Sub.: Lecture 8+9

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Diode non-idealety (Real diode)

For ideal diode (review)

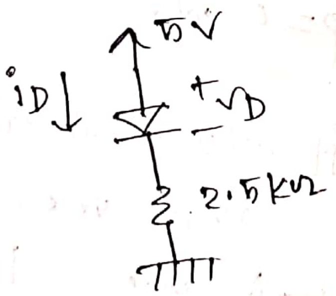
if ON, then act as short circuit

if OFF, then act as open circuit.

But in real lif nothing ideal.

so lets discuss about some non-idealety of real diode has:

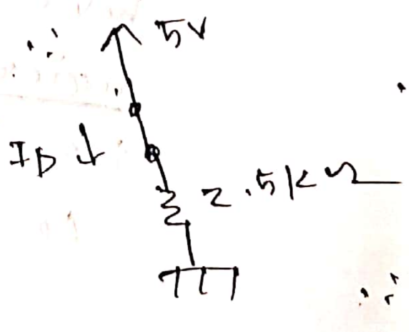
if ideal diode if ~~th~~ we have this circuit,



∴ ~~I_D~~ Diode is ON

∴ act as short circuit

∴ ~~I_D~~ =



$\therefore I_D = \frac{5-0}{2.5}$

$= 2mA$

$\therefore V_D = 0V$

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Now what about the power consumed by the diode ?-

$p = VI$ [power consumed by a device]

so for this circuit (diode)

$$p = V_D I_D$$
$$= 0 \times 2mA$$
$$= 0 \text{ W}$$

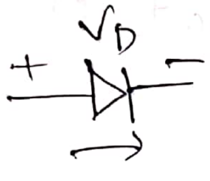
But this is odd because diode is a passive device so it must consume power so its not possible that consumed for diode ~~p=0~~

power $p = 0$ W.

~~But~~ ~~As~~ Again it also indicate that here $V_d = 0$ that means the materials that use to make the diode has no resistance $(R=0)$ so its also not possible.

Now lets consider these two issue.

(##) First the power case,



Now if we measure this V_D voltage and I_D current we can find the power consumed by this diode directly proportional to current I_D.

$\boxed{P \propto I_D}$ → Not like resistance

for resistor,

$$\boxed{\begin{array}{l} P = i^2 R \\ \therefore P \propto i^2 \end{array}}$$

Now for voltage source when voltage is constant then

$P = V_d \cdot i$

$\boxed{P \propto i}$

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so ~~di~~ we can tell that when diode is conducting or it is on mode, the power is proportional to current which is similar to that of a voltage source.

we can write,

$\cancel{P = KI_D}$

$P \propto I_D$

$\therefore P = KI_D$

For silicon diode we get $K = 0.7$

so if we match diode and voltage source power consuming equation we well get,

when diode is ON, we can replace it with voltage source.

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so, Diode [silicon only]

ON → ~~can~~ will replace the diode with voltage source

A

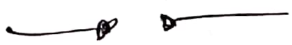
$V_D = 0.7\,V$

C

(★★)

Note that positive side of voltage source should be connected to Anode and Negative side to cathod.

when OFF → will replace the the diode with open circuit.



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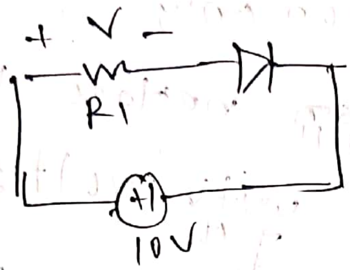
Ex :



what will be the voltage accross R1. [Here diode will consume 0.7 volt.]

$\therefore$ $V = 10 - 0.7 = 9.3V$ [if diode is ON]

Now the material case :

when diode is ON, can replace it with

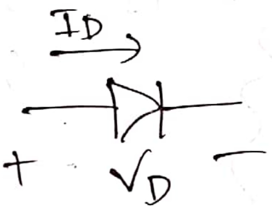
[voltage source series with resistor

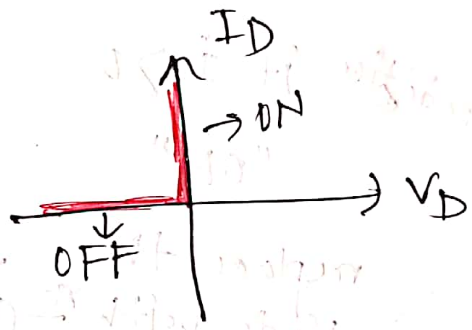
Here this r value will be very small. [i.e. 10Ω, 12Ω or 9Ω

Therefore these are two non-idealities of ~~diode~~ real diode has.

Review

For Ideal diode model





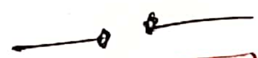
if $\boxed{I_D > 0}$ → this is called condition

ON

$\boxed{\text{then } V_D = 0}$ → this is called state equation

if: $\boxed{V_D < 0}$

OFF



$\boxed{I_D = 0}$

** V_{D0} = is called cut-in voltage.
the voltage need to supply to turn on the diode.

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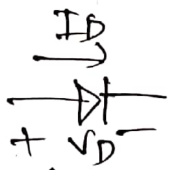
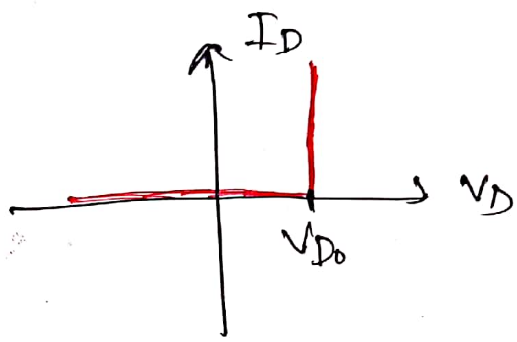
Now
Constant voltage drop model (CVD model)





condition ⇔ if $I_D > 0$

"ON"

replace the diode with A (+ −) C, V_{D0}

state equation ⇔ so, $V_D = V_{D0}$

For silicon (Si) diode its about $V_{D0} = 0.7\,V$

for Germenium it about $0.2\,V$

But mostly used Si

so $V_{D0} = 0.7\,V$

if $V_D < V_{D0}$ ⇔ condition

"OFF"

so $I_D = 0$ ⇔

⇕ state equation.

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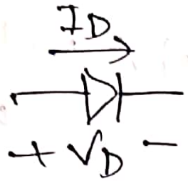
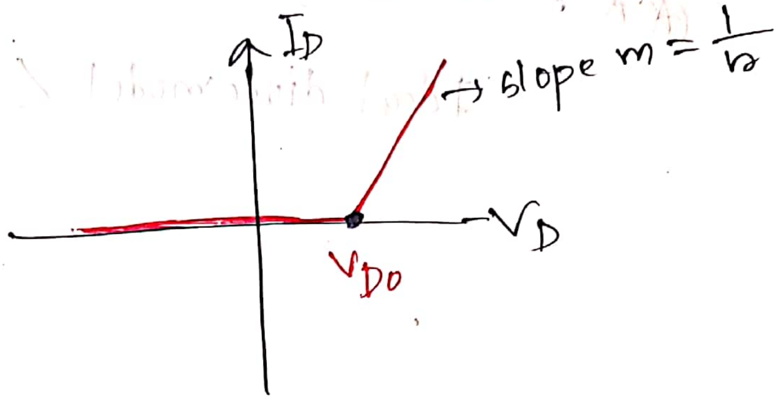
internal resistance of diode

Now voltage source + resistance model (CVD+rd)





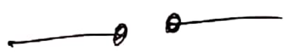
if $I_D > 0$, ON ↔ condition

then,

$V_D = V_{D0} + i r_d$ ↔ state equation

$V_D < V_{D0}$

"OFF"



$I_D = 0$

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Accuracy of the model (result accuracy)

Ideal diode model < CVD model < voltage source + resistor model (CVD + ro)

Now where to use which model?

Ans: depends on context of the question.

But mostly we use in this course CVD model.

Hardly use CVD + ro or Ideal model in this course

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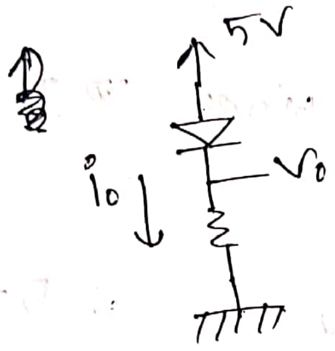
Ex:

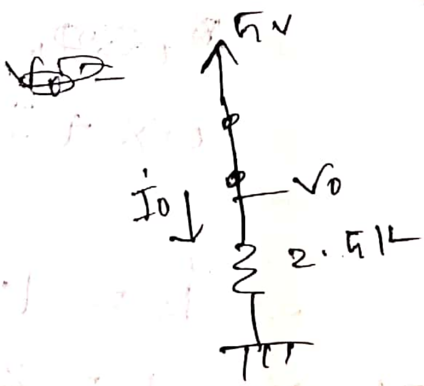


Qustion: Find V_o and i_o using:

1. ideal diode model
2. CVD model ($V_D = 0.7V$)
3. CVD + r_D model ($V_D = 0.7V$, $r_D = 10\Omega$)

(1) IDeal model

Diode is ON since $i_o = I_D > 0$.

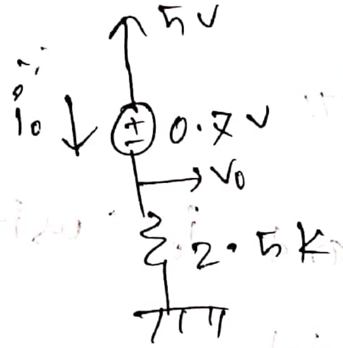


$\therefore V_o = 5V$

$$i_o = \frac{5-0}{2.5} = 2mA$$

(2) CVD model

Diode ON, since $I_0 = I_D > 0$



$\therefore 5 - V_0 = 0.7$

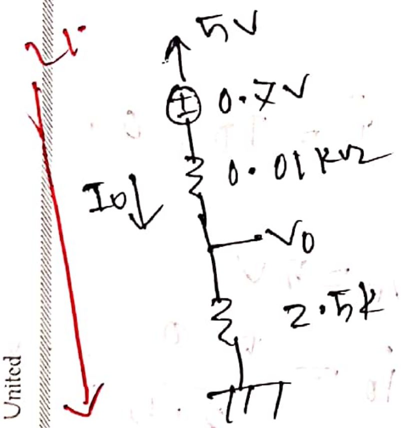
$\Rightarrow V_0 = 5 - 0.7 = 4.3V$

$\therefore i_0 = \dfrac{V_0 - 0}{2.5} = \dfrac{4.3}{2.5} \Rightarrow$

$= 1.72\,mA$

(3) CVD + r_d model

ON, since $I_0 = I_D > 0$



KVL along L1:

$0.7 + I_0 \times 0.01 + I_0 \times 2.5 = 5 - 0$

$\therefore I_0 = 1.713\,mA$

Now $V_0 - 0 = 2.5 \times I_0$

$\therefore V_0 = 2.5 \times 1.731 = 4.288V$

Real diode

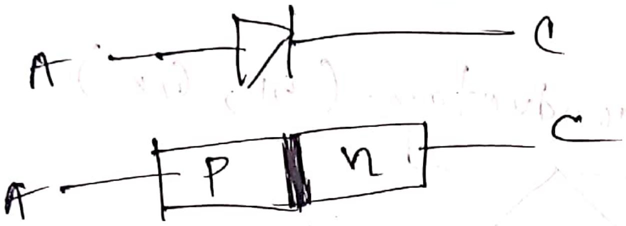
made with semiconductor. (Si, Ge)

- intrinsic (pure)
- extrinsic (impure)
  - mixed As, B in a controlled manner
    - p type
      - +ve most of charge carrier holes
      - [minor negative carrier]
    - n type
      - most of charge carrier are electrons.
      - [minor positive carrier]

semiconductor in between conductor and insulator

In lower temperature semiconductor works like insulator and if temperature is high then it works like conductor.

P-N junction diode



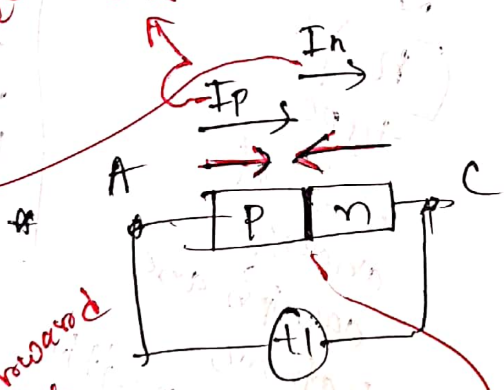
↓
junction

↓
this junction doesnot allow any positive charges from p side to n side.

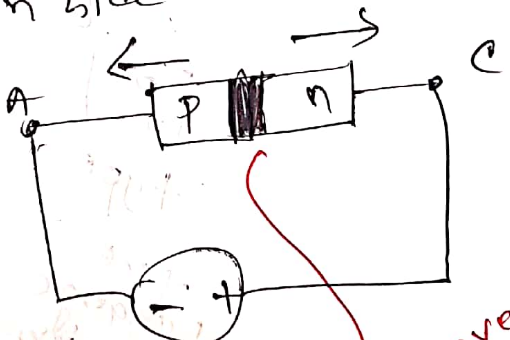
And doesn't allow any negative charges from n side to p side.

current flow due to negative charge. [current flow opposite of electron flow]

current flow due to positive charge



Forward Bias



Reverse Bias.

positive charge repeal By anode side also negative electron als repealed by cathod side. so current will flow from A to C. Junction gets thinner.

attaction A and P
" " C and n

so junction get wider. so carries cant cross it. so current will zero

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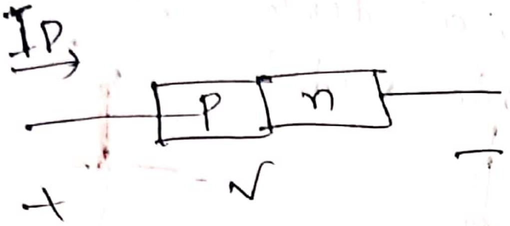
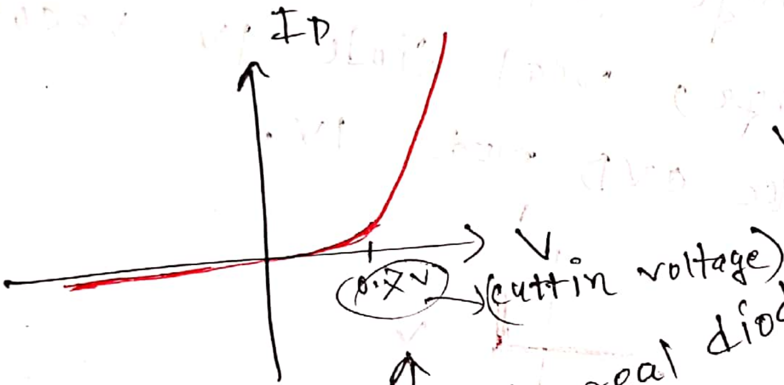
Real diode equation :



$$I_D = I_S \left(e^{\frac{V}{V_T}} - 1 \right)$$

I_S = Reverse saturation current [10^{-12} to 10^{-9} Ampere

V_T = thermal voltage
= 0.025 V
Typically.



IV of real diode.

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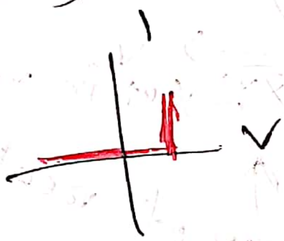
when operatign voltage is Higher voltage range [-50V to +50V]
this IV of real diode becomes
like Ideal diode model

when ~~voltage~~ operating voltage is lower
in range (-15V to 15V)
voltage, real diode IV becomes
like CVD model IV.



when o.v. is much lower (like -2V
to 2V) then it becomes like
CVD + r model

if the voltag too much lower than these
on that time ~~for~~ getting accurete
result we ~~ha~~ can use real diode IV curve.

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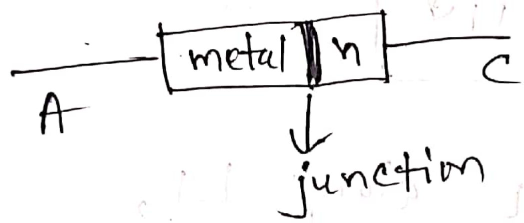
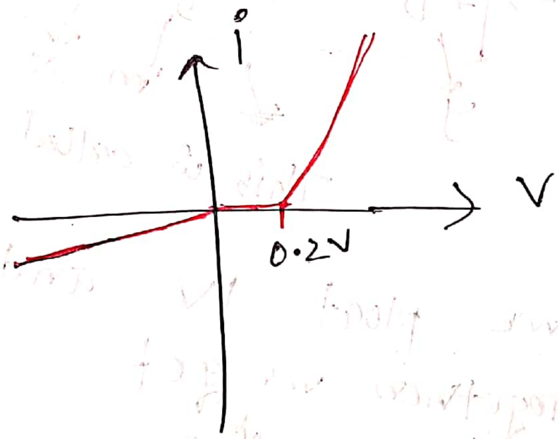
~~Sch~~ Schottky diode



IV of schottky diode



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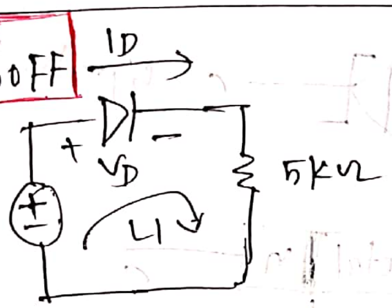
Solving diode circuit

A-A Wheather diode is ON or OFF

[For CVD mode]



Using KVL along L1,

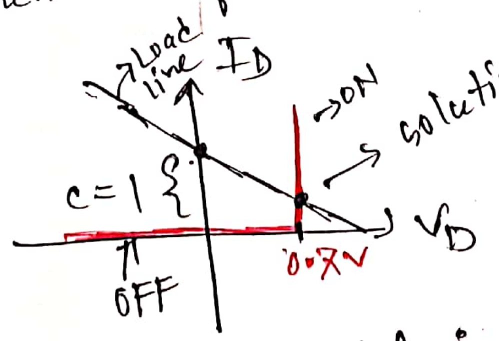
$$5 = V_D + 5I_D$$

$$\Rightarrow \boxed{I_D = -\frac{1}{5}V_D + 1} \quad \because y = -mx + c$$

y, m, x, c

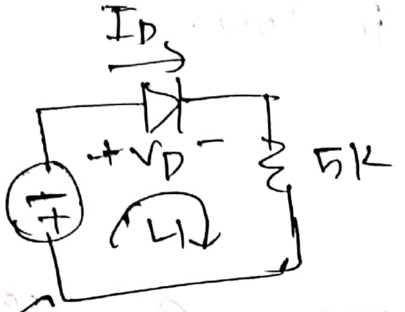
This is called Load Line

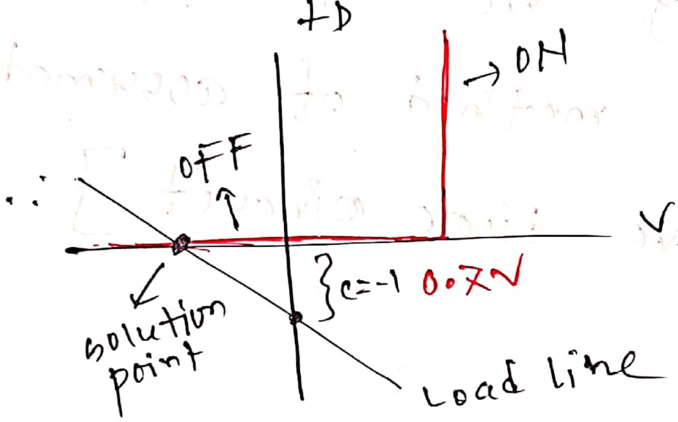
∴ If we ploat IV and load line together we get



And since, solution point is on segment of diode we can easily assume diode is ON.

Now lets the circuit is like.





equation using KVL

$$-5 = V_D + 5 I_D$$

$$\therefore \underbrace{I_D}_{y} = \underbrace{-\frac{1}{5}}_{m} \underbrace{V_D}_{x} \underbrace{-1}_{c}$$ [load line equation]

$$\therefore y = mx - c$$

∴ Now the solution point is on the off segment. so we can assume Diode is OFF.

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DATE: / /

But this approach is only works when the numbers is low.

** [That is why we use a technique called method of assumed state to solve diode circuit]

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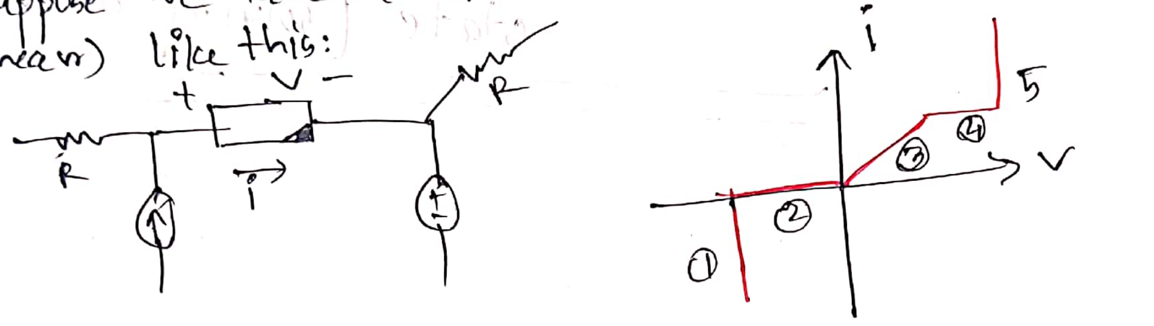
suppose we have a circuit and IV (piece wise linear) like this:



For solving this circuit we need to know i and v accross the nonlinear device. we can solve it via piece wise linear approximation using this IV but that is troublesome and lengthy. so we use method of assumed state to solve circuit with ~~???~~ non-linear device.

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DATE: / /

Steps :

1. Assume states of the device

* For example: for diode assume each diode is off or ON, or both are ON or both are off, one is one another is OFF etc.

2. Solve the linear circuit and find v_D, i_D

* For example: based on assumption of ON or off of diode we replace it with linear device and solve the circuit to find V_D and i_D.
  (V_D voltage across diode, i_D current across diode)

3. Verify

ON → [$i_D > 0$

OFF → [$v_D \leq 0$ ideal model
$v_D \leq v_{D0}$ CVD model

For example: if we assumed diode is ON but get $i_D < 0$, so technically diode is OFF that is why our assumption is wrong.

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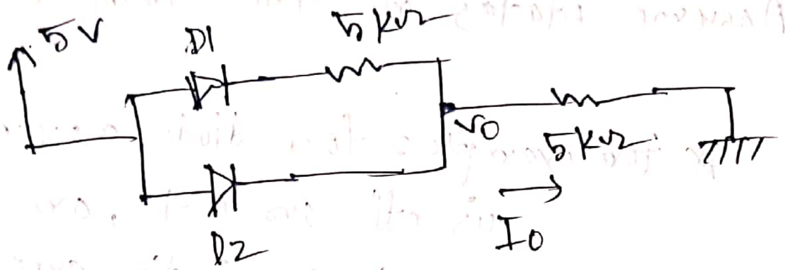
EX 1 .



* Find V_o and I_o use CVD model with

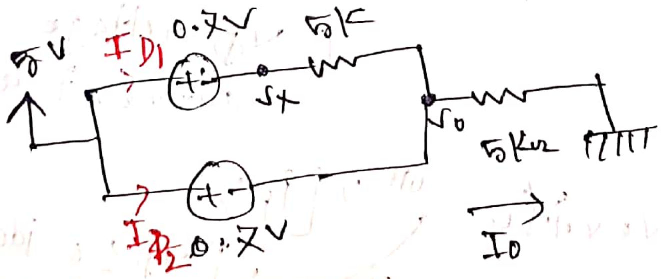
$V_{D0} = 0.7$ V

solve :

1. Assumption - 1

$D_1 = ON$

$D_2 = ON$



$\therefore 0.7 = 5 - \cancel{0.7}\ V_o$

$\therefore V_o = 5 - 0.7 = 4.3$ V

$\therefore I_o = \frac{V_o - 0}{5} = \frac{4.3}{5} = 0.86$ mA

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again,

$$0.7 = 5 - V_x$$

$$\therefore V_x = 5 - 0.7 = 4.3V$$

Now $I_{D_1} = \frac{V_x - V_0}{5} = \frac{4.3 - 4.3}{5} = 0$

Now ~~KCL~~ on using KCL

$$\Rightarrow I_{D_1} + I_{D_2} = I_0$$

$$I_{D_2} = I_0 ~~+0~~$$

$$= 0.86\,mA$$

Now verification.

Here ~~assumption~~ assumption was $D_1 = D_2 = ON$

but ~~I_{D_2}~~ $I_{D_1} = 0$ ∴ but for we need D_1 in ON mode

$I_{D_1} > 0$.

So assumption is not correct.

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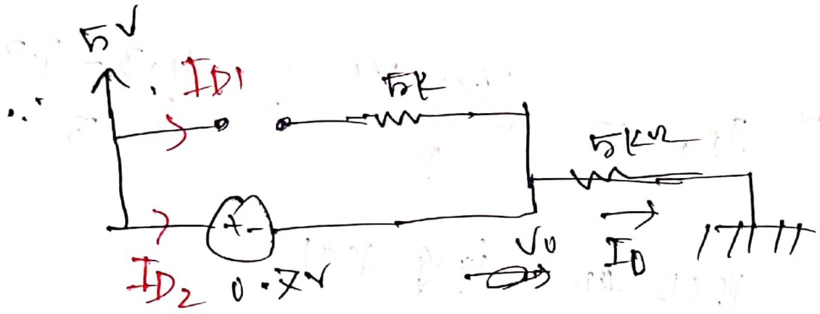
Assumption - 2

D1 = OFF

D2 = ON



$\therefore \; I_{D1} = 0$

$\therefore \; 0.7 = 5 - V_o$

$\therefore V_o = 4.3V$

$\therefore \; I_o = \dfrac{V_o - 0}{5} = \dfrac{4.3}{5} = 0.86 \text{ mA}$

$\therefore$ Using KCL:

$I_o = I_{D1} + I_{D2}$

$\Rightarrow I_o = 0 + I_{D2}$

$\therefore I_{D2} = I_o = 0.86 \text{ mA}$

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DATE: / /

Verification

For diode 2 or D2,

$I_{D2} = 0.86\ mA > 0 \therefore I_{D2} > 0$

$\therefore$ ON so for D2 assumption correct.

For D1,

$V_A = 5V$

$V_C = V_0 = 4.3V$

$\therefore V_D = V_A - V_C = 0.7V$

and $V_{D0} = 0.7V$

$\therefore V_D \leq V_{D0}$

$\therefore D1 = OFF$

$\therefore$ so for D1 assumption is correct.

$\therefore$ we can say ~~D1D2~~ $D1 = OFF$

$D2 = ON$ assumption is correct.

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$\therefore I_D = 0.86\ mA$

$V_D = 4.3V$ } (Ans)

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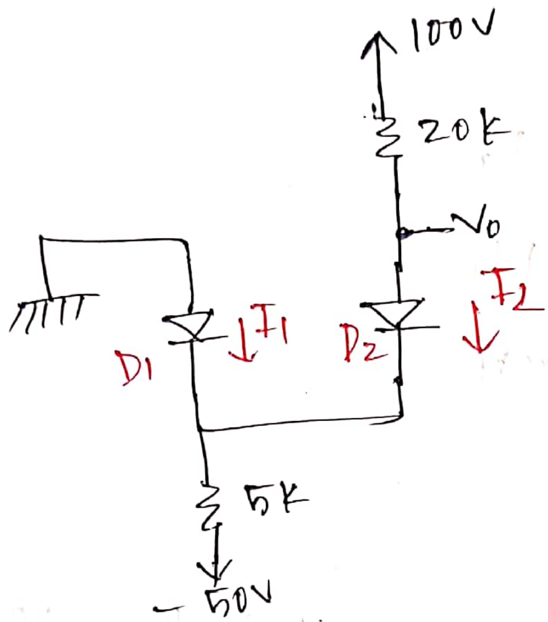
EX 2:



* Find V_o, I_1, I_2

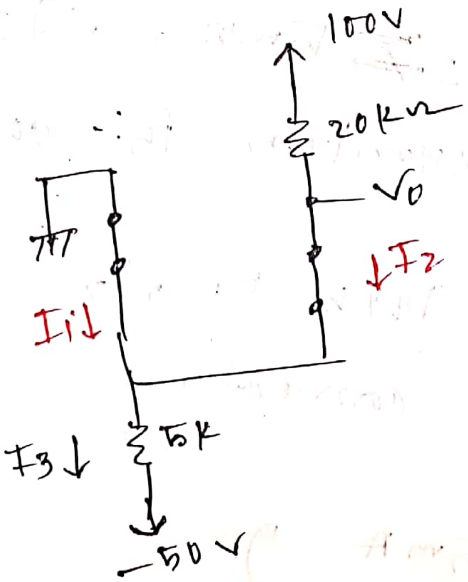
use Ideal diode model.

solve:

Assumption 1

$D_1 = ON$

$D_2 = ON$



$\because V_o = 0V$

$$I_2 = \frac{100 - V_o}{20} = \frac{100-0}{20} = 5mA$$

$$I_3 = \frac{0-(-50)}{5} = \frac{50}{5} = 10mA$$

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Using KCL

$$I_3 = I_1 + I_2$$

$$\Rightarrow 10 = I_1 + 5$$

$$\therefore I_1 = 5\,mA$$

Verification

For D1, $I_1 = 5\,mA$ $\therefore I_1 > 0$, so ON assumption is correct

For D_2 $I_2 = 5\,mA$, $\therefore I_2 > 0$ $\therefore$ ON assumption is correct.

$\therefore$ For both D1, D_2 assumption is correct.

$$\therefore \left.\begin{array}{l} I_1 = 5\,mA \\ I_2 = 5\,mA \\ V_0 = 0\,V \end{array}\right\} \text{(Ans)}$$

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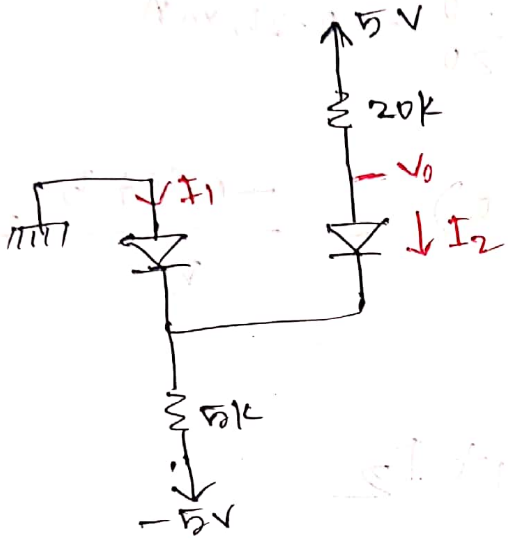
DATE: / /

Ex2:

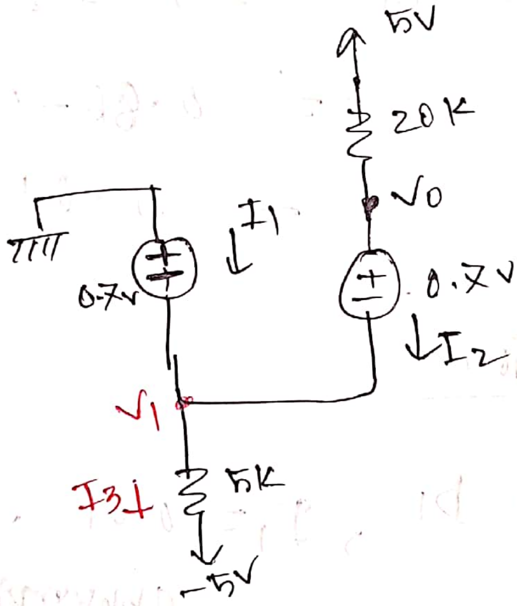


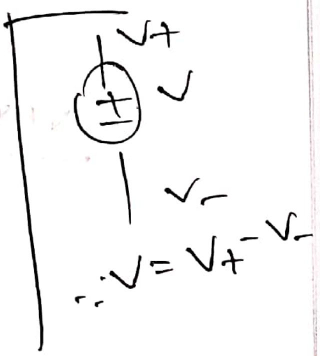
Find I_1, I_2 and V_0
use CVD [$V_{D_1} = 0.7V$]

Solve:

Assumption 1:

$D_1 = ON$
$D_2 = ON$





$\therefore \; 0 - V_1 = 0.7$

$\therefore V_1 = -0.7V$

now $V_0 - V_1 = 0.7 V$

$\therefore V_0 = 0.7 V + V_1$

$= 0.7 + (-0.7) = 0V$

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$$I_2 = \frac{5-0}{20} = \frac{5-0}{20} = 0.25\ mA$$

$$I_3 = \frac{V_1-(-5)}{5} = \frac{-0.7+5}{5} = 0.86\ mA$$

KCL

$$I_3 = I_1 + I_2$$

$$\Rightarrow I_1 = I_3 - I_2$$

$$= 0.86 - 0.25$$

$$= 0.61\ mA$$

verification

For D1, $I_1 = 0.61$ ∴ $I_1 > 0$ ∴ ON
∴ assumption correct

For D2, $I_2 = 0.25$ ∴ $I_2 > 0$ ∴ ON

∴ assumption correct.

∴ Assumption 1 is correct

∴ $I_1 = 0.61 mA$, $I_2 = 0.25 mA$
$V_0 = 0V$ (Answer)

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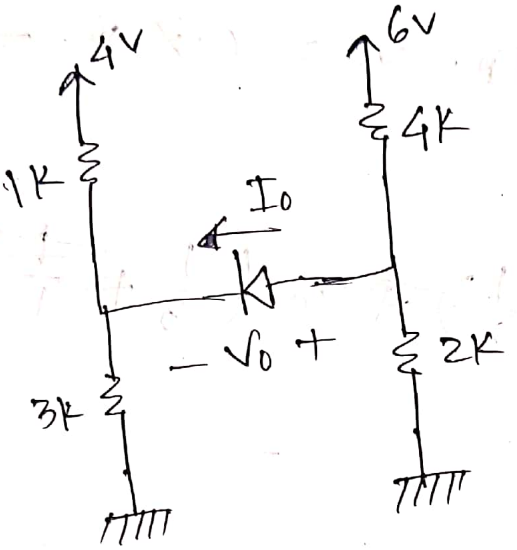
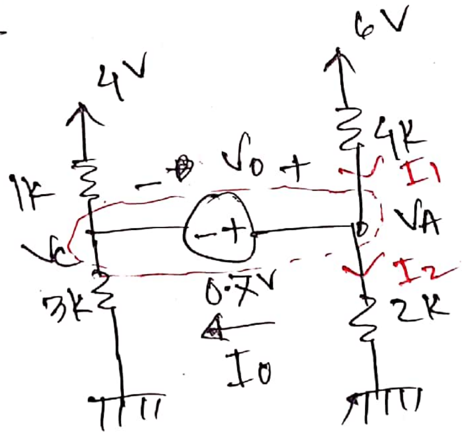
EX3 :



Find I_o and V_o use CVD [$V_{Do} = 0.7V$]

Assumption, D=ON



$\therefore V_o = 0.7V$

* using super node [As here floating voltage source we can't use direct nodal analysis, we have to use super Node]

$$\frac{V_A - 6}{4} + \frac{V_A - 0}{2} + \frac{V_c - 0}{3} + \frac{V_c - 4}{1} = 0 \quad (1)$$

~~Again~~

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or,

$$V_A\left(\frac{1}{4}+\frac{1}{2}\right)-\frac{6}{4}-\frac{0}{2}+V_C\left(\frac{1}{3}+\frac{1}{1}\right)-\frac{0}{3}-\frac{4}{1}=0 \quad \text{---} (1)$$

Again, $V_A - V_C = 0.7$ — (2)

Now from (1) and (2) we get,

$V_A = 3.09V$

$V_C = 2.39V$

Now

$I_1 = \dfrac{6-V_A}{4} = \dfrac{6-3.09}{4} = 0.7275$

$I_2 = \dfrac{V_A - 0}{2} = 1.545 \text{ mA}$

KCL $\because I_1 = I_0 + I_2$

$\therefore I_0 = I_1 - I_2 = = -0.8175 \text{ mA}$

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verification,

Here for D, $I_D = -0.8175$

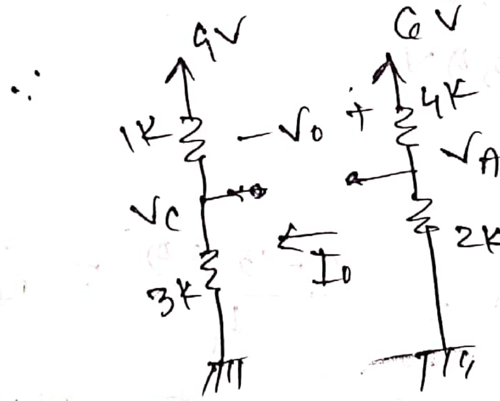
$\therefore I_D < 0$

$\therefore$ D is OFF

Assumption wrong.

So Here diode should be OFF

$\therefore$



$\therefore I_D = 0 \text{ mA}$

Voltage division rule

$V_A - 0 = \frac{2}{2+4} \times 6 = 2V$

$V_C - 0 = \frac{3}{3+1} \times 4 = 3V$

$\therefore V_D = V_A - V_C$

$= 3 - 2$

$= -1V$

Sub.:

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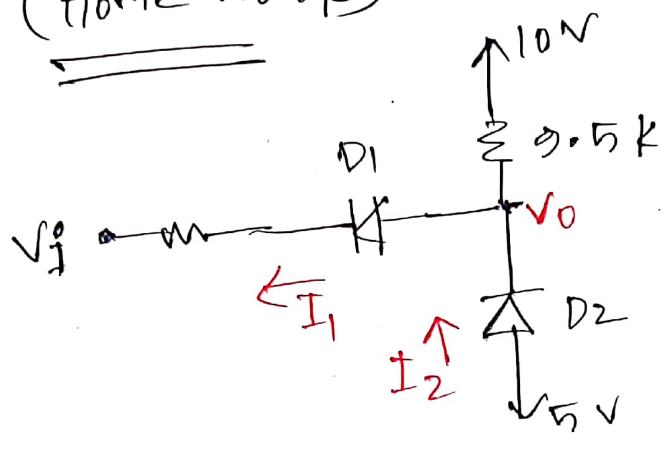
Ex: (Home Work)



Find V_o when,

① $V_i = 2V$

② $V_i = 4V$

use CVD [$V_{D_0} = 0.6V$] model.

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