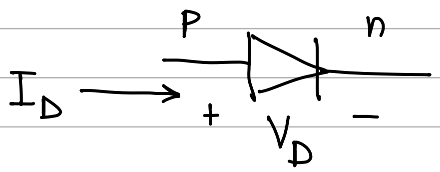
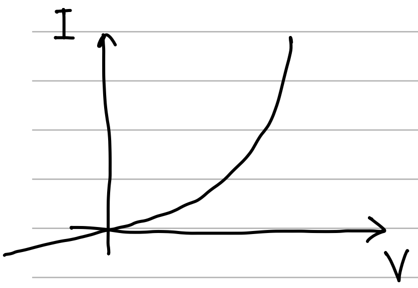
Diode (Lecture-2)

22/2/24



1) $I_D = I_S\left[\exp\left(\frac{V_D}{nV_T}\right) - 1\right]$

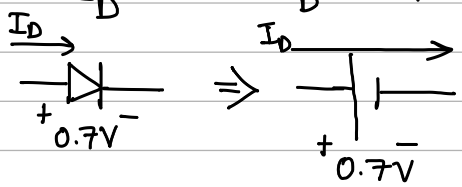


(Constant Voltage Drop)

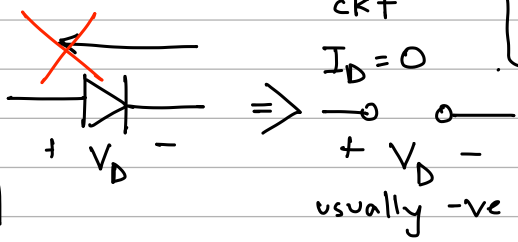
2) CVD model:

Approximation:

− $I_D > 0$: $V_D = 0.7V$

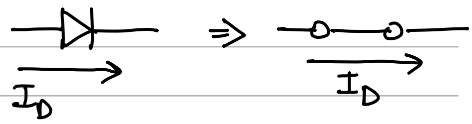


− $I_D < 0$ if ckt tries to do this: Diode "open ckt"

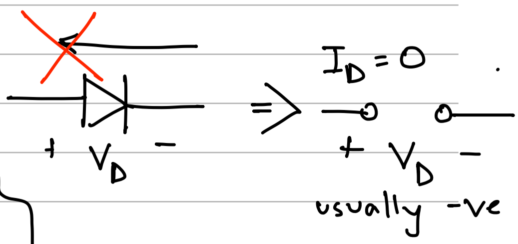


3) Ideal model:

− $I_D > 0$: Diode "shorted"



− $I_D < 0$: Diode "open"



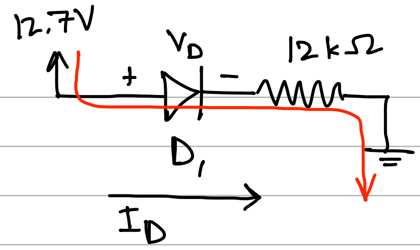
Diode has 2 states : ① ON [$I_D > 0$] ② OFF [$I_D = 0$]

Objective : ① Solve circuit with diodes and finding the right state of operation of diodes.

② Assume a state of operation, then solve the ckt, then check if diode state is consistent with it's operating conditions.

This method of solving : Method of Assumed States [MAS]

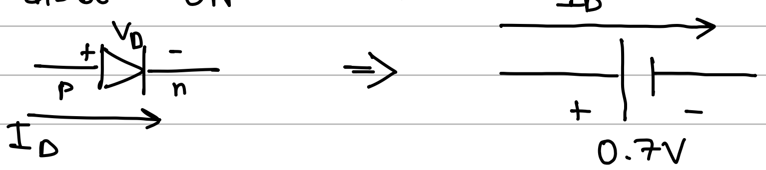
Example 1: find I_D.



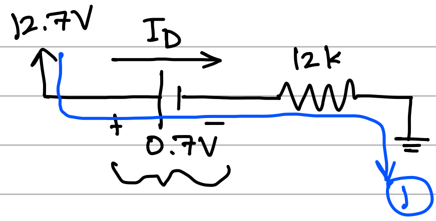
$I_D > 0$ since ckt tries to flow current from source to gnd.

∴ Diode should be 'ON'. Assume D_1 is 'ON'.

diode 'ON' ⟶



Ckt becomes:



Line ① KVL:

$$0.7 + 12 I_D = 12.7 - 0$$

$$\Rightarrow I_D = \frac{12.7 - 0.7}{12}$$

$$= 1 \text{ mA}$$

We know, diode 'ON':

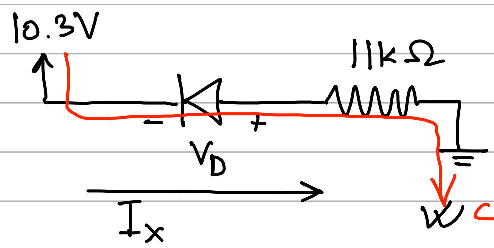
$I_D > 0$, $V_D = 0.7V$.

→ $I_D = 1$ mA ✓ $[I_D > 0]$

→ $V_D = 0.7V$ ✓ $[V_D = 0.7V]$

∴ Assumption correct! Ckt solved!

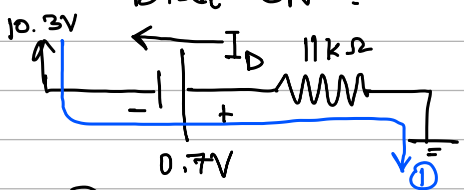
Ex 2: Find I_x.



✓ ckt tries to flow current like this.

but $I_D < 0$. Diode should be OFF

Assume Diode 'ON':



Line ① KVL:

$$-0.7 + 11 I_x = 10.3 - 0$$

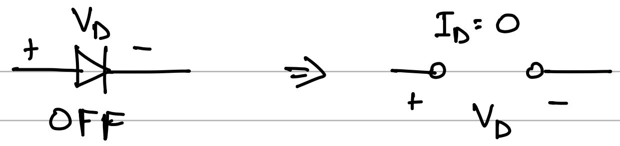
$$I_x = \frac{11}{11} = 1 \text{ mA}$$

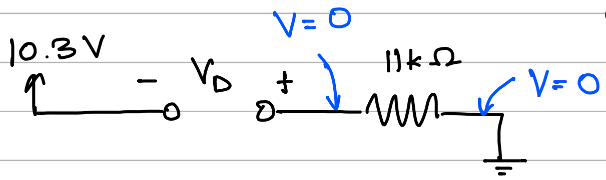
$I_D = -I_x = -1$ mA $\Rightarrow I_D < 0$

∴ Inconsistency. So, assumption wrong.

∴ So, Diode must be OFF

Assume Diode 'OFF' :



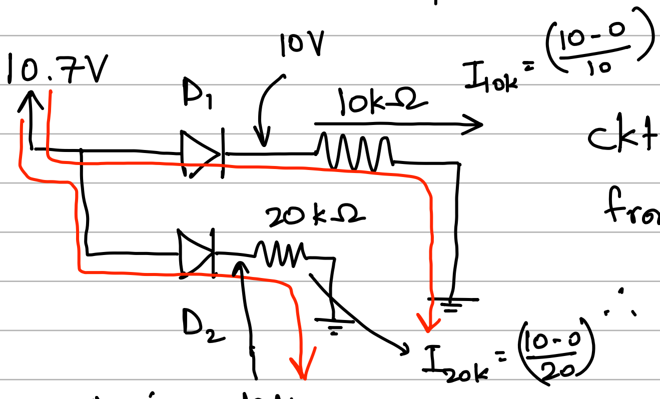


$I_x = 0$, $I_D = 0$

$V_D = 0 - 10.3 = -10.3V$

Diode OFF : $I_D = 0$, V_D −ve ($< 0.7V$)

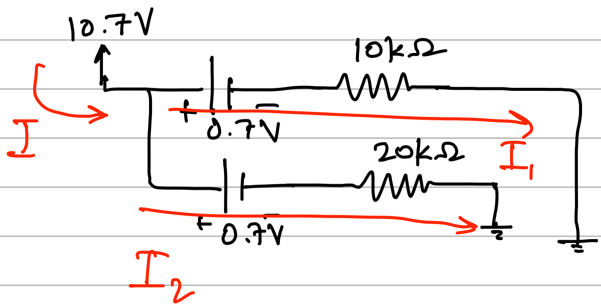
Ex 2 :



ckt trying to flow current from p side of both diodes

∴ Both diodes 'ON'

Assume D_1, D_2 ON :



$0.7 + 10I_1 = 10.7 - 0$

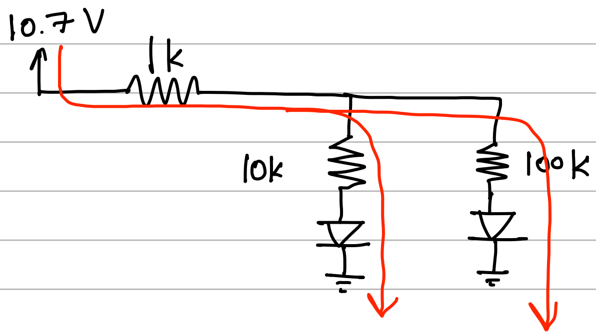
$I_1 = \frac{10}{10} = 1\,mA$

$0.7 + 20I_2 = 10.7 - 0$

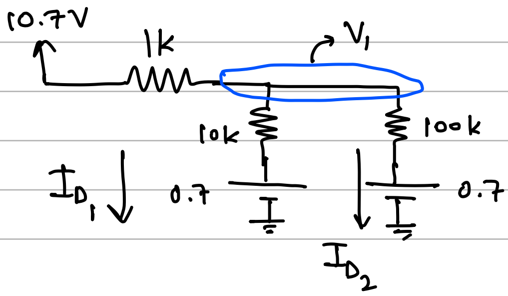
$\Rightarrow I_2 = \frac{10}{20} = 0.5\,mA$

$I = I_1 + I_2 = 1.5\,mA$

Ex 3 :



Assume diodes ON :



$$\frac{V_1 - 10.7}{1} + \frac{V_1 - 0.7}{10} + \frac{V_1 - 0.7}{100} = 0$$

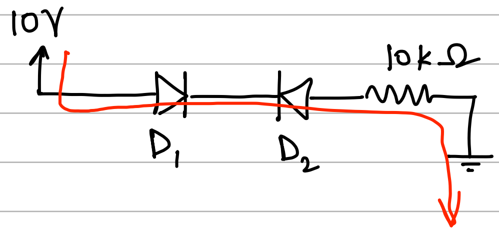
$\Rightarrow 100V_1 - 1070 + 10V_1 - 7 + V_1 - 0.7 = 0$

$\Rightarrow 111V_1 = 1077.7 \Rightarrow V_1 = 9.709\,V$

$$I_{D_1} = \frac{V_1 - 0.7}{10k} = 0.9009\ mA > 0 \quad D_1 \text{ "ON" correct}$$

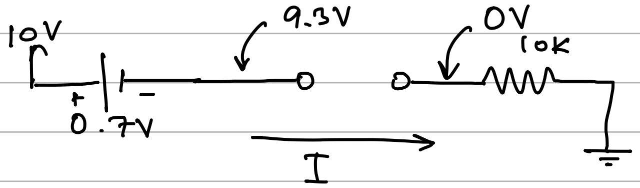
$$I_{D_2} = \frac{V_1 - 0.7}{100k} = 0.09009\ mA > 0 \quad D_2 \text{ 'ON' correct}$$

Ex 4 :



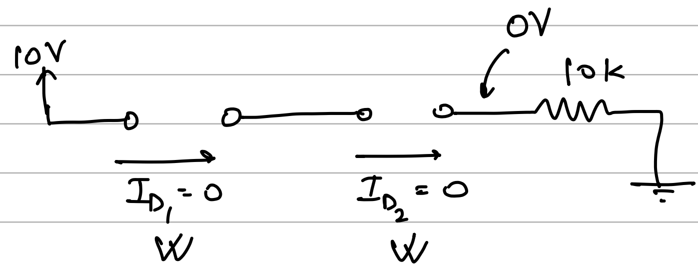
D_1 should be ON. But D_2 should be OFF

D_1 ON, D_2 OFF :



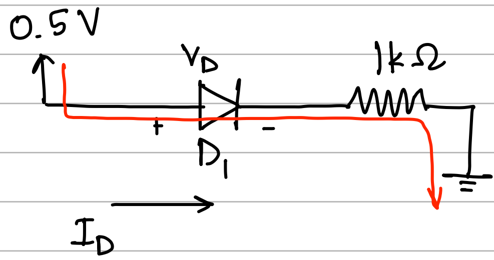
$I = 0$. D_1 cannot be ON ! Inconsistency. $V_{D_2} = -9.3V$ D_2 assumption most likely correct.

Then, D_1, D_2 OFF :

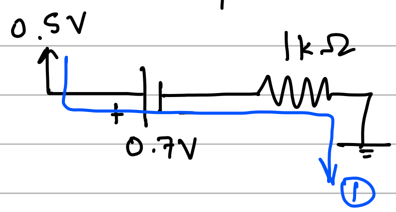


D_1, D_2 off is correct assumption.

Ex 5 :



Assume D_1 'ON' :



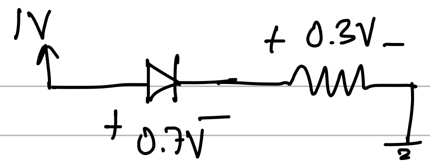
Line ① KVL :

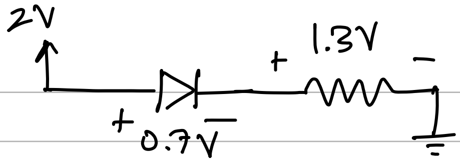
$$0.7 + I \times 1 = 0.5 - 0$$

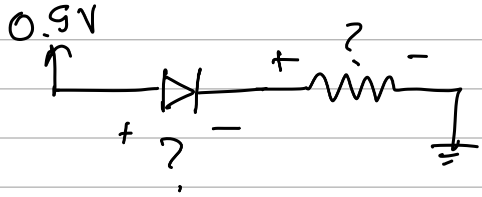
$$\Rightarrow I = 0.5 - 0.7 = -0.2\ mA < 0$$

$\Rightarrow I_D < 0$! Diode cannot be 'ON'

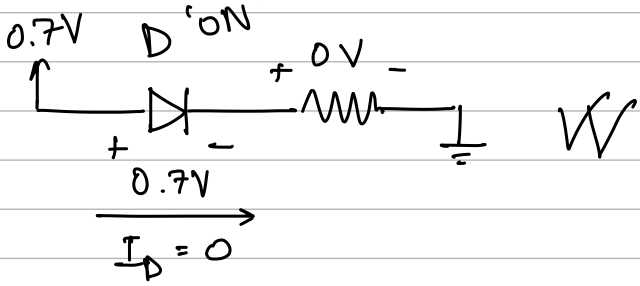
Diode is 'OFF'. Ckt must provide 0.7V drop to diode to function and turn on diode.







* If $V_s = 0.7V$:



Diode Logic :

→ Can implement AND, OR Logic.

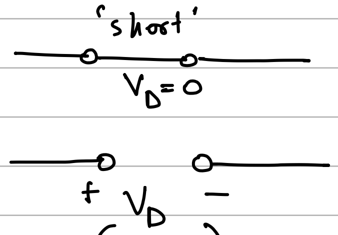
→ Can't implement NOT logic. [0V input → 5V output]

Since, diode cannot generate voltage on it's own.

→ We will verify diode logic with ideal diode model.

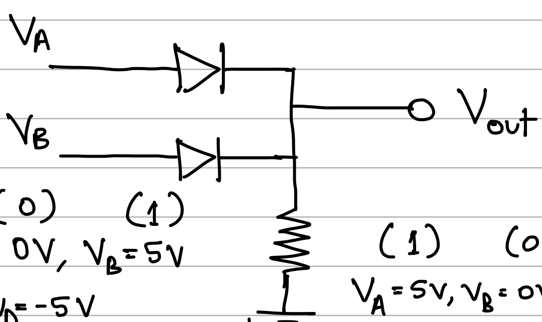
[Ideal : $I_D > 0$: 'short' $V_D = 0$

$I_D < 0$: $+ V_D -$ (−ve)]



0V → 0 logic
5V → 1 logic

OR Logic :

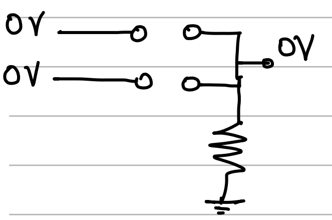


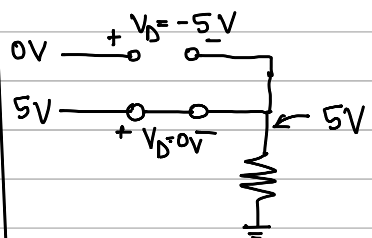
(0) (0)
$V_A = 0V, V_B = 0V$

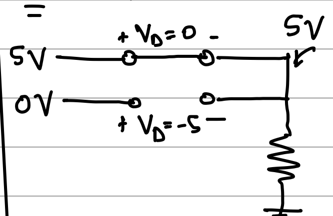
(0) (1)
$V_A = 0V, V_B = 5V$

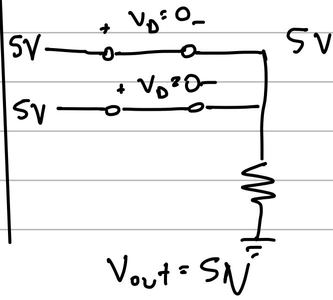
(1) (0)
$V_A = 5V, V_B = 0V$

$V_A = 5V, V_B = 5V$









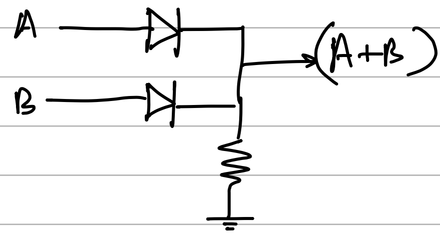
$V_{out} = 0V$

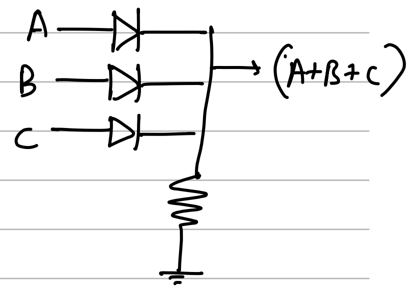
$V_{out} = 5V$

$V_{out} = 5V$

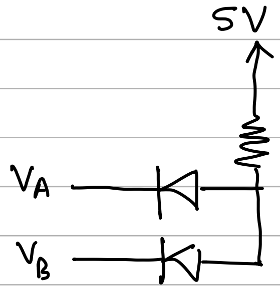
$V_{out} = 5V$

V_A	V_B	V_{out}
0	0	0
0	5	5
5	0	5
5	5	5

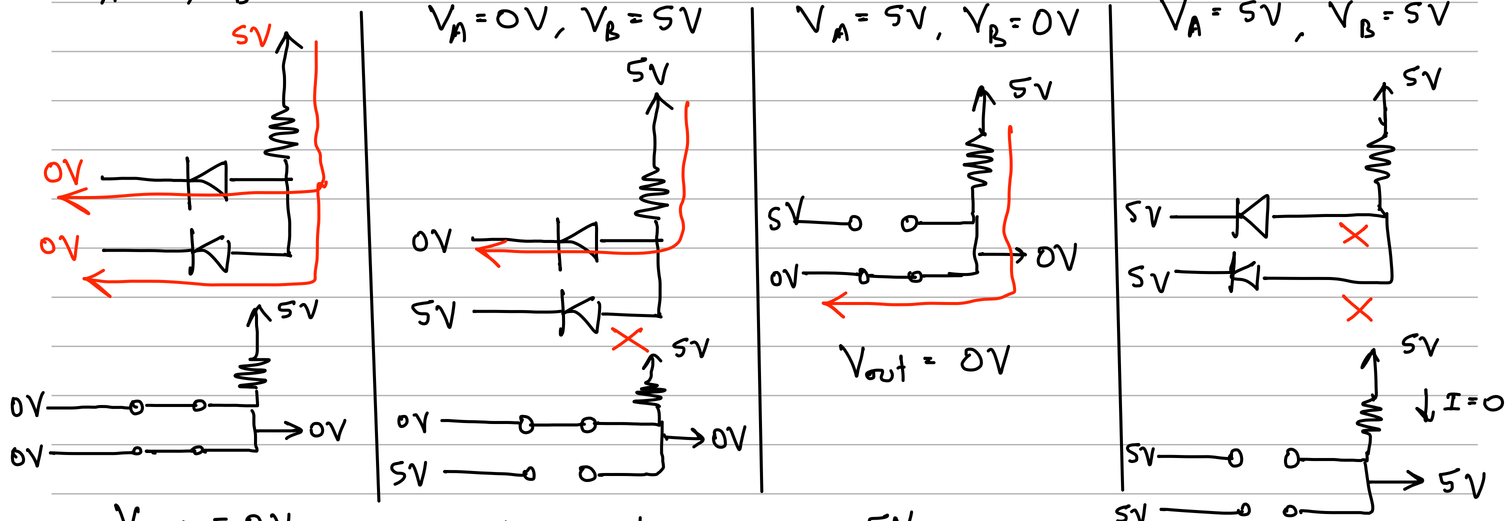




AND Logic :



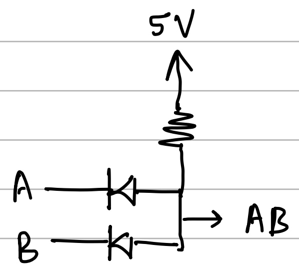
(0) (0) $V_A = 0V$, $V_B = 0V$ | (0) (1) $V_A = 0V$, $V_B = 5V$ | (1) (0) $V_A = 5V$, $V_B = 0V$ | $V_A = 5V$, $V_B = 5V$

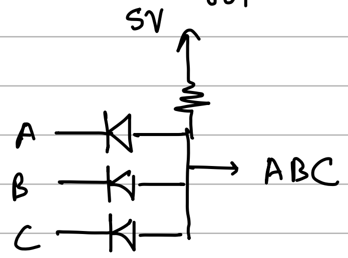


$V_{out} = 0V$ | $V_{out} = 0V$ | $V_{out} = 0V$ | $V_{out} = 5V$

V_A	V_B	V_{out}
0	0	0
0	5	0
5	0	0
5	5	5

'AND'



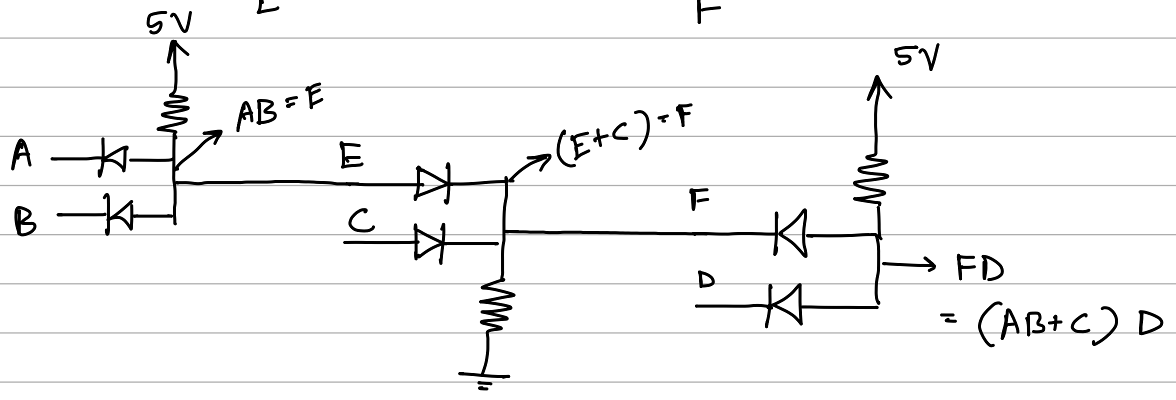


* Input high voltage (5V) and low voltage (0V) is same for these analysis.

If not kept same, they implement something different.

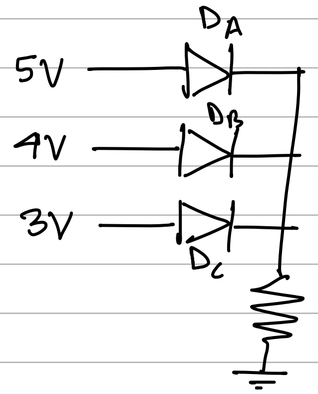
* We can implement complex boolean logic with these gates.

Ex: $f = (\underbrace{AB}_{E} + C)D = (\underbrace{E + C}_{F})D = FD$



Q. What happens for unequal voltage in OR / AND logic?

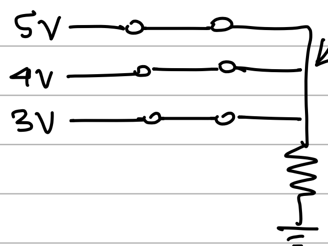
① OR:



Ckt looks like all 3 should be ON.

[all 3 should conduct current in right dir.]

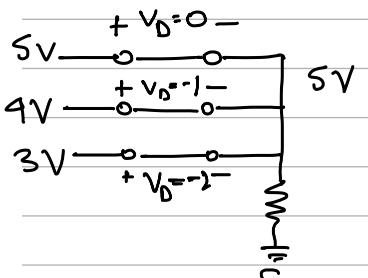
Assume all 3 'ON':



V_{out} = 5? 4? 3? ambiguity

①

If $V_{out} = 5V$:



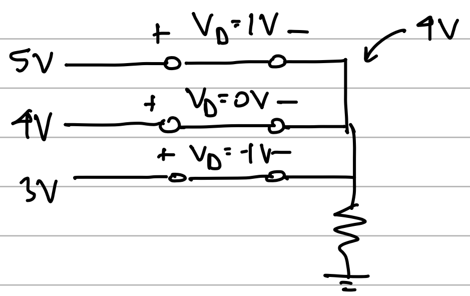
D_A is correct $[V_D = 0,\ I_D > 0]$

D_B, D_C wrong $[V_D < 0]$

Then D_B, D_C must be off

②

If $V_{out} = 4V$

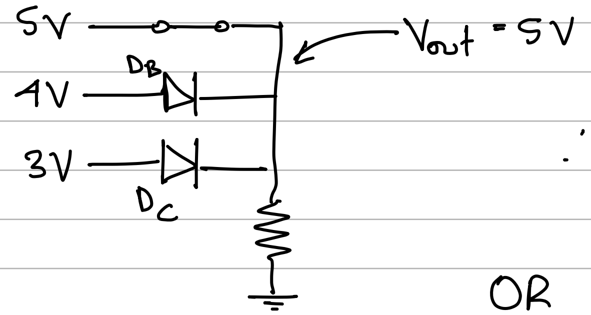


D_A must be on $[V_D = 1V]$

⇒ V_{out} must be 5V

③

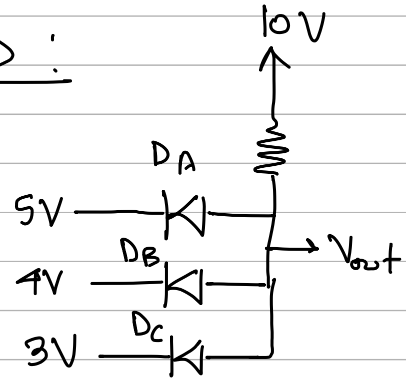
∴ 5V diode only ON. Rest off.



$\therefore V_{out} = \max(V_A, V_B, V_C)$

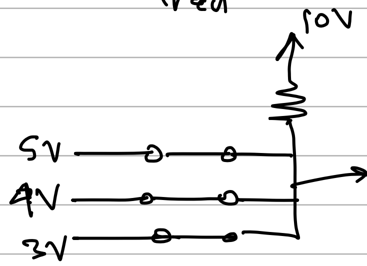
OR gate replicates max function. Gives max of input voltages.

AND :



Current should flow through all three?

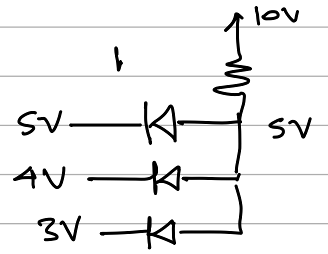
Then



V_{out} = 5? 4? 3?

ambiguity

If $V_{out} = 5V$:



D_A 'ON' → short

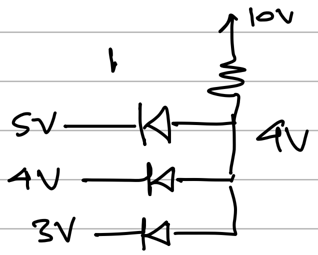
D_B 'ON' → $V_D = 5 - 4 = 1V$

D_C 'ON' → $V_D = 5 - 3 = 2V$

but V_{out} cannot be 3V, 4V, 5V at once

×

$V_{out} = 4V$:



D_A 'OFF' → $V_D = -1V$

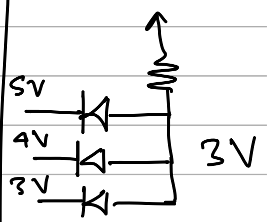
D_B 'ON' → $V_D = 0V$ [short]

D_C 'ON' → $V_D = 4 - 3 = 1V$

V_{out} cannot be 4V, 3V at once

×

$V_{out} = 3V$:



D_A 'OFF' → $V_D = -2V$

D_B 'OFF' → $V_D = -1V$

D_C 'ON' → $V_D = 0V$

$V_{out} = 3V$

✓

no ambiguity.

$\therefore$ Correct is $V_{out} = 3V$. D_A, D_B OFF. D_C ON.

Thus, implementing $V_{out} = \min(V_A, V_B, V_C)$

* OR ckt with unequal inputs : $V_{out} = \max(V_1, V_2, \dots, V_n)$
  AND " " " " : $V_{out} = \min(V_1, V_2, \dots, V_n)$

* When inspecting such unequal input ckts, find case where V_{out} has no ambiguity.