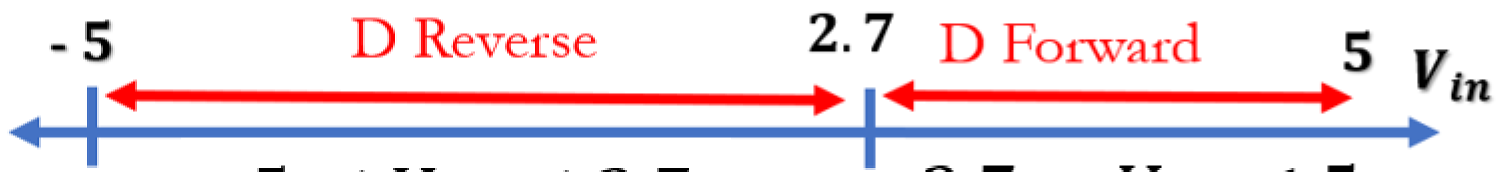
$[2]\ 2.7 < V_{in} \leq 5$

D is forward



$$V_o - 0.7 - 2 = 0$$

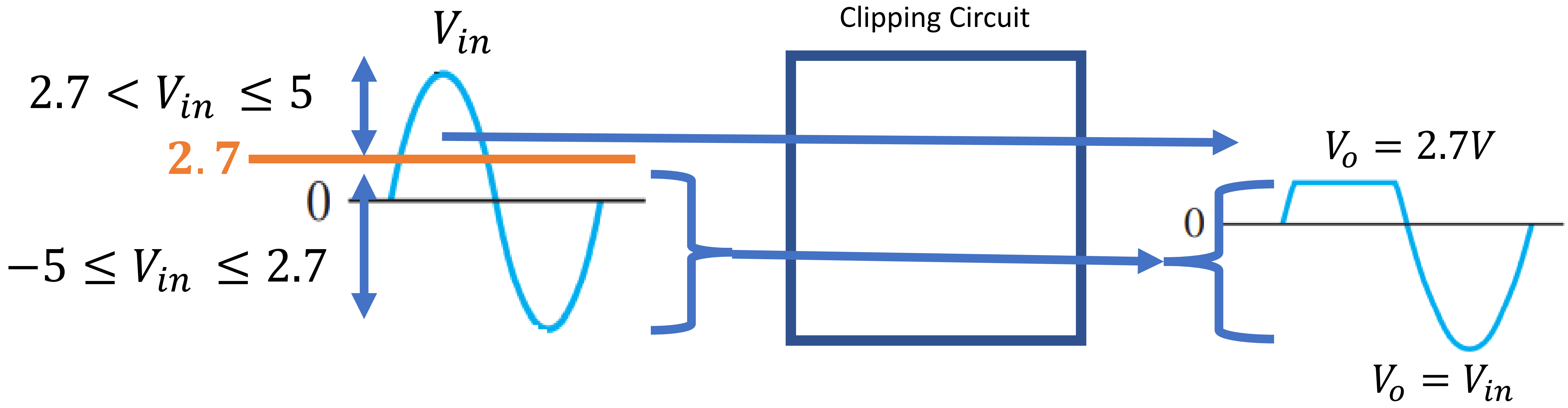
$$V_o = 2.7V$$



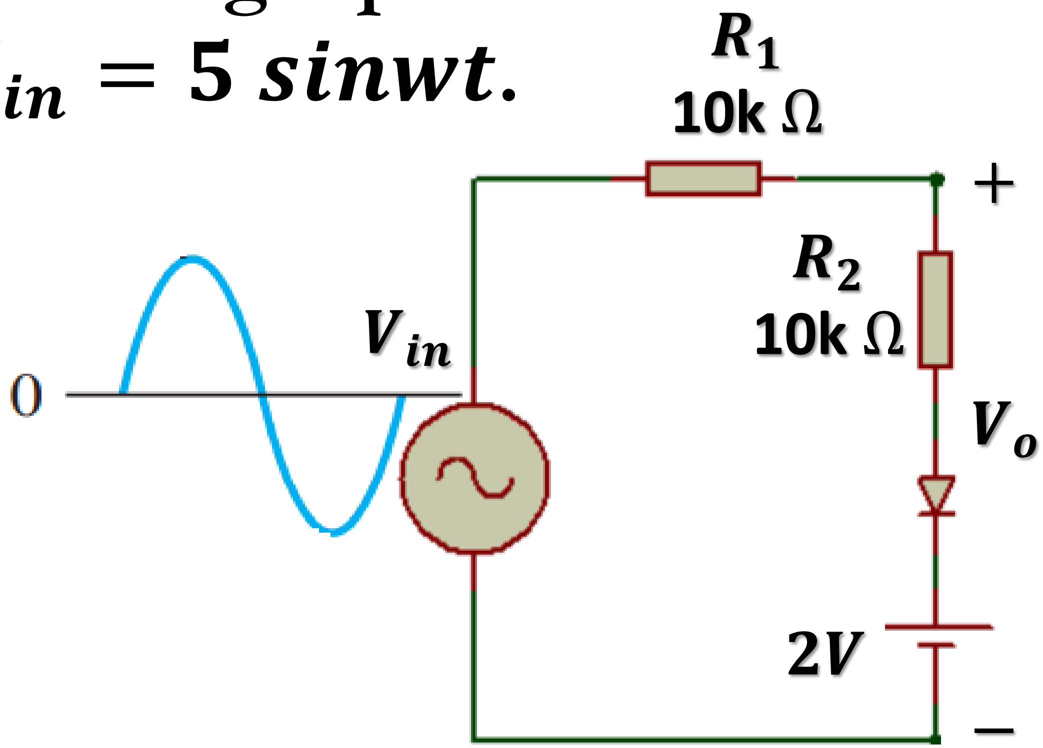
$-5 \leq V_{in} \leq 2.7$ $\quad$ $2.7 < V_{in} \leq 5$

$V_o = V_{in}$ $\quad$ $V_o = 2.7V$

The output voltage waveform:



Sketch the output voltage waveform, assuming a practical diode with barrier potential $V_B = 0.6V$ and $V_{in} = 5\ sinwt$.

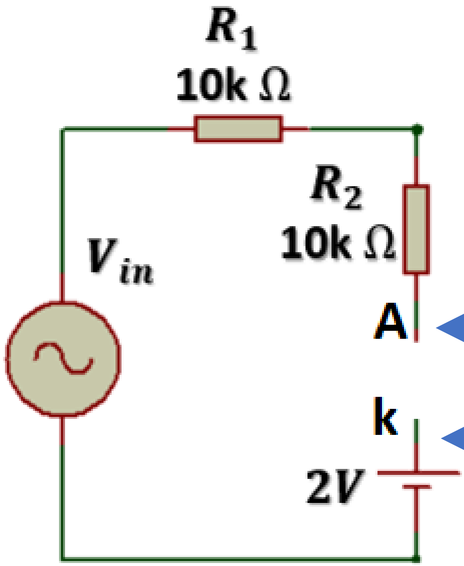


Diode is reverse and appears as open switch ($R_r = \infty$) when:

$$V_A \leq V_K + V_B$$

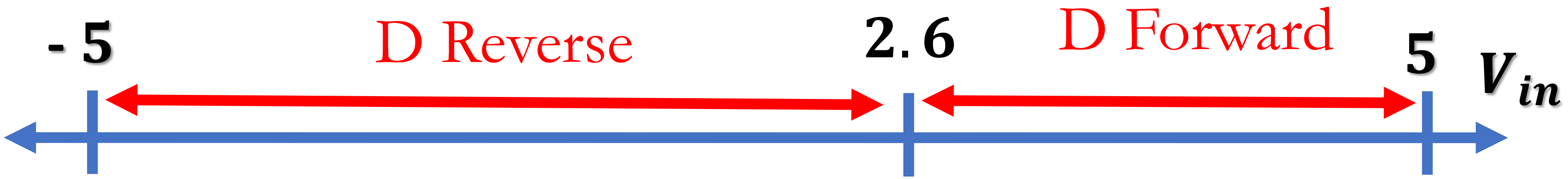
$$V_{in} \leq 2 + 0.6$$

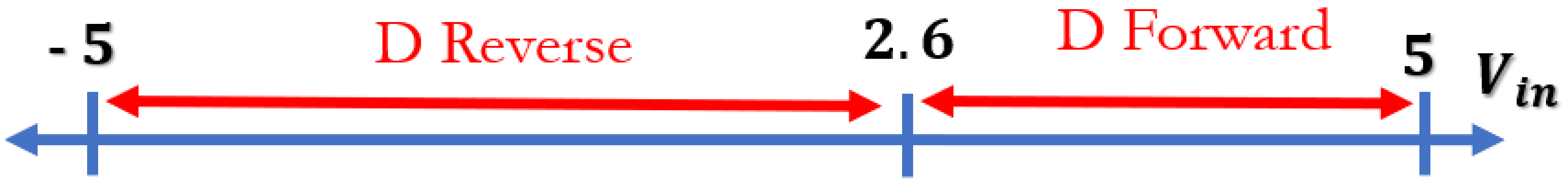
$$V_{in} \leq 2.6$$



$$V_A = V_{in}$$

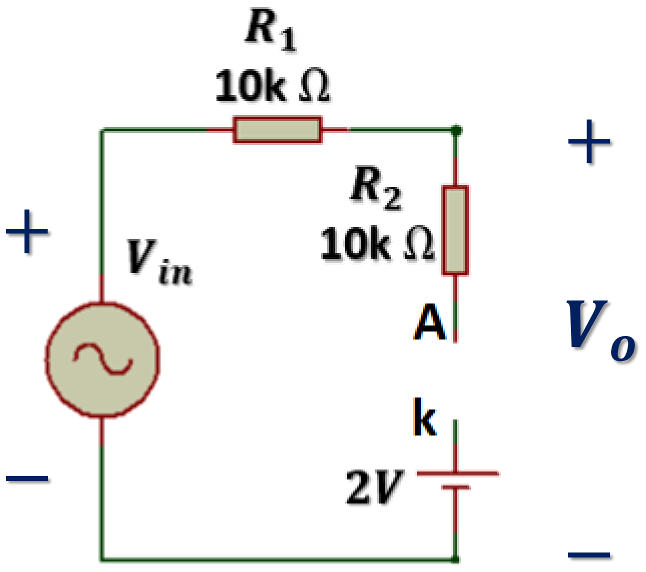
$$V_K = 2V$$





$[1] \; -5 \leq V_{in} \leq 2.6$

D is reverse

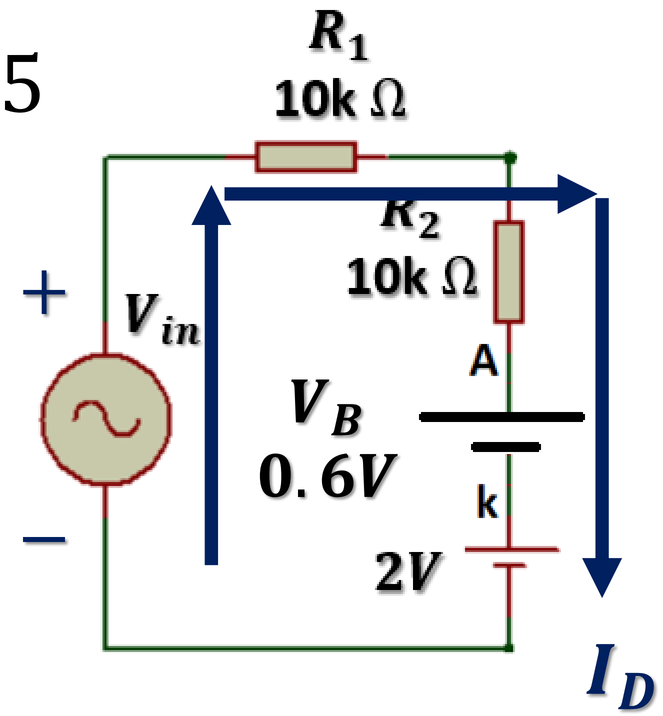


$$V_o - V_{in} = 0$$

$$V_o = V_{in}$$

$[2] \; 2.6 < V_{in} \leq 5$

D is forward

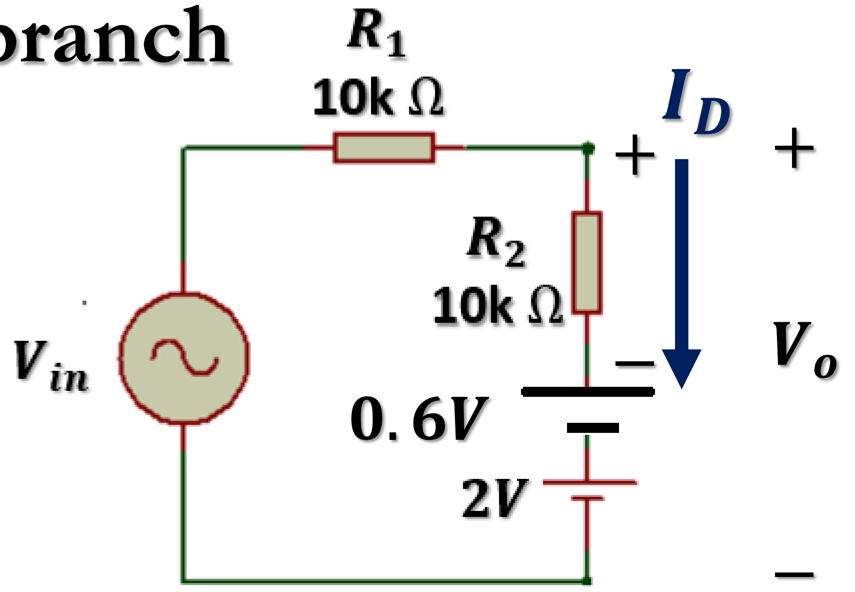


$$\sum \boldsymbol{V \; in \; closed \; loop = 0}$$

$$V_{in} - I_D(10k + 10k) - 0.6 - 2 = 0$$

$$\frac{V_{in} - 2.6}{20k} = I_D$$

To find $\boldsymbol{V_o}$, write KVL between $\boldsymbol{V_o}$ and **the branch** (that you calculate on it the voltage drop):



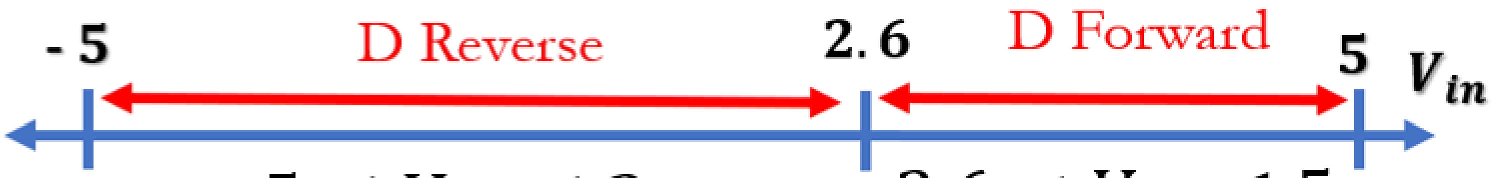
$$V_o - I_D(10k) - 0.6 - 2 = 0$$

$$V_o = I_D(10k) + 2.6$$

$$\because I_D = \frac{V_{in} - 2.6}{20k}$$

$$V_o = \left(\frac{V_{in} - 2.6}{20k}\right)(10k) + 2.6$$

$$V_o = \frac{V_{in} - 2.6}{2} + 2.6$$



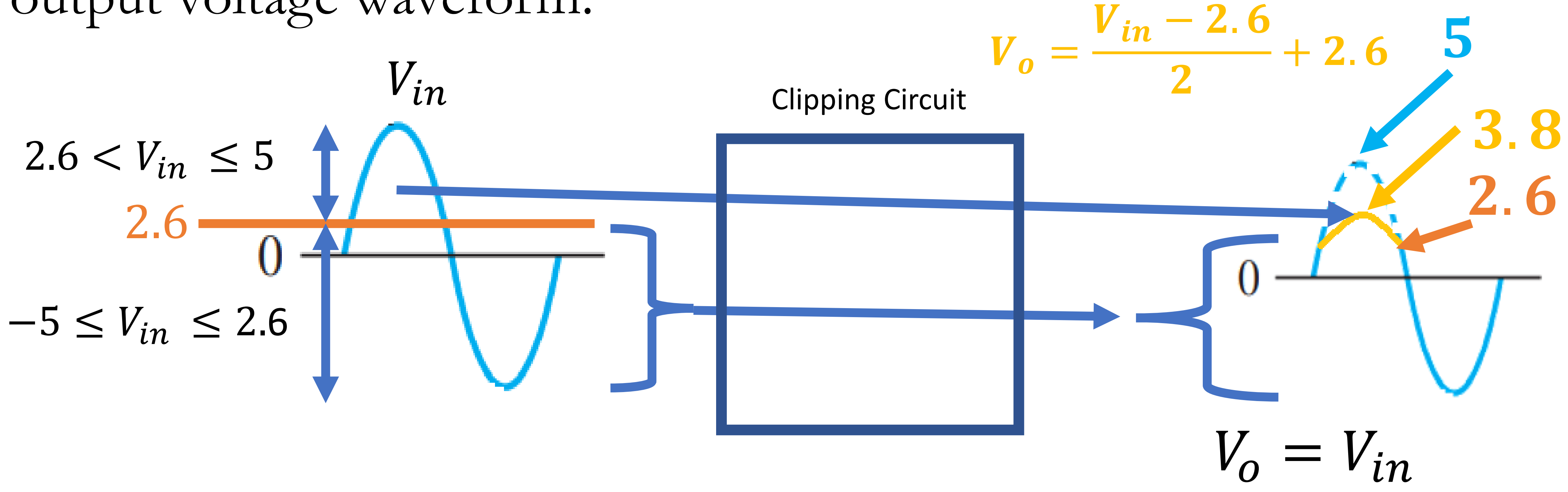
$-5 \leq V_{in} \leq 2.6$

$V_o = V_{in}$

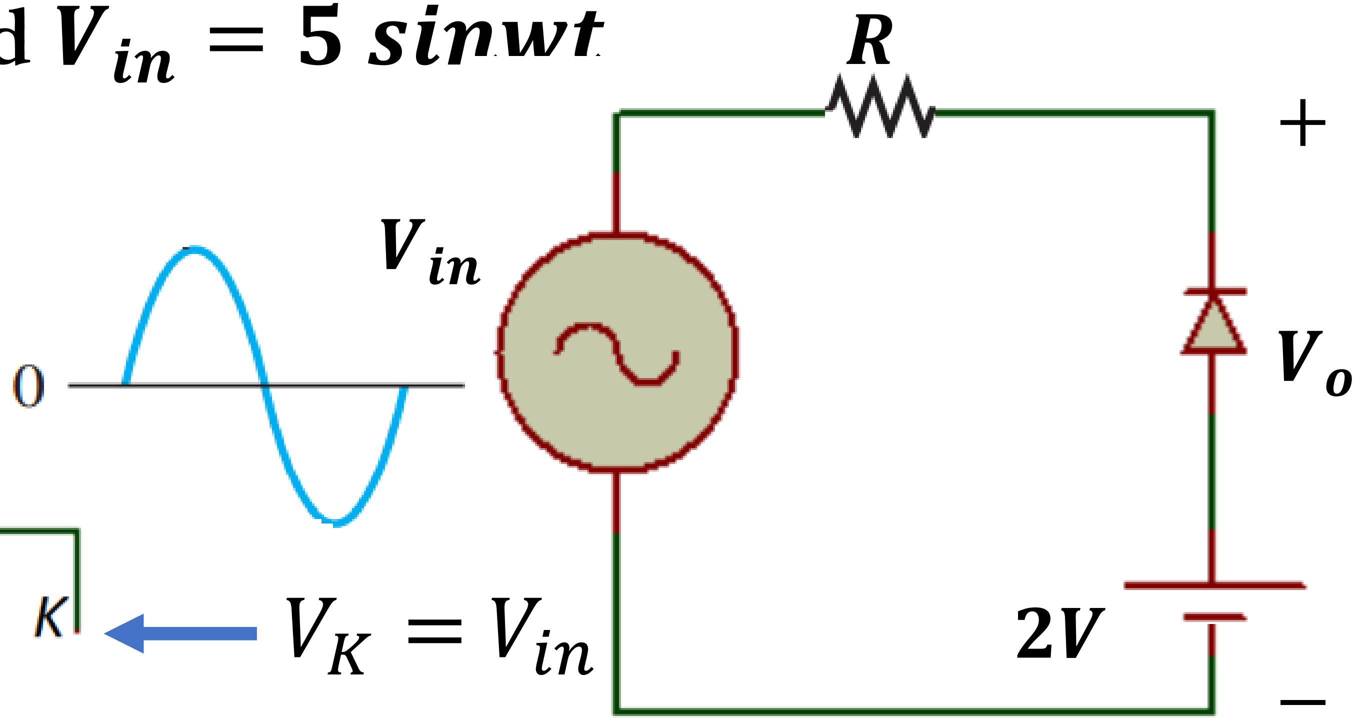
$2.6 < V_{in} \leq 5$

$$V_o = \frac{V_{in} - 2.6}{2} + 2.6$$

The output voltage waveform:



Sketch the output voltage waveform, assuming practical diode with barrier potential $V_B = 0.7V$ and $V_{in} = 5\ sinwt$



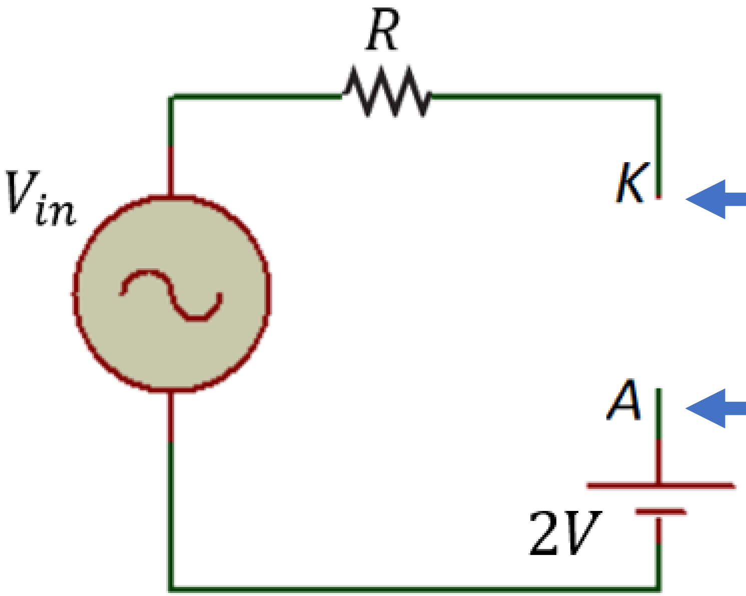
Diode is reverse and appears as open switch ($R_r = \infty$) when:

$$V_A \leq V_K + V_B$$

$$2 \leq V_{in} + 0.7$$

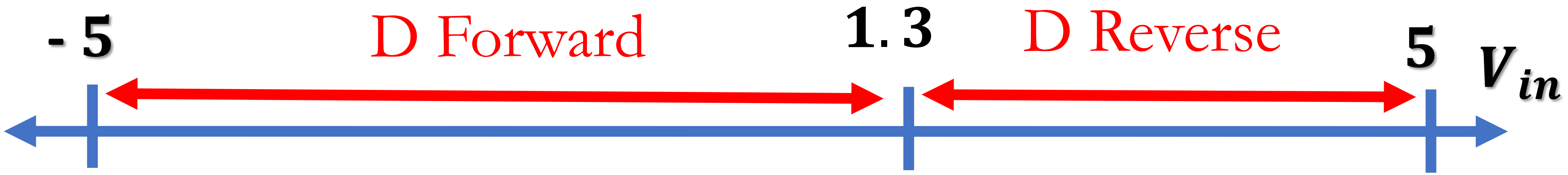
$$2 - 0.7 \leq V_{in}$$

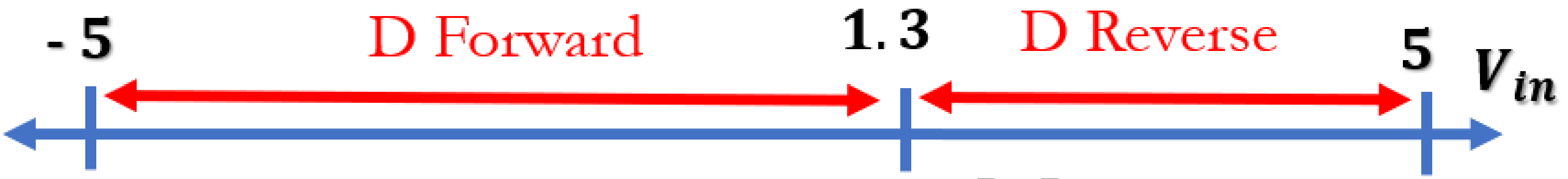
$$1.3 \leq V_{in}$$



$V_K = V_{in}$

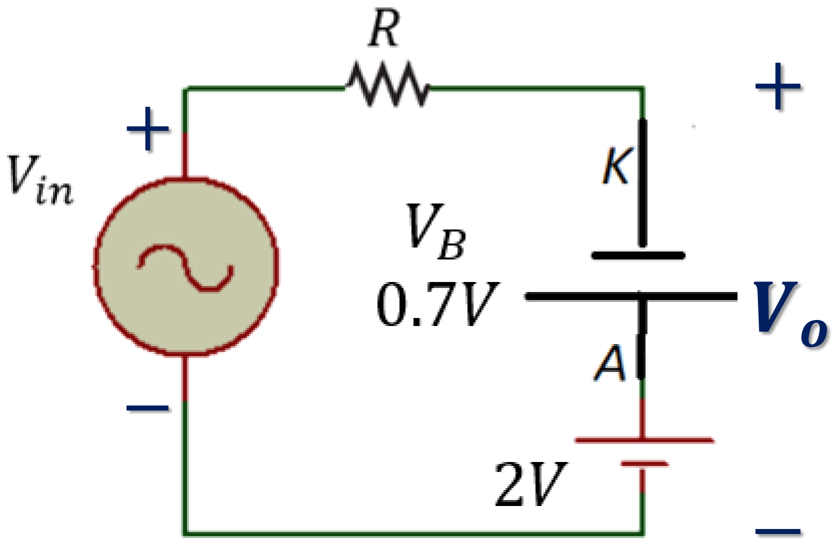
$V_A = 2V$





$[1]\ -5 \le V_{in} \le 1.3$

D is forward

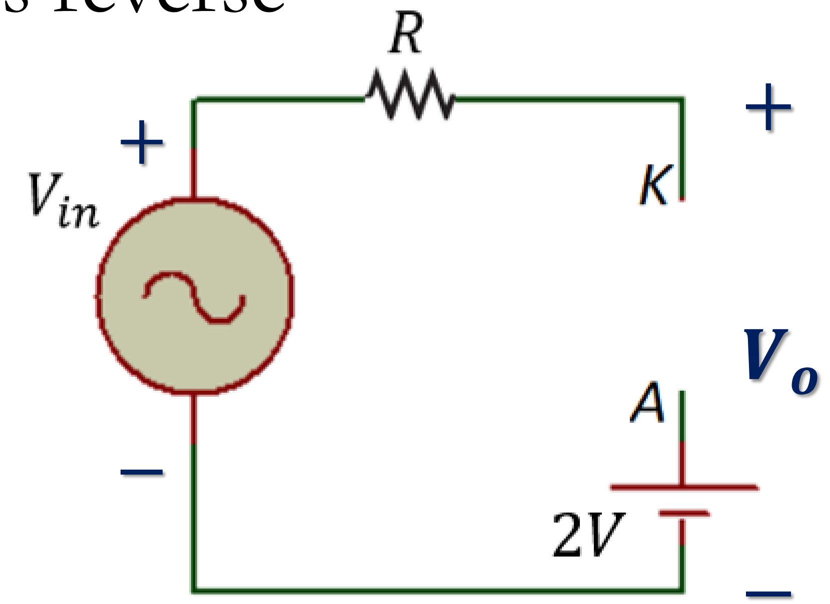


$$V_o + 0.7 - 2 = 0$$

$$V_o = 2 - 0.7 = 1.3V$$

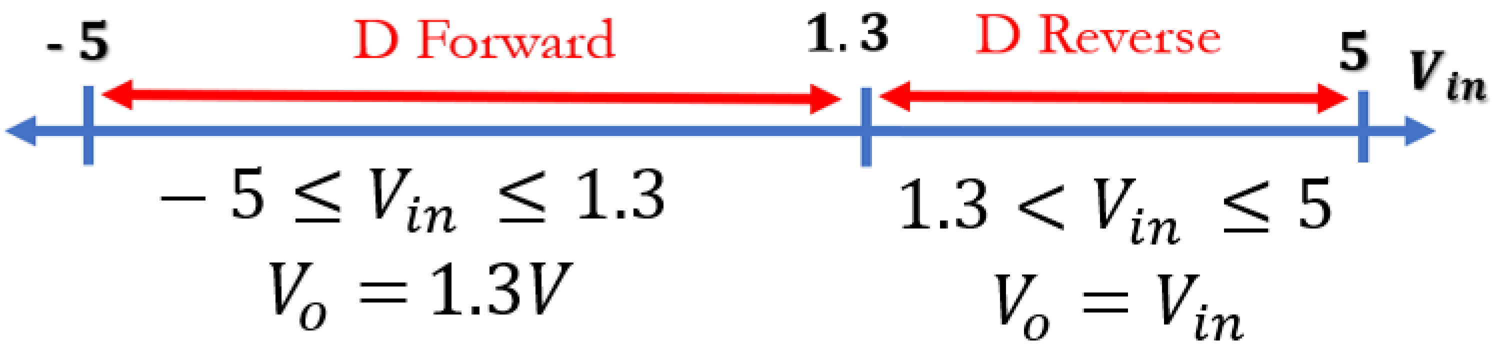
$[2]\ 1.3 < V_{in} \le 5$

D is reverse

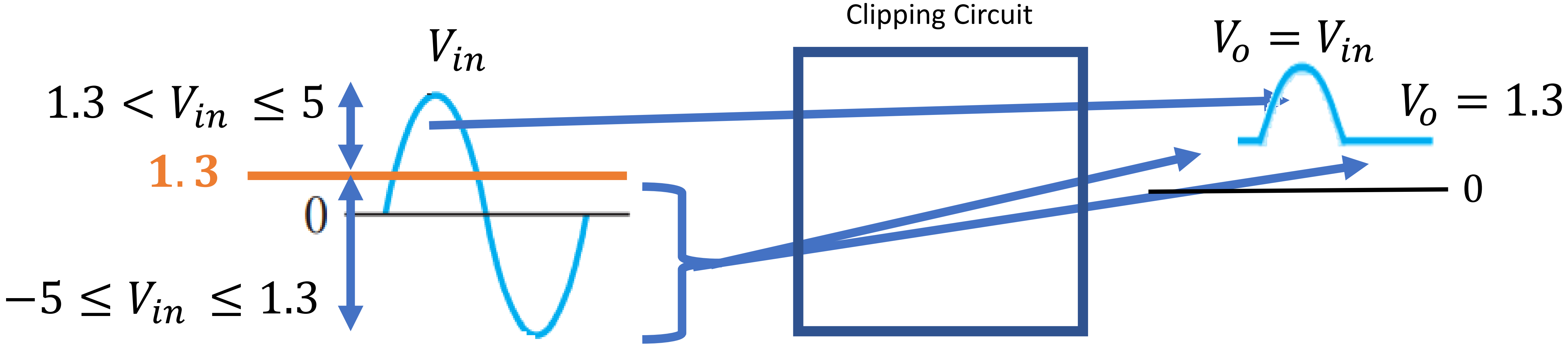


$$V_o - V_{in} = 0$$

$$V_o = V_{in}$$



The output voltage waveform:



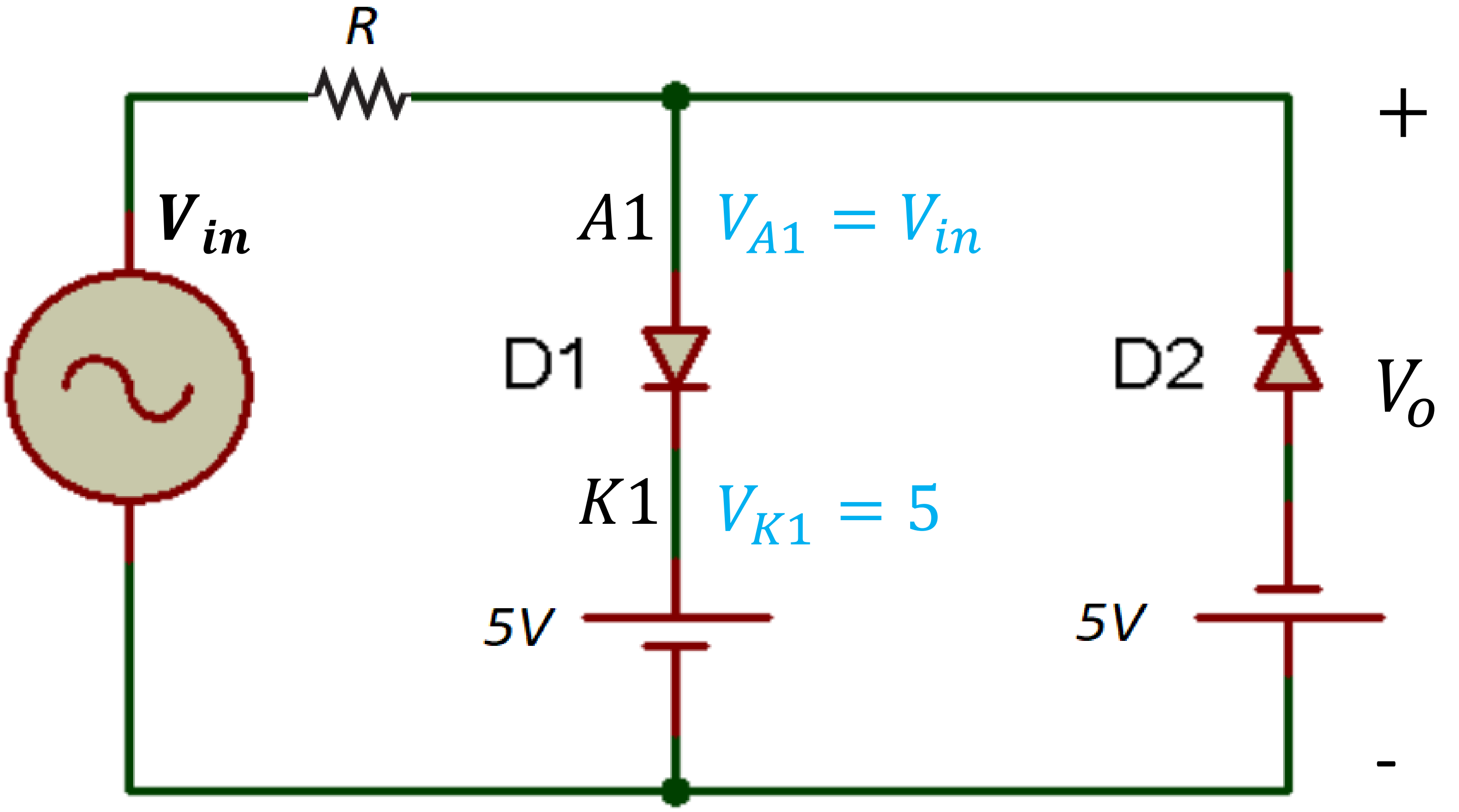
Assume practical diodes with barrier potential $\boldsymbol{V_B = 0.7V}$.
Sketch the output voltage waveform when $\boldsymbol{V_{in} = 10sinwt}$.

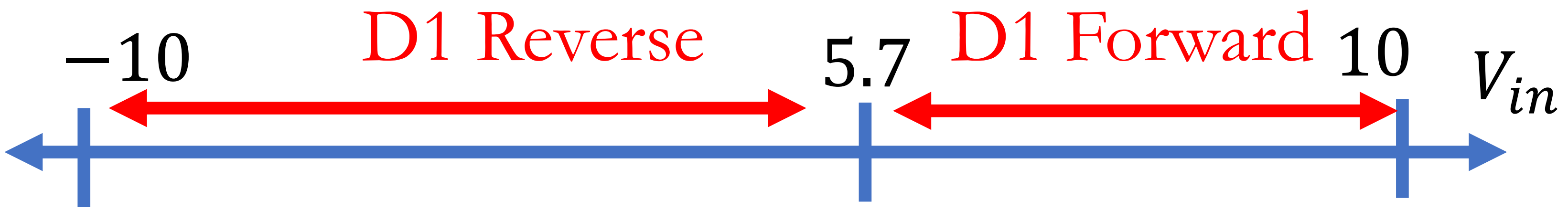
D1 is reverse and appears as open switch ($R_r = \infty$) when:

$$V_{A1} \leq V_{K1} + V_B$$

$$V_{in} \leq 5 + 0.7$$

$$V_{in} \leq 5.7$$





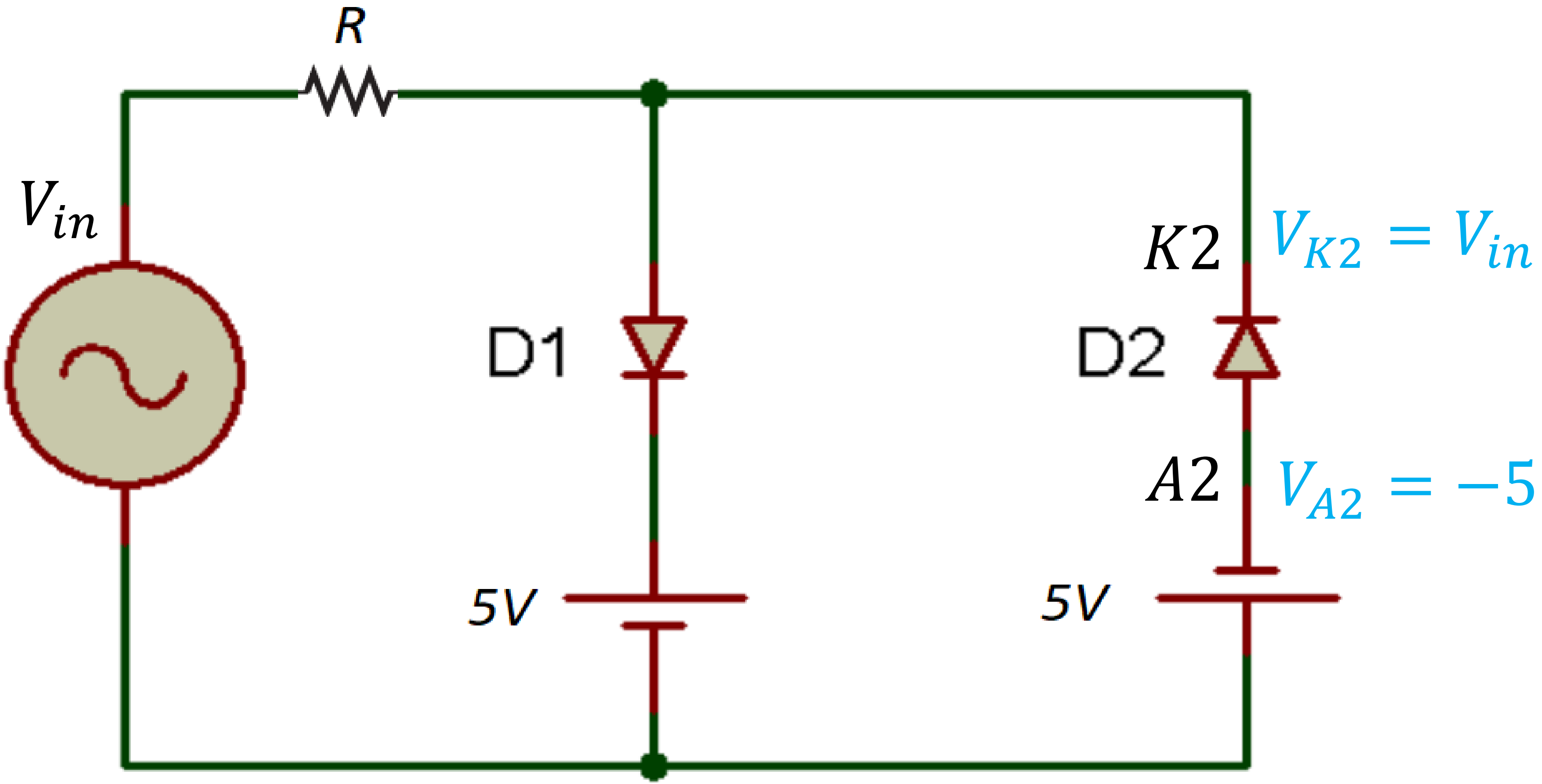
D2 is reverse and appears as open switch $(R_r = \infty)$ when:

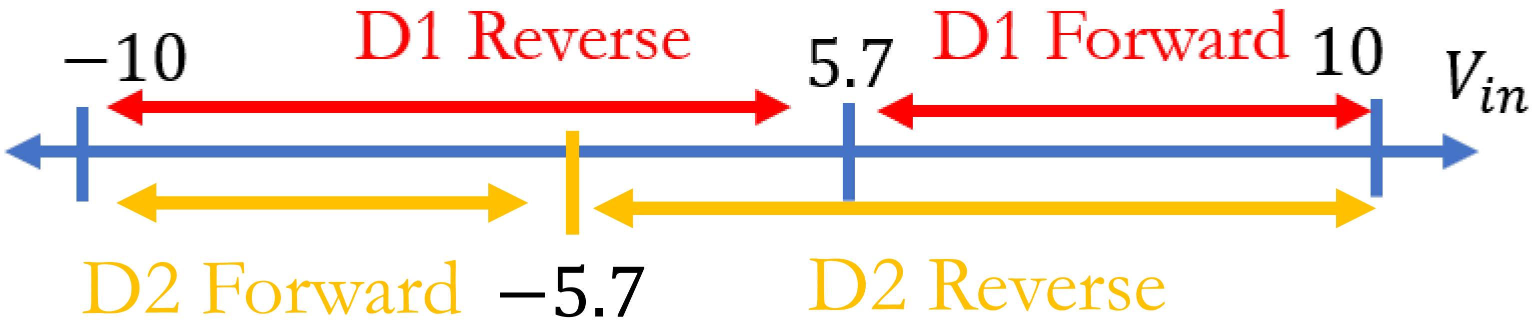
$$V_{A2} \leq V_{K2} + V_B$$

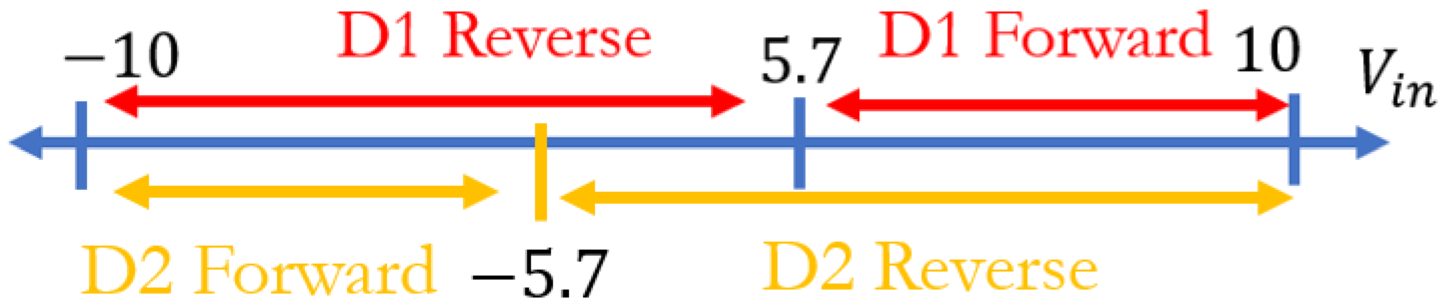
$$-5 \leq V_{in} + 0.7$$

$$-5 - 0.7 \leq V_{in}$$

$$-5.7 \leq V_{in}$$







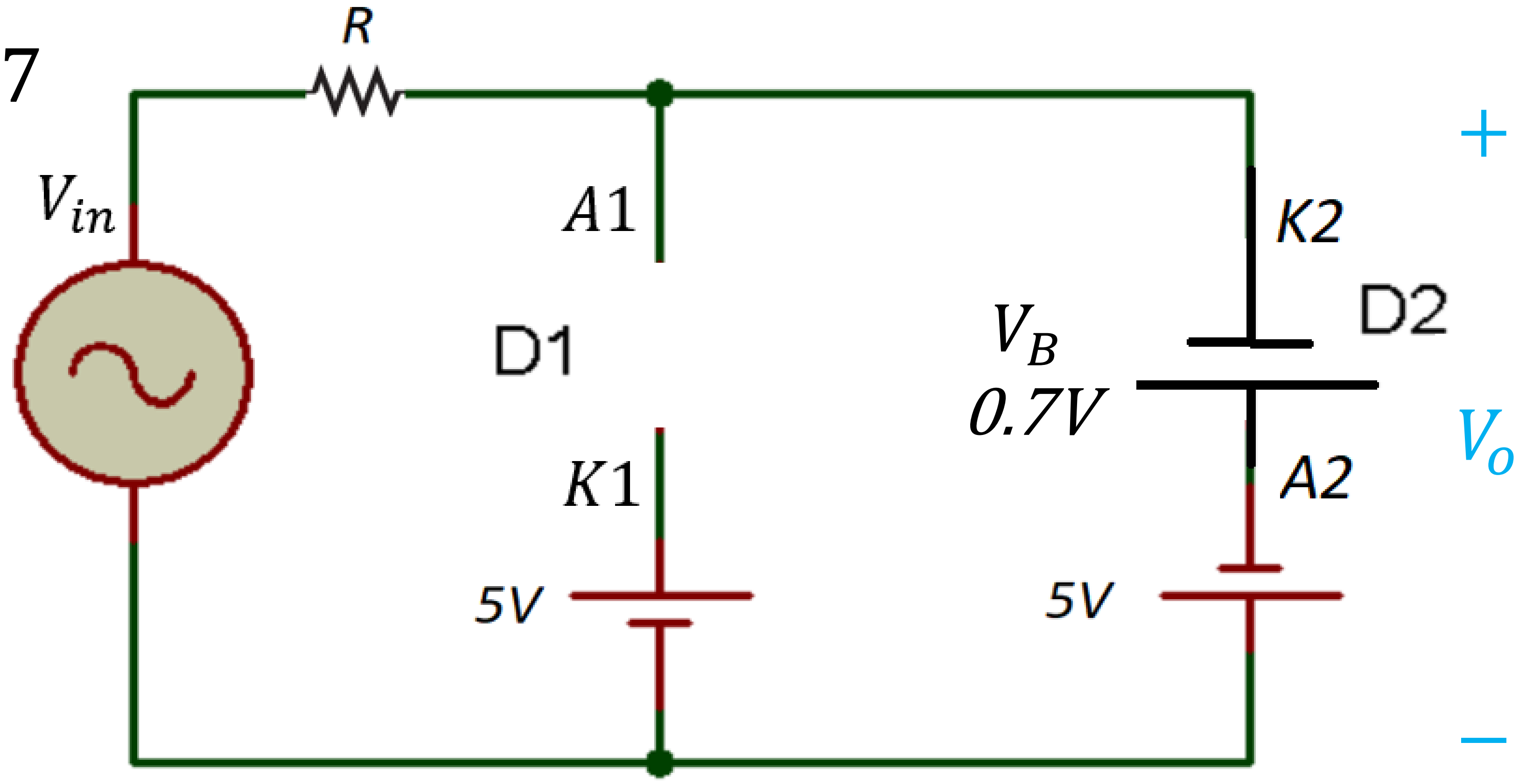
[1] $-10 \leq V_{in} < -5.7$

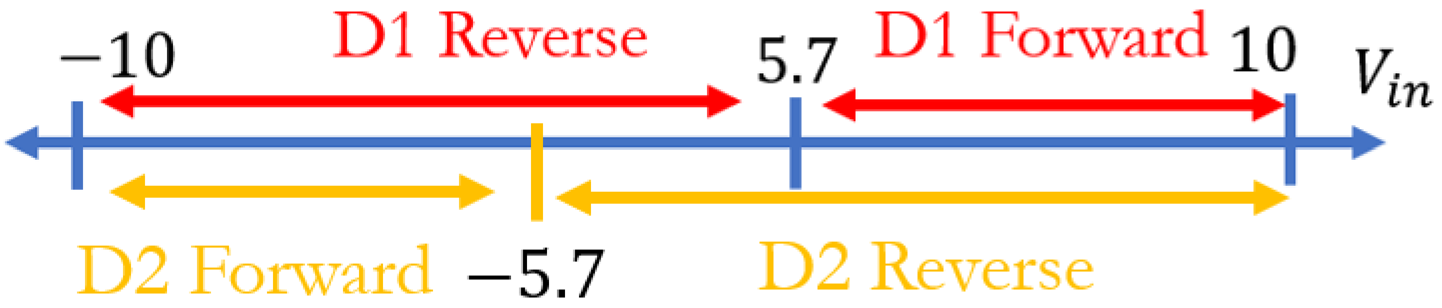
D1 is reverse

D2 is forward

$V_o + 0.7 + 5 = 0$

$V_o = -5.7\text{V}$





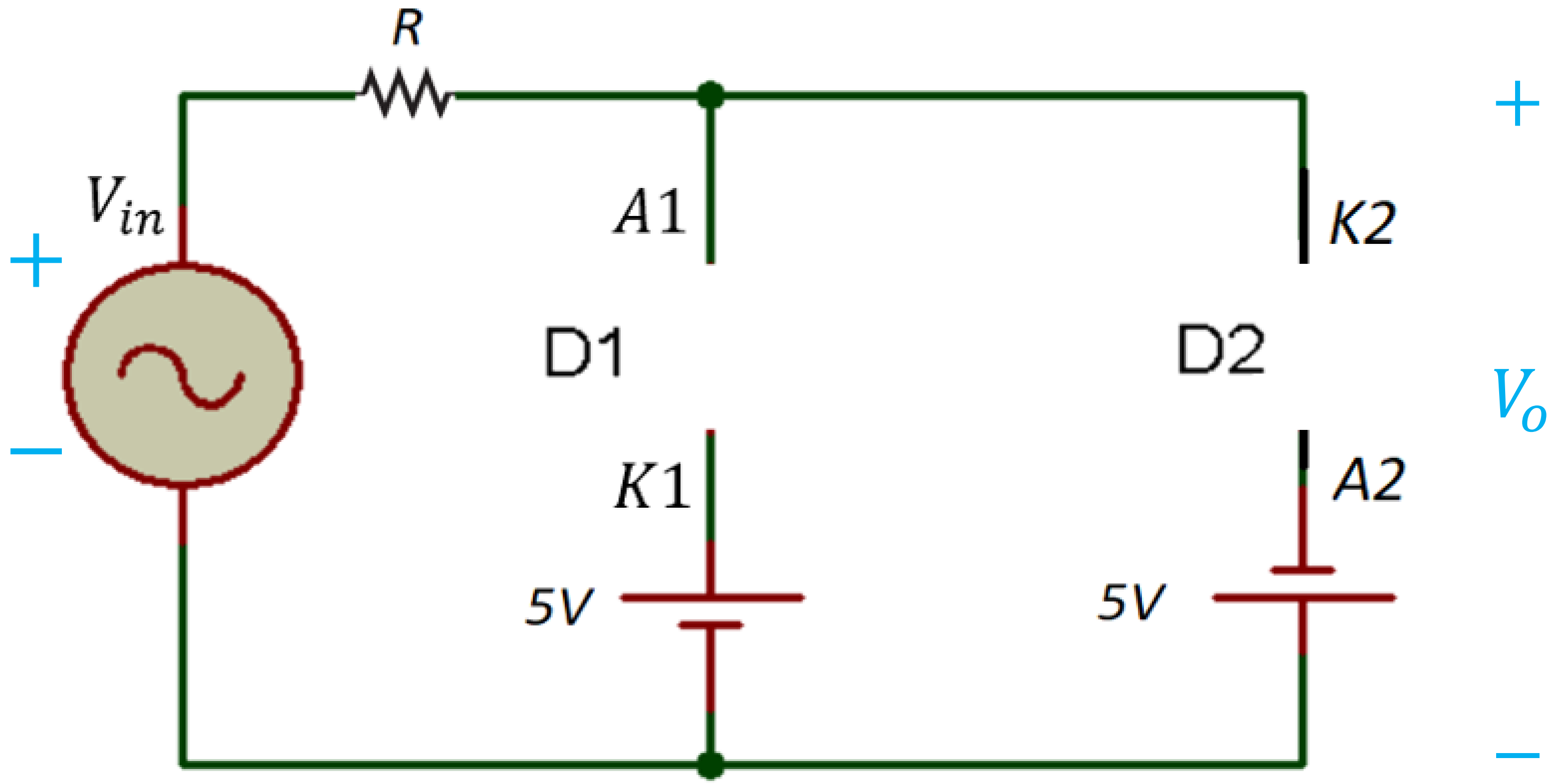
[2] $-5.7 \leq V_{in} \leq 5.7$

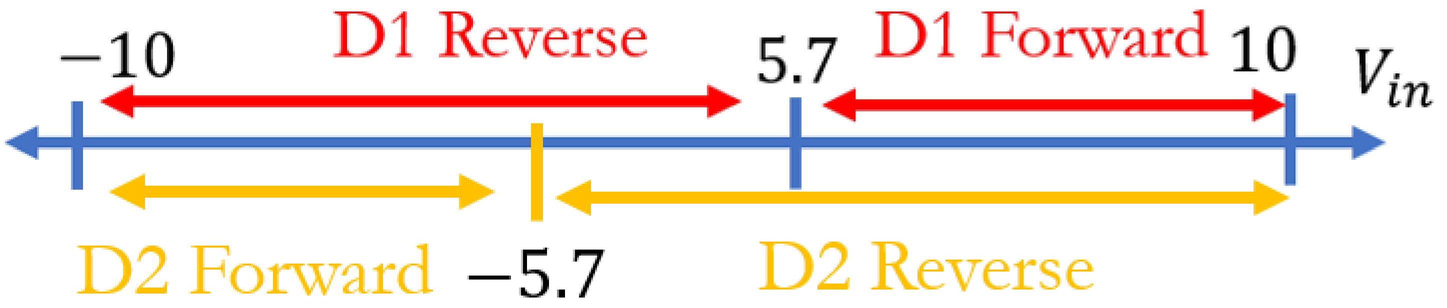
D1 is reverse

D2 is reverse

$$V_o - V_{in} = 0$$

$$V_o = V_{in}$$





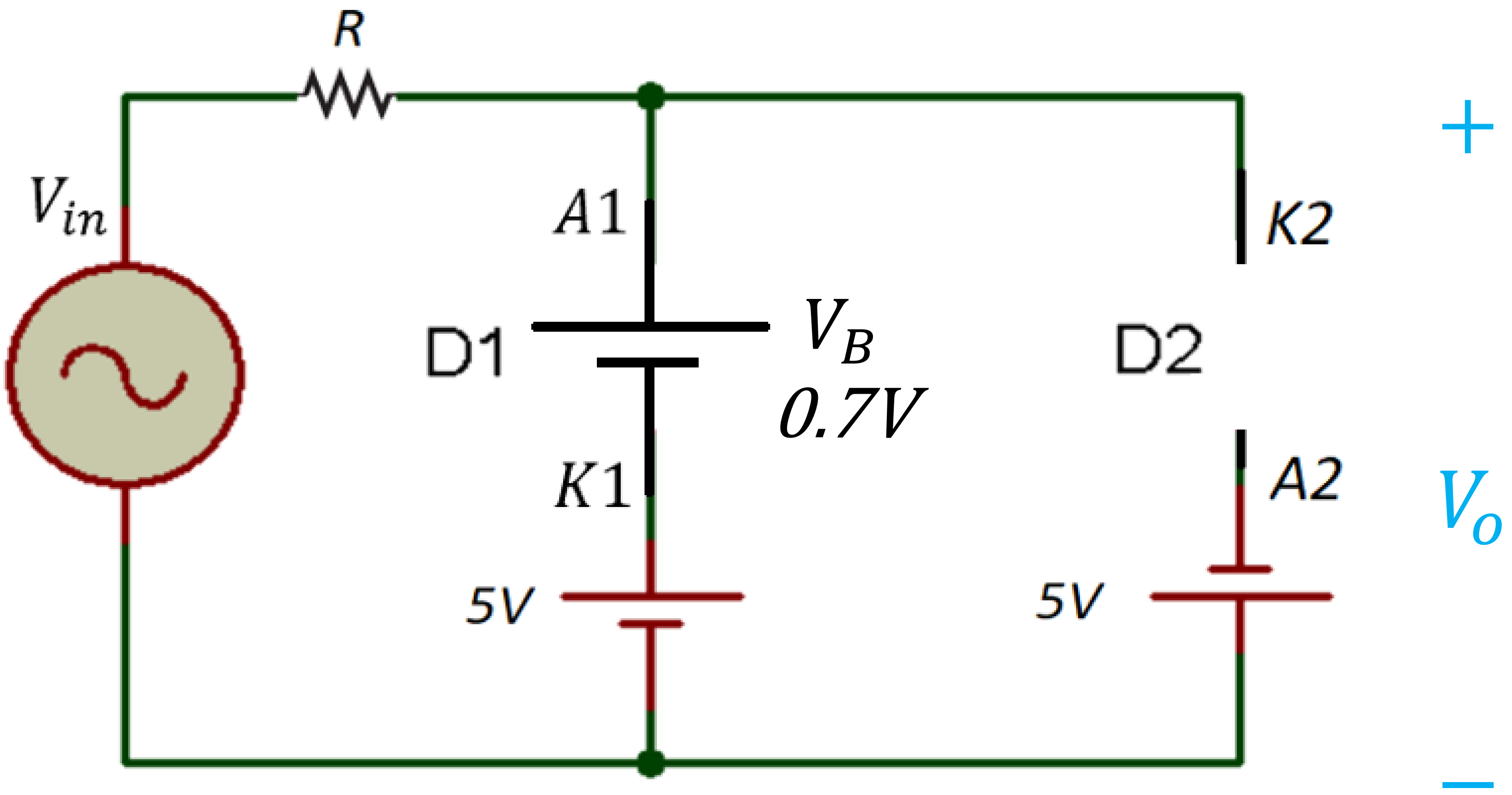
[3] $5.7 < V_{in} \leq 10$

D1 is forward

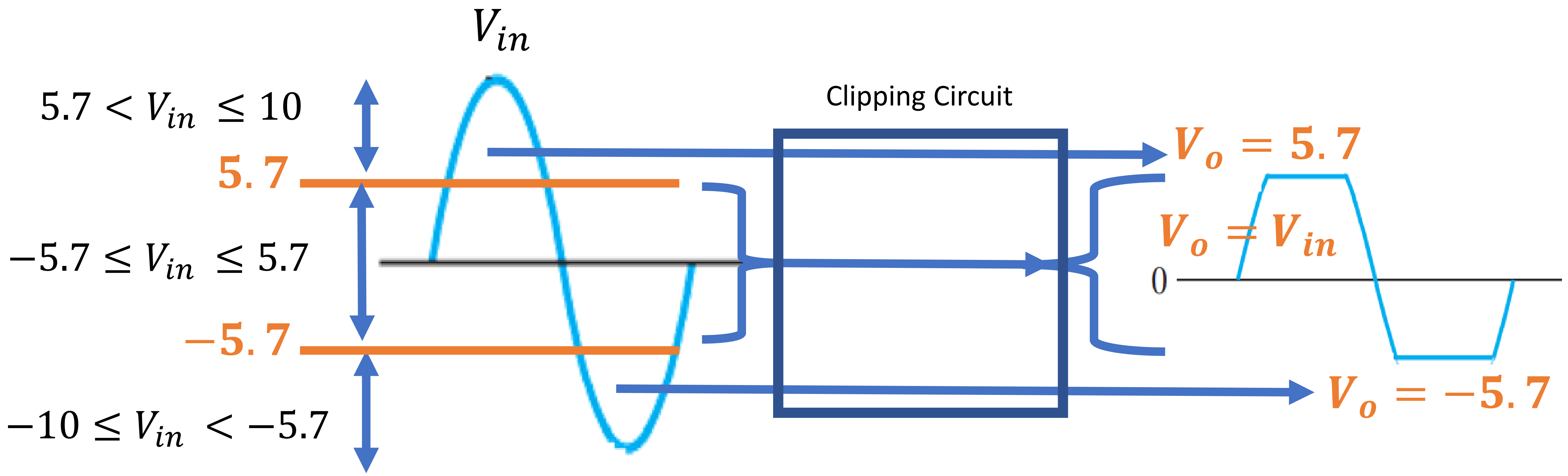
D2 is reverse

$$V_o - 0.7 - 5 = 0$$

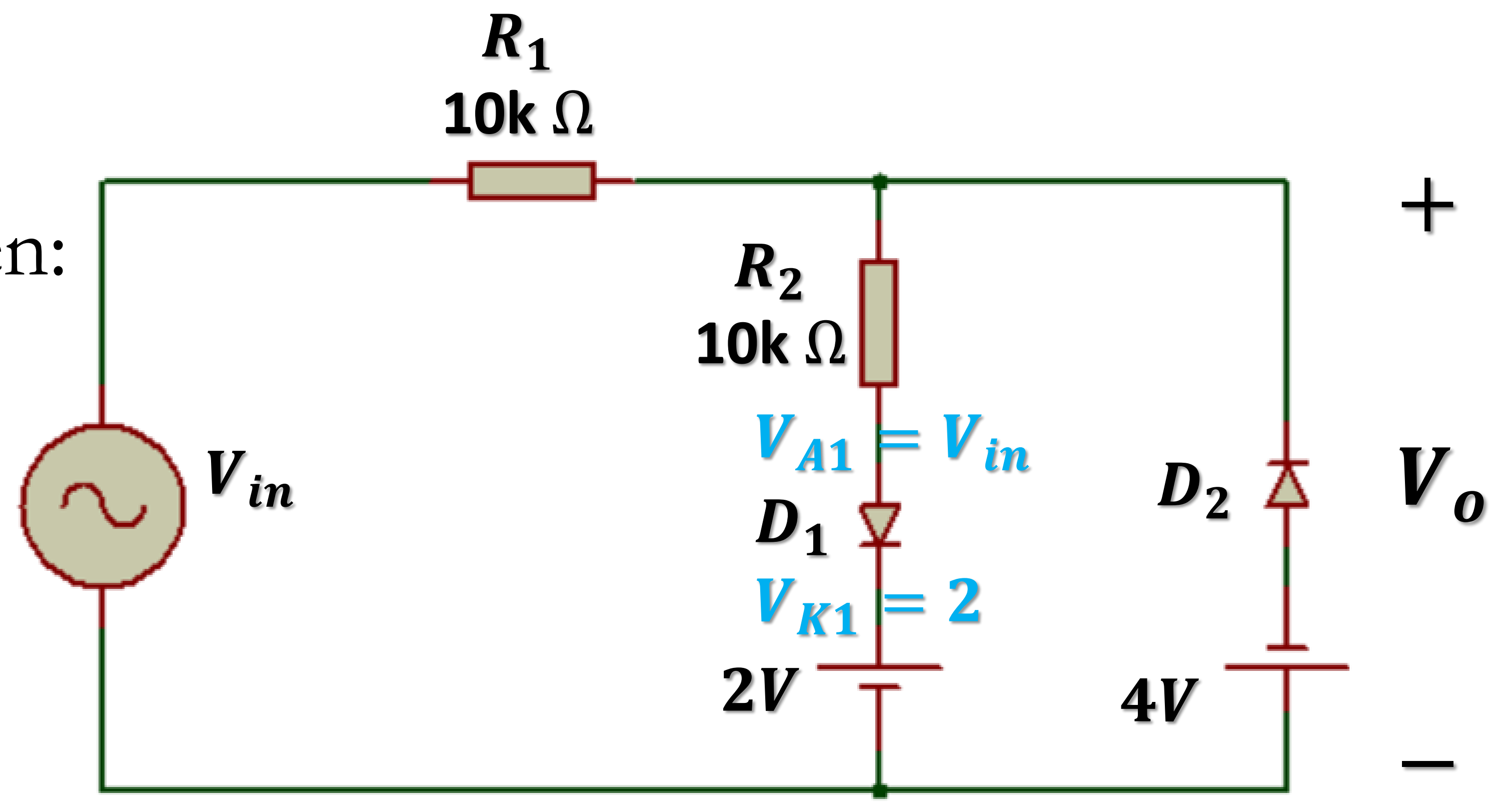
$$V_o = 5.7V$$



The output voltage waveform:



Sketch the output waveform (V_o versus time) of the circuit shown, assuming practical diode with barrier potential $V_B = 0.6V$ and $V_{in} = 10\ sinwt$.

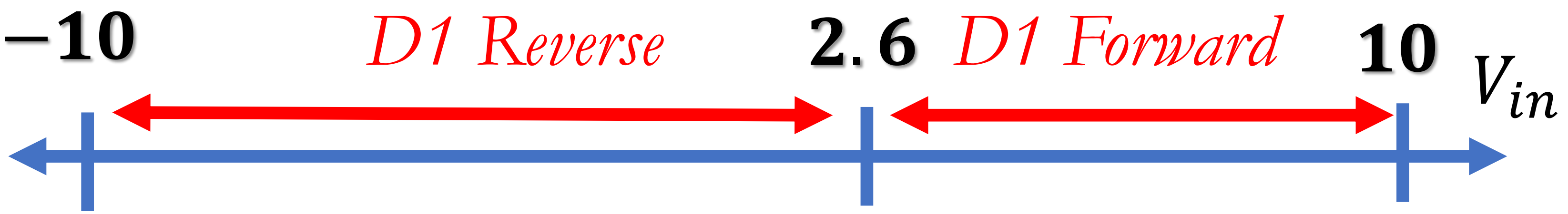


D1 is reverse ($R_r = \infty$) when:

$$V_{A1} \leq V_{K1} + V_B$$

$$V_{in} \leq 2 + 0.6$$

$$V_{in} \leq 2.6$$



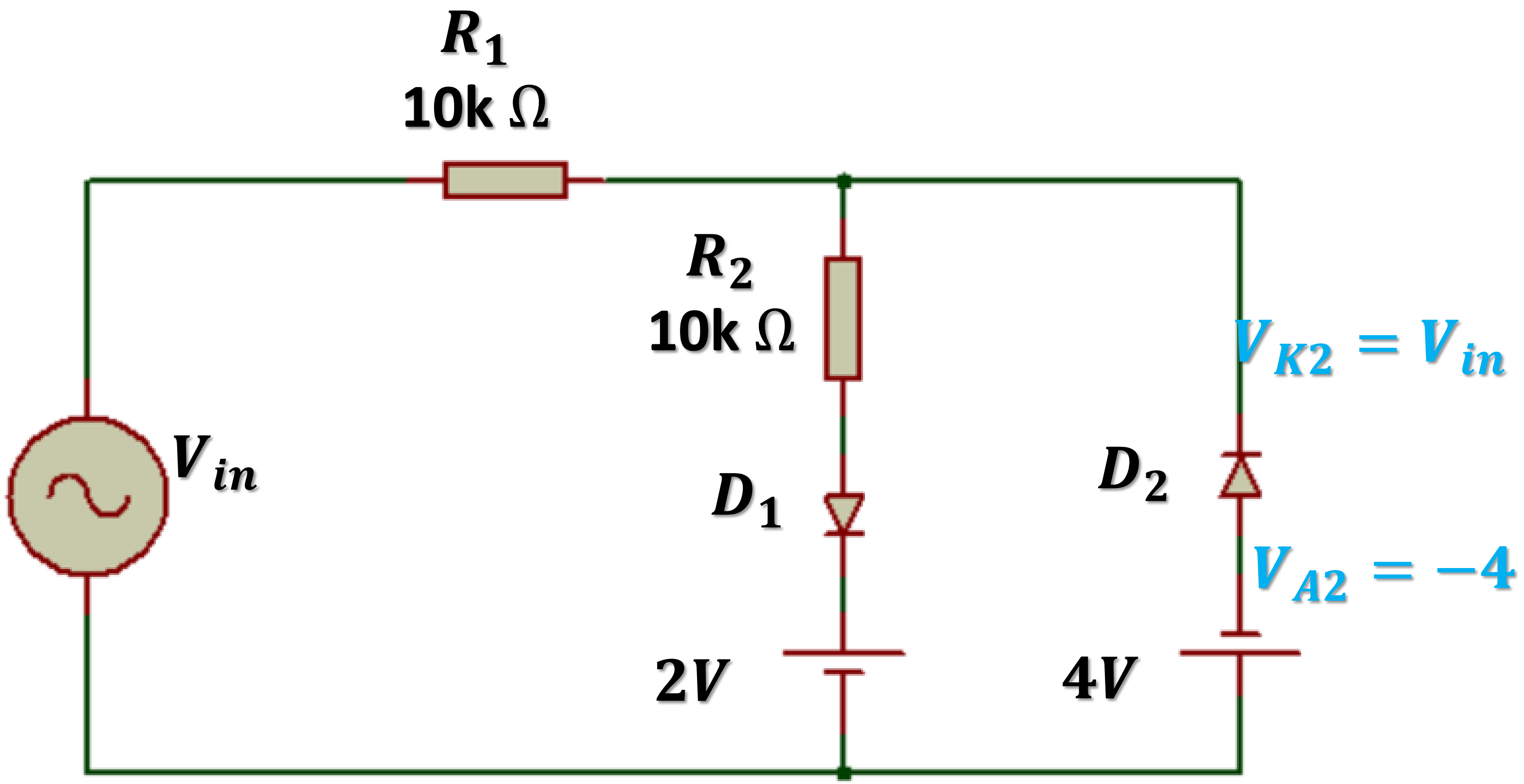
D2 is reverse ($R_r = \infty$) when:

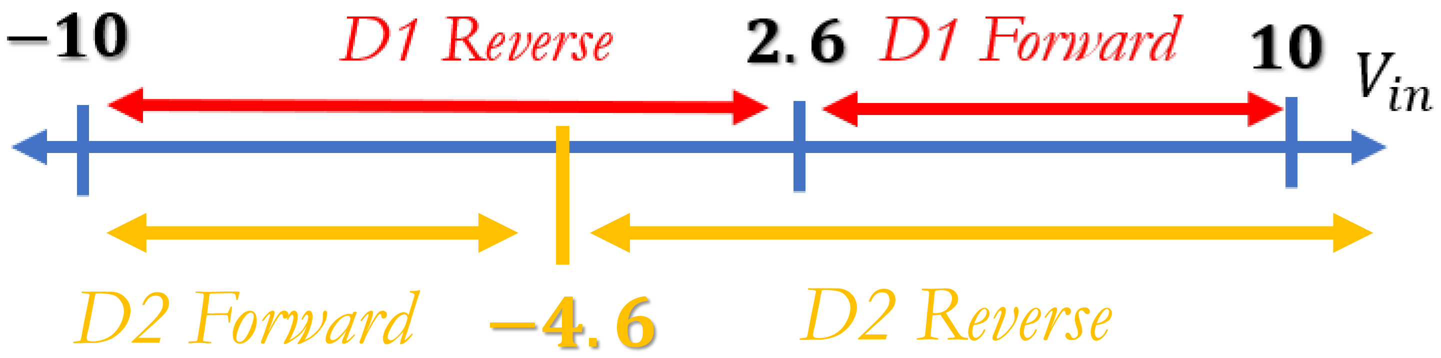
$$V_{A2} \leq V_{K2} + V_B$$

$$-4 \leq V_{in} + 0.6$$

$$-4 - 0.6 \leq V_{in}$$

$$-4.6 \leq V_{in}$$

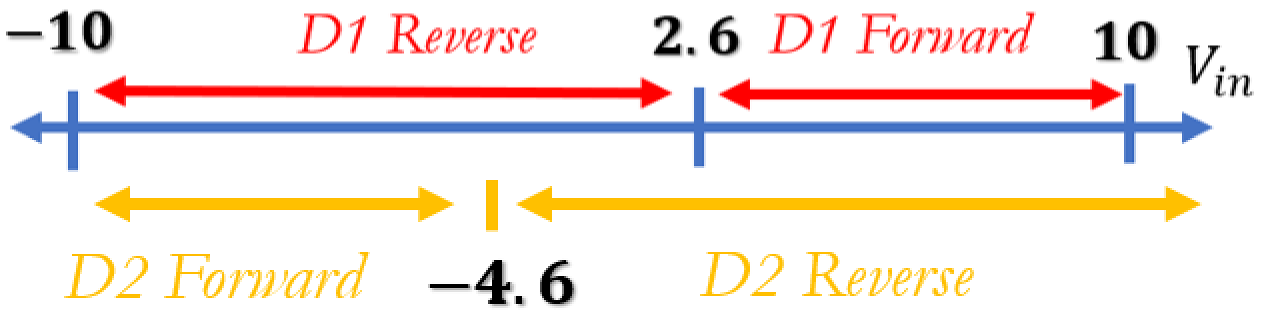




$[1] - 10 \le V_{in} < -4.6$

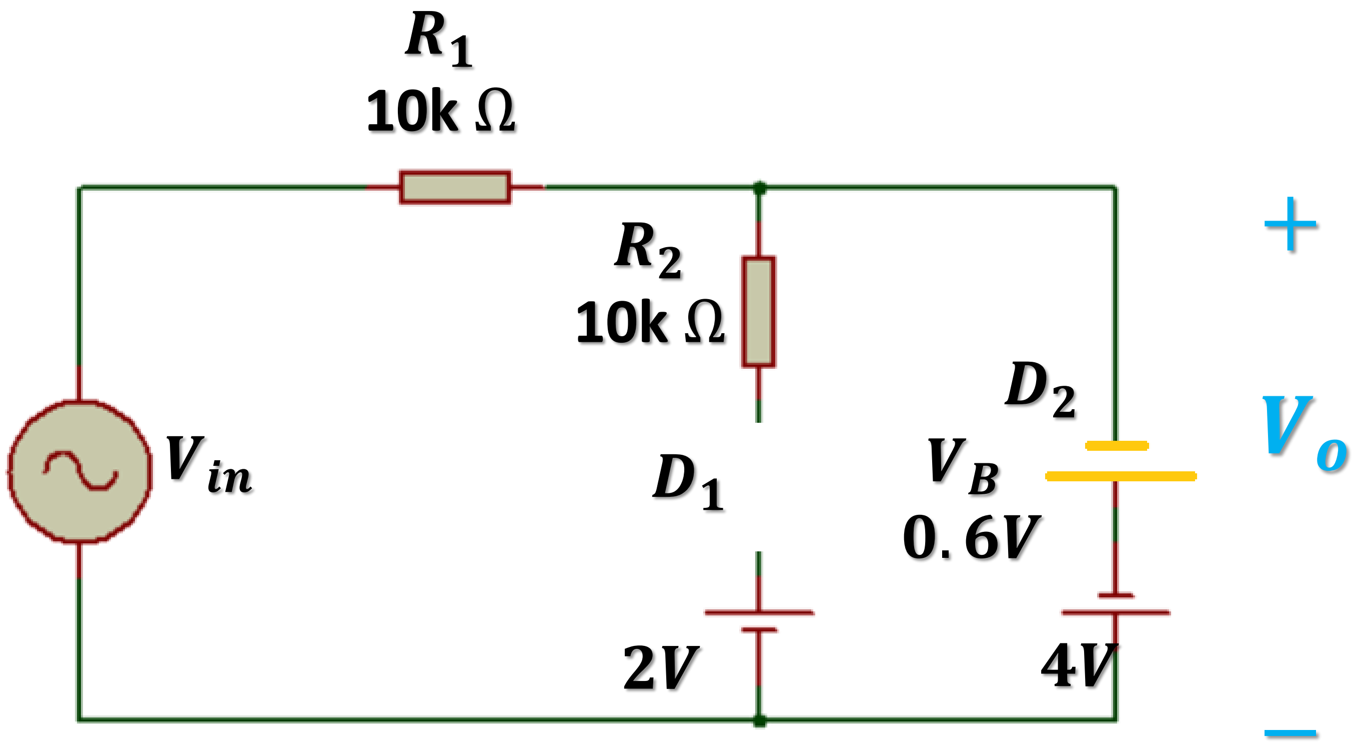
D1 is reverse

D2 is forward



$$V_o + 0.6 + 4 = 0$$

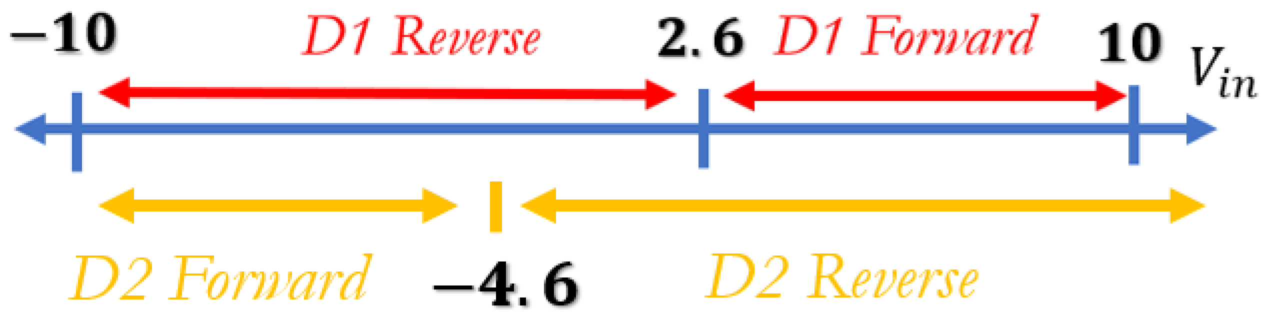
$$V_o = -4.6$$



$[2] -4.6 \le V_{in} \le 2.6$

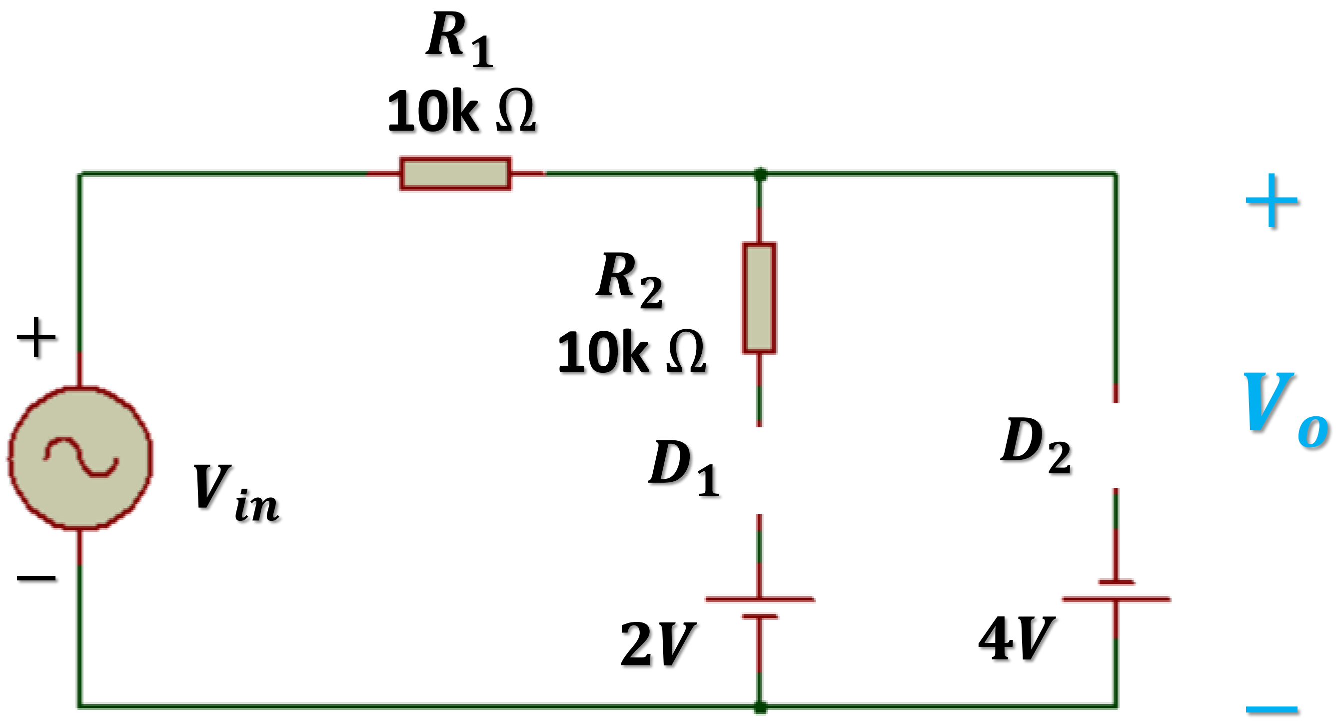
D1 is reverse

D2 is reverse

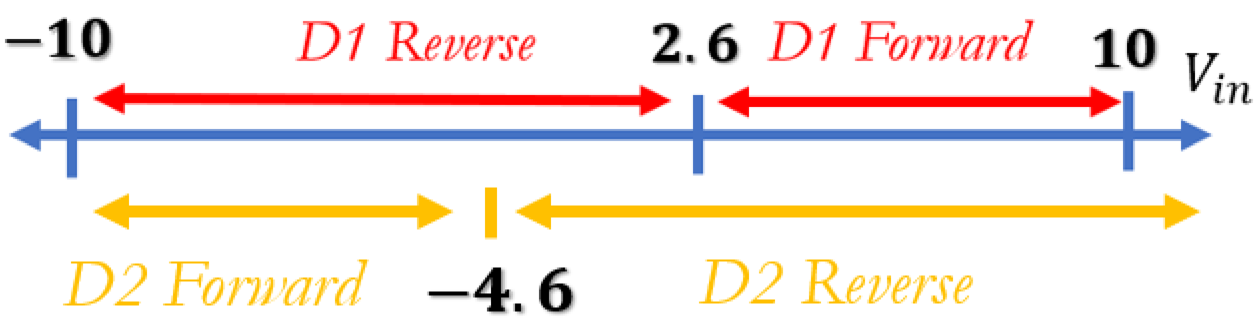


$$V_o - V_{in} = 0$$

$$V_o = V_{in}$$



[3] $2.6 < V_{in} \leq 10$



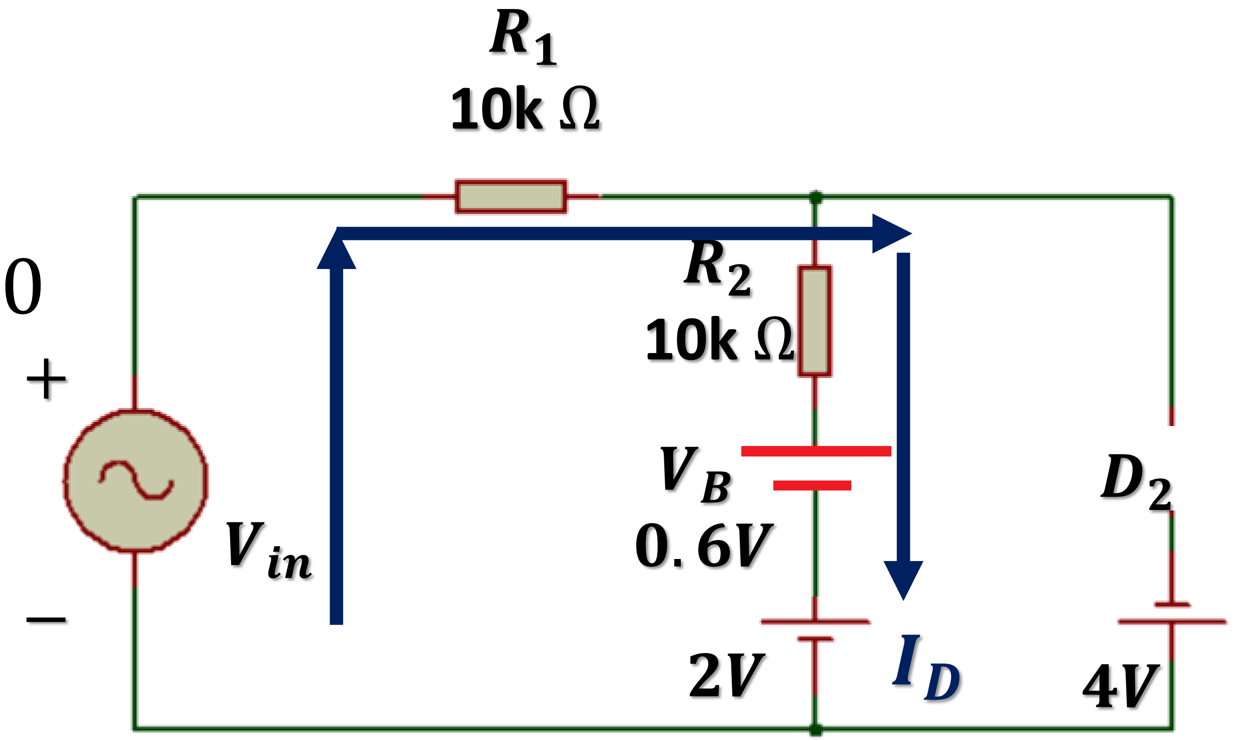
D1 is forward

D2 is reverse

$$\sum \boldsymbol{V\ in\ closed\ loop = 0}$$

$$V_{in} - I_D(10k + 10k) - 0.6 - 2 = 0$$

$$\frac{V_{in} - 2.6}{20k} = I_D$$



To find $\boldsymbol{V_o}$, write KVL between $\boldsymbol{V_o}$ and **the branch** :

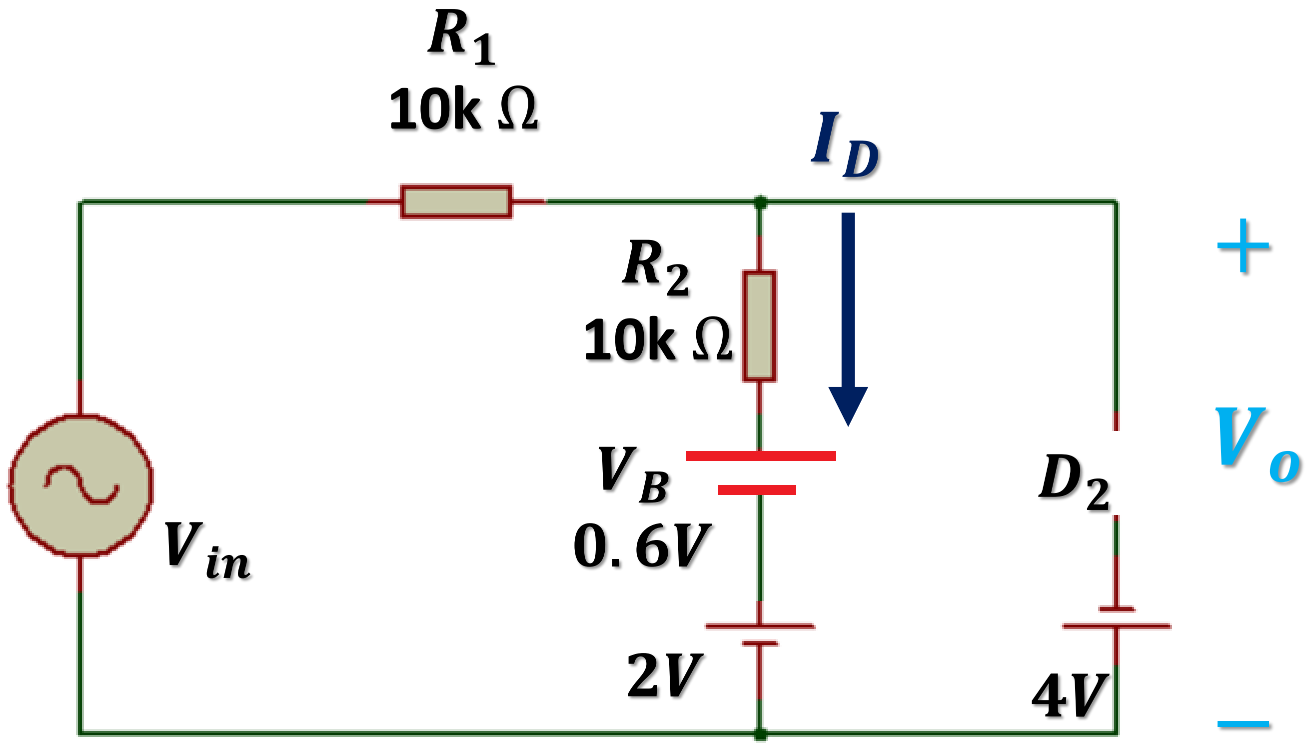
$$V_o - I_D(10k) - 0.6 - 2 = 0$$

$$V_o = I_D(10k) + 2.6$$

$$\because I_D = \frac{V_{in} - 2.6}{20k}$$

$$V_o = \left(\frac{V_{in} - 2.6}{20k}\right)(10k) + 2.6$$

$$V_o = \frac{V_{in} - 2.6}{2} + 2.6$$



The output voltage waveform: