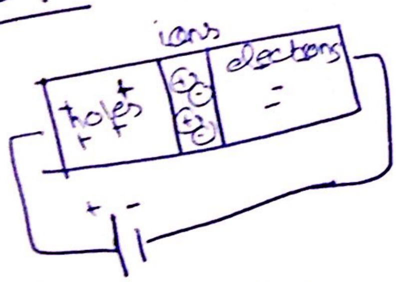
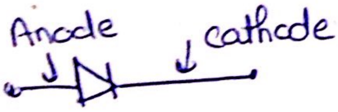
Diodes

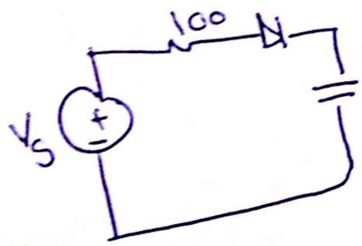
1) P-N Junction :-



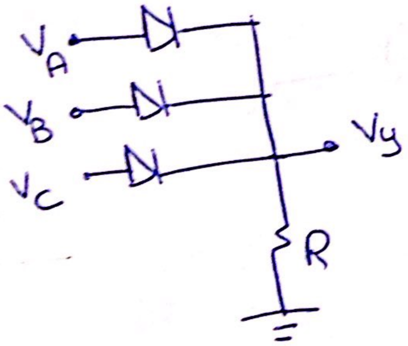
- Forward & Reverse Biased
- Diffusion & drift currents



- ideal Diode is Represented as a SC if on & OC if off.
- the diodes can be used as Rectifiers or logic gates ...



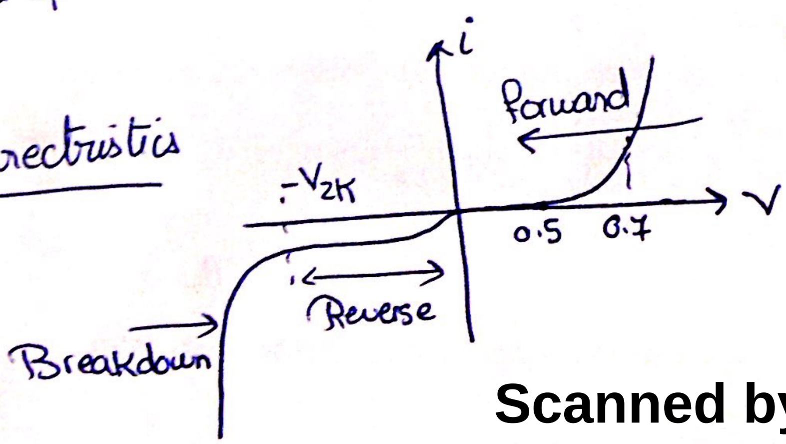
12 V → Rectifier → operates only in the +ve half cycle of the V_i.



OR gate → if any of the diodes are on, V_y will have a value

* what if we don't Know which diode is conducting ? We make a plausible assumption, proceed with the analysis & then check whether we end up with a consistent Solution.

→ IV charectristics



FW Bias → $V>0$
Reverse → $V<0$
Breakdown → $V<-V_{ZK}$

*Forward Bias Region:-

$$i = I_S\left(e^{V/\eta V_T} - 1\right) \simeq I_S e^{V/V_t} \; ; \quad \eta \text{ : ideally} = 1 \text{ (depends on material)}$$

(2)

I_S: Saturation current $\propto$ Diode cross sectional Area.

V_T: thermal voltage : $V_T = \dfrac{kT}{q}$

$k \rightarrow$ Boltzmann's constant

$T \rightarrow$ absolute Temp. in Kelvin

$q \rightarrow$ Magnitude of Electronic charge

$$\rightarrow \frac{I_2}{I_1} = e^{(V_2 - V_1)/V_t}$$

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* Reverse-Bias Region:-

$i \simeq I_S$

* Breakdown Region:-

→ It's Entered when the magnitude of the Reverse voltage exceeds a threshold Value called the Breakdown Voltage

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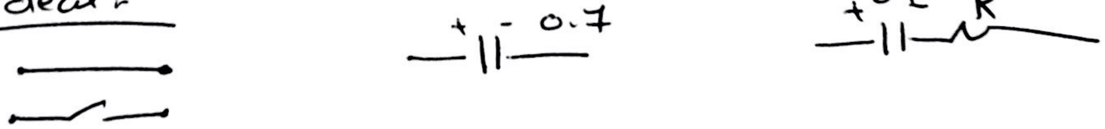
* Diode Models:-

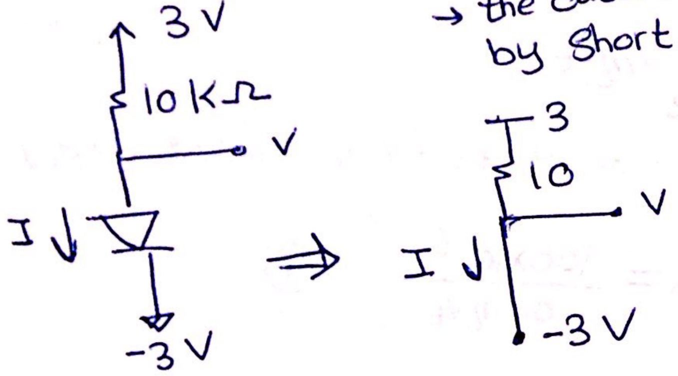
ideal:-



Sheet 2 Solution

Problem 1 :-

a) Find I & V

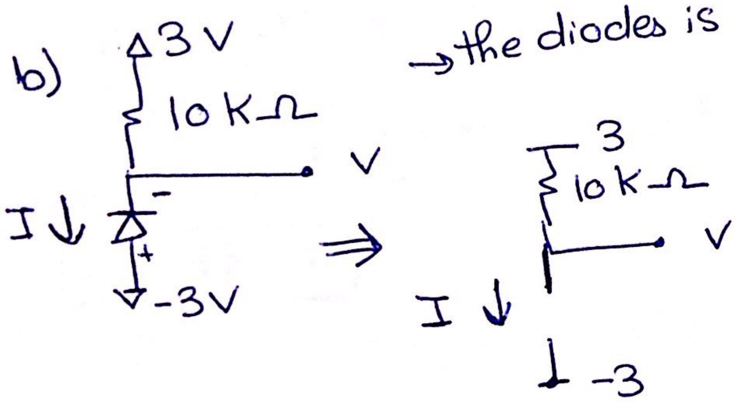


→ the diode is on & FW biased → Replaced by Short Circuit

$\therefore V = -3\text{ V}$

$I = \frac{3-(-3)}{10K} = 0.6\text{ mA}$

b)

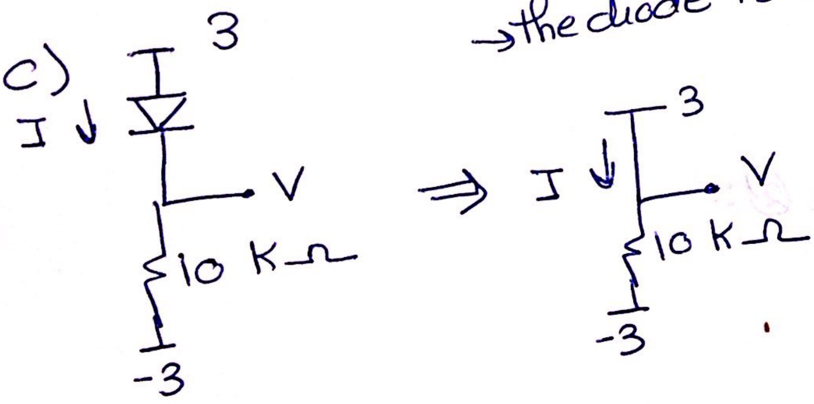


→ the diodes is off → Replaced by open circuit

$\therefore V = 3\text{ V}$

I = zero.

c)

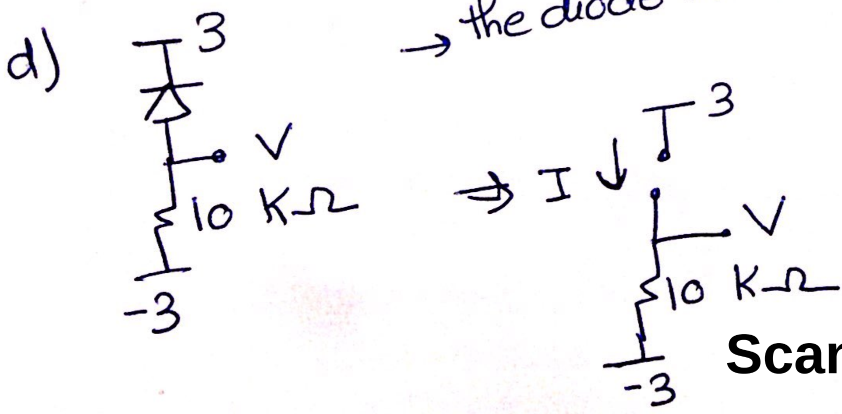


→ the diode is on → Replaced by SC

$V = 3\text{ V}$

$I = \frac{3-(-3)}{10K} = 0.6\text{ mA}$

d)



→ the diode is off → Replaced by OC

$V = -3V$

I = zero

Problem 2 :.

(2)

$I_D = 100\ \mu A$ @ $V = 0.7\ V$

$I_D = 1\ mA$ @ $0.815\ V$

$I_D = I_S\left(e^{V/\eta V_T} - 1\right) \simeq I_S e^{V/\eta V_t}$

A small discrete Silicon diode is found to conduct $100\ \mu A$ at $0.7\ V$ & $1\ mA$ at $0.815\ V$. Find the values of I_S & η.

(1) $100\times10^{-6} \simeq I_S \times e^{0.7/\eta V_t} \Rightarrow I_S \simeq \dfrac{100\times10^{-6}}{e^{0.7/\eta V_t}}$ (1)

$1\times10^{-3} \simeq I_S \times e^{0.8/\eta V_t}$ (2)

$\therefore 1\times10^{-3} = \dfrac{100\times10^{-6}}{e^{0.7/\eta V_t}} \times e^{0.8/\eta V_t}$

$1\times10^{-3} = 100\times10^{-6} \times e^{\frac{1}{\eta V_t}(0.115)}$

$\ln\left(\dfrac{1\times10^{-3}}{100\times10^{-6}}\right) = \dfrac{1}{\eta V_t} \times 0.115$

$\dfrac{1}{\eta V_t} = 20.022$

$\therefore \eta V_t = 0.0499$

$\because V_t \simeq 25\ mV$ @ $300\ K$

$\boxed{\therefore \eta \simeq 2}$

→ By substituting in Either (1) or (2) :.

$\boxed{I_S = 8.085\times10^{-11}}$

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(2) A diode for which $\eta=1$ conducts 0.1 mA at 0.7 V. Find the voltage drop at 1 mA. for what current is the voltage drop equal 0.815 V? (3)

$\eta=1 \quad I=0.1\ mA \quad V=0.7$

$V=?$ @ 1mA

$$I_D = I_S\, e^{V/\eta V_t}$$

$$\rightarrow 0.1\times10^{-3} = I_S \times e^{0.7/1\times25\times10^{-3}}$$

$$\boxed{\therefore I_S = 6.9\times10^{-17}}$$

$$\therefore V = V_T \ln\frac{I}{I_S}$$

$$= 25\times10^{-3} \ln\left(\frac{1\times10^{-3}}{6.9\times10^{-17}}\right)$$

$$\boxed{= 0.758\ V}$$

$$I_D = 6.9\times10^{-17}\times e^{0.815/1\times25\times10^{-3}}$$

$$\boxed{= 9.93\ mA}$$

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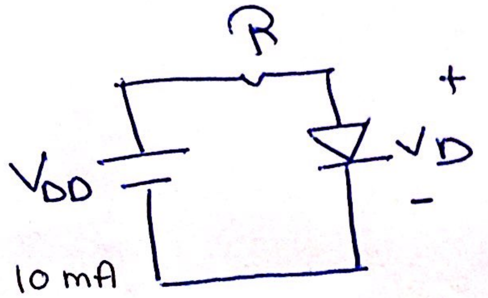
Problem 3 :

→ for the following Example we have to get the intersection between a line we draw & the Exponential charectiristic curve.

→ the coordinates of the line are (V, I)

1st point → (0, I)
2nd point → (V, 0)

→ get I & V and draw a straight line (load line) then get the intersection with the Exponential charec. curve.



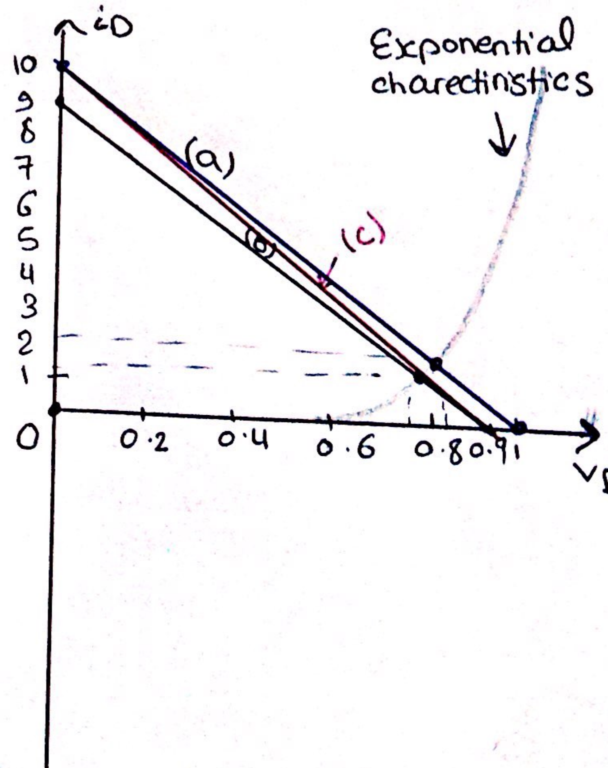
a) $V_{DD} = 1\ V$ $R = 100\ \Omega$

→ when $V_D = 0$ (e.g. S.C), $I = \frac{V_{DD}}{R}$

$= \frac{1\ V}{100\ \Omega} = 10\ mA$

→ when $I = 0$ (e.g OC), $V = V_{DD} \rightarrow V = 1V$

$\boxed{\text{Sol: } V_D = 0.75,\ I_D = 2.5\ mA}$



(b) $V_{DD} = 0.9\ V$, $R = 100\ \Omega$

→ when $V = 0 \rightarrow I = \frac{V_{DD}}{R} = 9\ mA$

when $I = 0 \rightarrow V = V_{DD} = 0.9\ V$

$\boxed{\text{Sol: } V_D = 0.73\ V,\ I = 1.7\ mA}$

(c) $V_{DD} = 0.9V$, $R = 90\ \Omega$

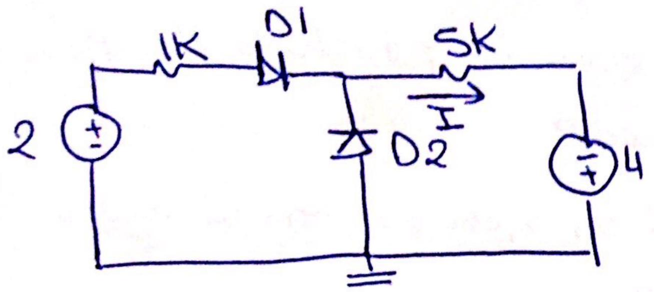
→ when $V = 0 \rightarrow I = \frac{V_{DD}}{R} = 10\ mA$

→ when $I = 0 \rightarrow V = V_{DD} = 0.9\ V$

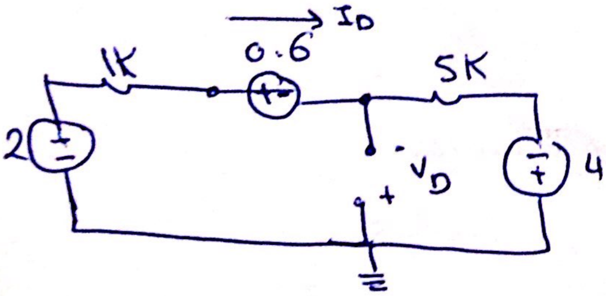
$\boxed{\text{Sol: } V_D = 0.74\ V,\ I_D = 1.8\ mA}$

Problem 4 :

$V_{th} = 0.6$



Assume D1 ON & D2 off :



$-2 + 1K I_D + 0.6 + 5K I_D - 4 = 0$

$-5.4 + 6K I_D = 0$

$I_D = \frac{-5.4}{-6K}$ → +ve ✓ $= 0.9mA$

check for V_D :

$V_{D+} = \text{zero}$

$V_{D-} = 5K I_D - 4$

$= (0.9)5 - 4$

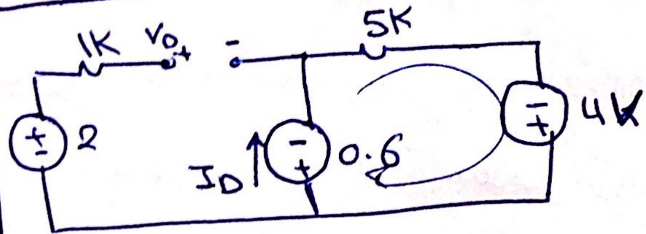
$= 0.5$

$\therefore V_{D-} > V_{D+}$ → D2 off ✓

$\boxed{\therefore I = 0.9mA}$

wrong Assumption :

D1 off & D2 ON :



$0.6 + 5K I_D - 4K = 0$

$-3.4 = -5K I_D$

$I_D = 1.6\ mA$ ✓

check for V_D :

$V_{D+} = 2$

$V_{D-} = -0.6$

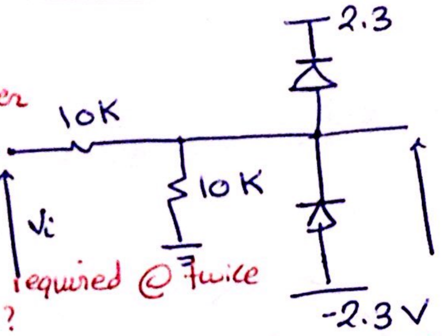
→ the Diode should be ON

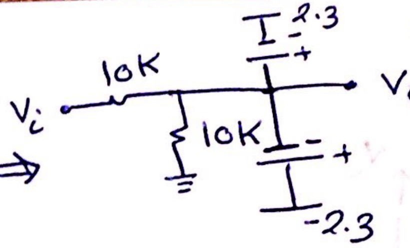
∴ Wrong Assumption

- Problem 5 :-

a) Find the upper & lower limiting levels (0.7 drop), the gain, & the upper & lower i/p threshold levels.

b) what's the i/p current required @ twice the upper threshold value?





c) Sketch V_o Vs time @ Sin V_i of amplitude 15V & freq. 1KHz

• Voltage drop on diodes = 0.7 → DC Source = 0.7

a) What's the Max Value that V_o Can Reach?

* limiting level ? →

DI ON → $V_o \geq 3V$ → $(2.3+0.7)$

D2 ON → $V_o \leq -3V$ → $(-2.3+(-0.7))$

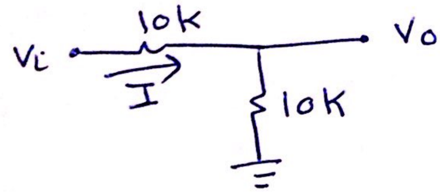
N.B. V_o will never pass 3 or -3V because the voltage becomes constant as ~~the~~ it's taken from 2 DC Sources rather than V_i.

upper & lower input threshold ?

→ At which Value will V_o Start depending on the DC sources instead of V_i?

1st let's get the circuit gain to Know the relation between V_i & V_o.

⇒ Gain V_o/V_i is when all other DC Sources are off.



$$\frac{V_o}{V_i} = \frac{10K}{10K+10K} = 0.5$$

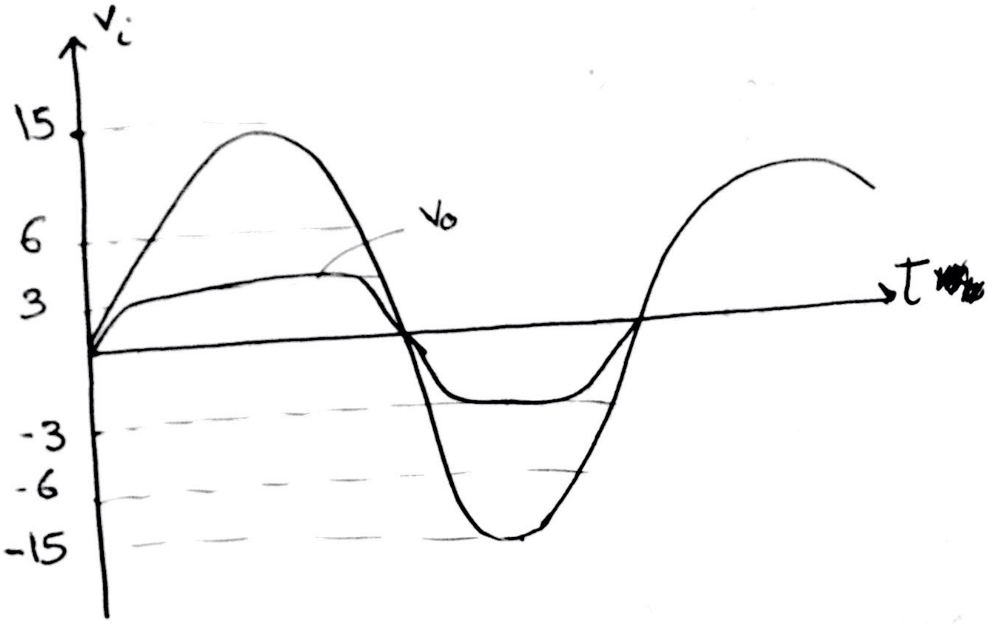
∴ threshold → $\frac{3/-3}{V_i} = 0.5$ → $V_i = 6/-6$ V

b) $V_i = 2(\text{upper threshold}) = 12$ V

DI ON → $V_o = 3V$ (no increase in V_o if $V_i \geq 6$ V)

⇒ i/p current (I in the 1st 10K) → $\frac{V_i - V_o}{10K} = \frac{12-3}{10K} = 0.9$ mA

ⓒ



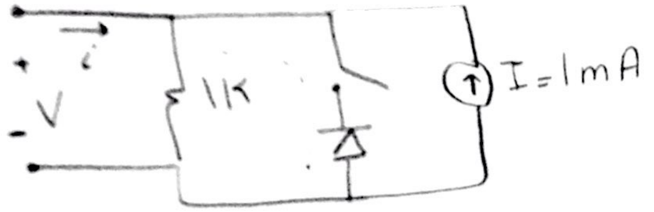
* when $V_i = 6\,V \rightarrow D1$ ON , V_o will be Sketched to $3V$ $(2.3+0.7)$

* when $V_i < 6\,V \rightarrow$ $V_o = 0.5\,V_i$

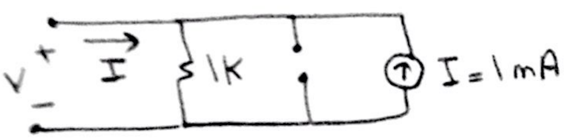
* Same thing for the negative part.

Problem 6 :-

Sketch I-V input characteristics of the circuit.



a) when Switch is open:-



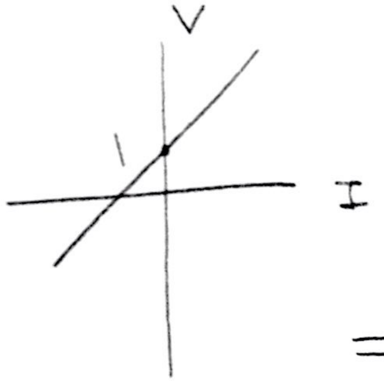
$V = (1mA + i) \times 1K$

$\therefore$ linear relationship between I & V

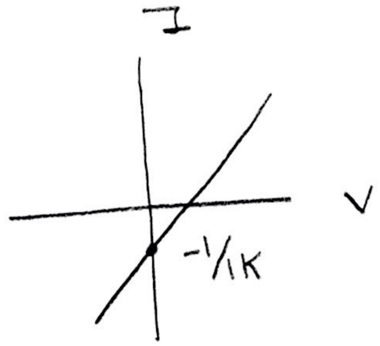
$V = (1mA \times 1K) + 1K i$

$y = c + mx$

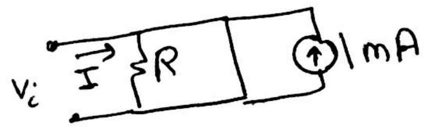
$$i = \frac{V-1}{1K} = \underbrace{\frac{V}{1K}}_{\text{slope}} - \frac{1}{1K} \rightarrow c$$



$\Longrightarrow$



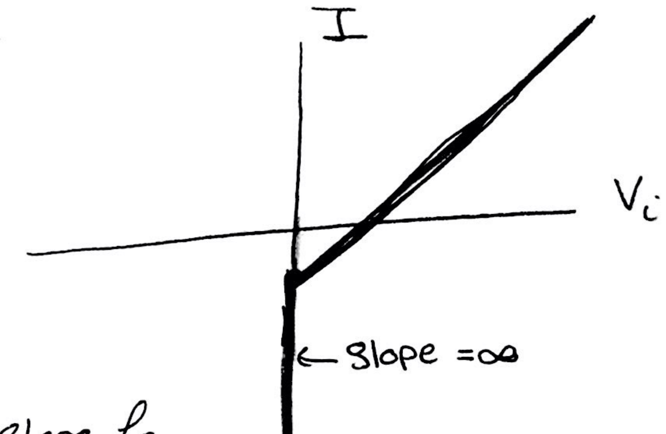
b) when Switch is closed :-



if $V<0 \rightarrow$ Diode becomes Short circuit

& $I = \infty$

if $V>0 \rightarrow$ Same linear Relationship as Before

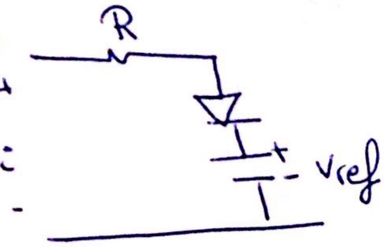


N.B: for any -ve value for Vi, same slope for I.

Problem 7 :-

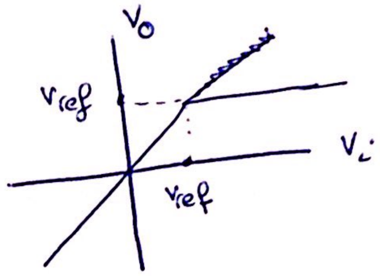
Find V_o, Draw V_o Vs V_i.

a)

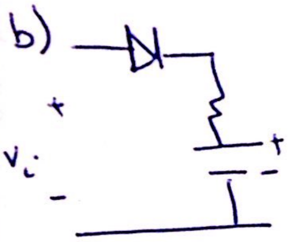


if $V_i > V_{ref} \rightarrow V_o = V_{ref}$

$V_i < V_{ref} \rightarrow V_o = V_i$

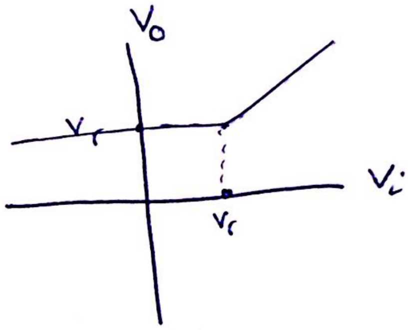


b)

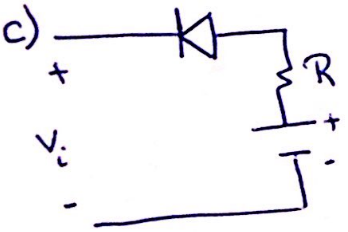


if $V_i > V_{ref} \rightarrow V_o = V_i$

$V_i < V_{ref} \rightarrow V_o = V_{ref}$

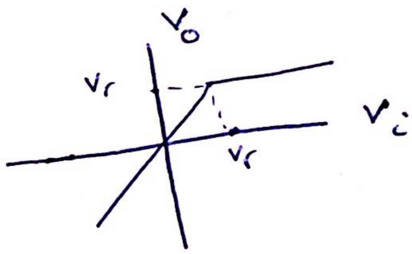


c)

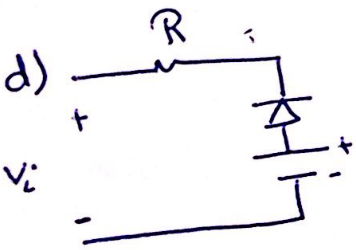


if $V_i > V_{ref} \rightarrow V_o = V_{ref}$

$V_i < V_{ref} \rightarrow V_o = V_i$

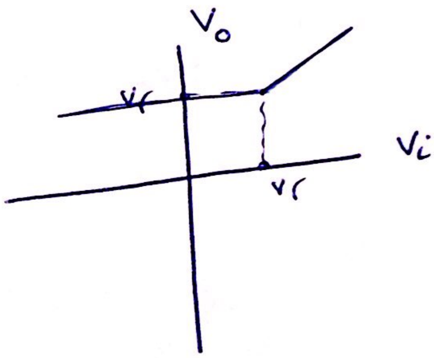


d)

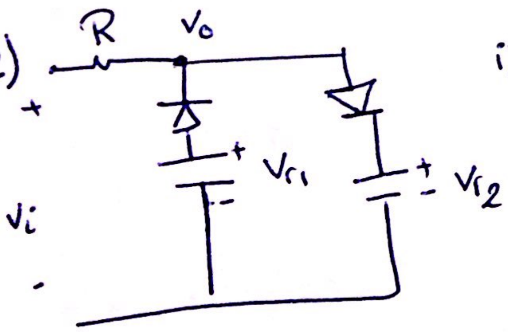


if $V_i > V_{ref} \rightarrow V_o = V_i$

$V_i < V_{ref} \rightarrow V_o = V_{ref}$.



e)

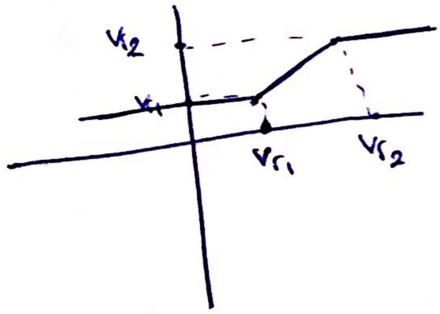


if $V_i > V_{r2} \rightarrow V_o = V_{r2}$

if $V_i < V_{r1} \rightarrow V_o = V_{r1}$

if $V_{r1} < V_i < V_{r2} \rightarrow$

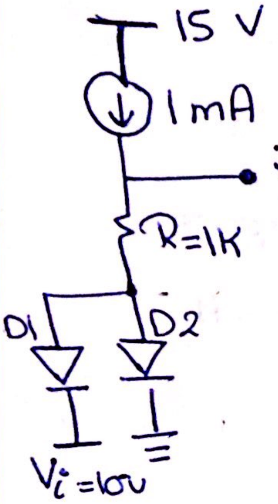
$V_o = V_i$



problem 8 :.

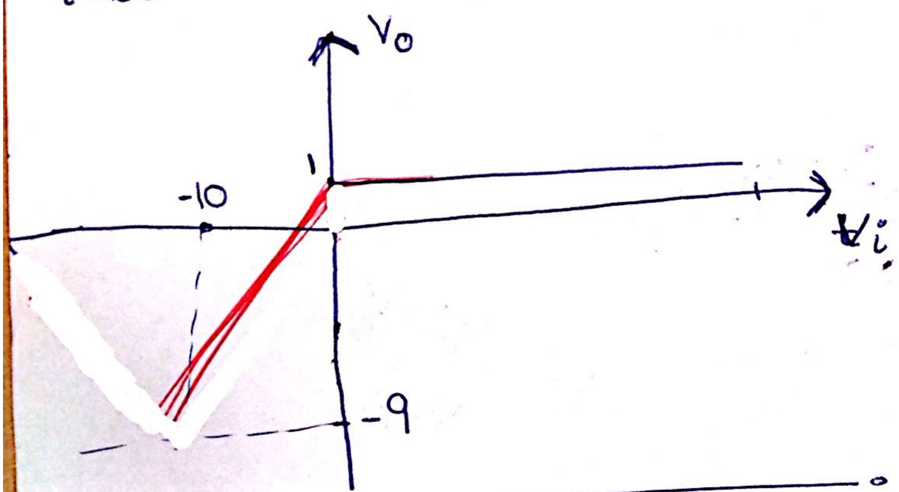
Sketch V_o for V_i 1K-Hz, 10 V Peak Sin wave

$V_o = 1mA \times 1K = 1V$ (when +ve)



* V_{in} is a Sin wave :.

- when +ve D_1 is off → $V_i > 0$
  D_2 is on
  $V_o = 1V$
- when -ve D_1 ON; D_2 off → $V_i < 0$
  $V_o = -10 + (1mA \times 1K\Omega)$
  $= -9V$



problem 9 :-

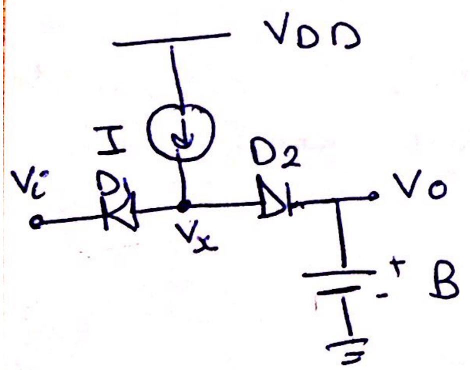
V_i is a 10-V Peak Sine wave
Sketch the waveform of the battery current.

Determine $i_{Battery}$:-

$V_i = 10$-V peak Sine wave

$I = 100$ mA

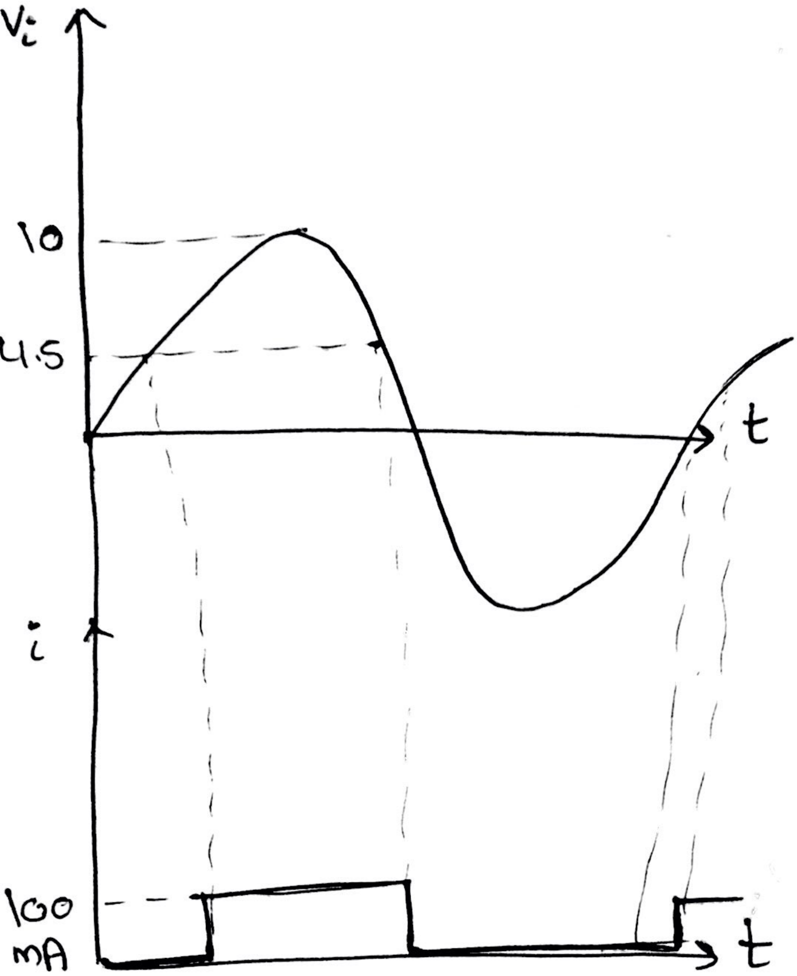
$V_B = 4.5$ V



Assuming D1 ON & D_2 off :-
∴ $V_x = V_i$
this can happen only if $V_x < 4.5V$
@ this case, i_B = zero

Assuming D_1 off & D_2 ON :-
$V_x > 4.5$ & $V_i > V_x$ → $V_i > 4.5$

∴ I = 100 mA



$V_i < 4.5 \rightarrow i_B = \text{zero}$

$V_i > 4.5 \rightarrow i_B = 100\ mA$