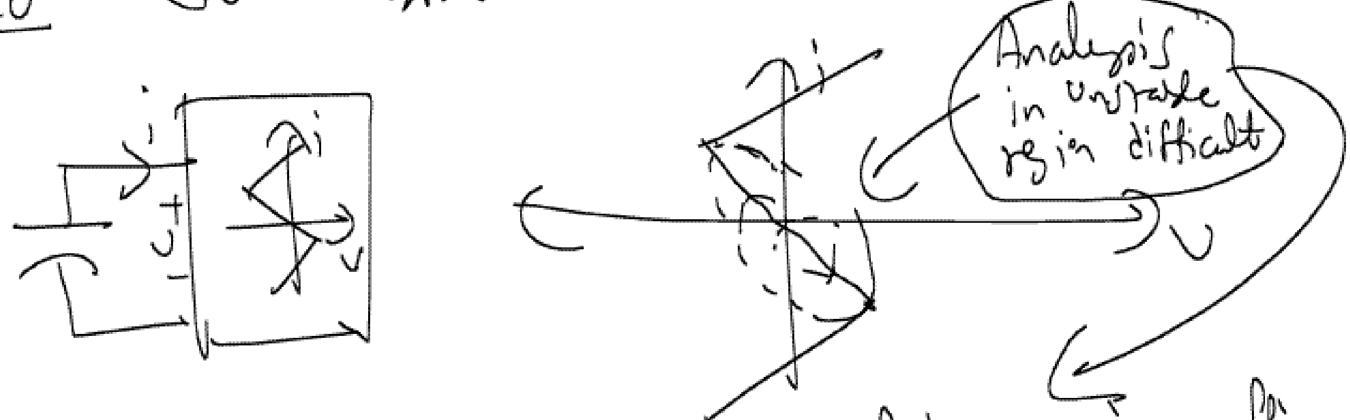
Lecture 21 - Introduction to diodes.

Administrivia → Next week: midterm week

- look for info online by the end of this week.
- Topics: Op-amps: Linear & nonlinear [HW #7, HW #8]
- Like midterm 1
  - Thursday (03/07): Review session
  - Tuesday (04/12): In-lecture Q/A session
    - (??) 5:00 pm - 7:00 pm: Justin review
  - Thursday (04/14): MT II, makeup MT II

Today: (1) Question from last time:



Ask me in office hours

You are not responsible for such difficult regions.

For midterm ⇒ understand HW due this week, look at midterm II review problems

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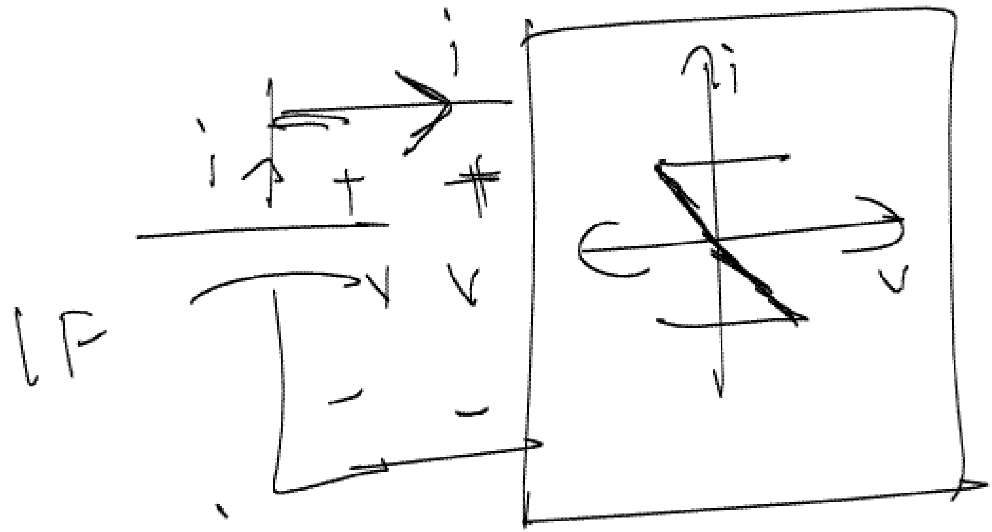
(2) Diodes: Intro, but first, I just feel like doing this problem:

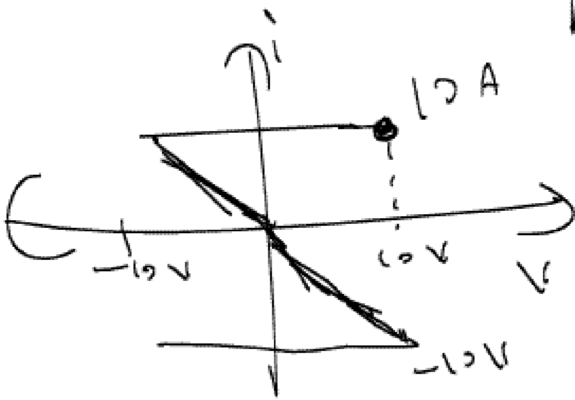
(Eg.)



(Q:) ~~(i) Find i(t) & v(t)~~

(i) Plot i(t) & v(t)

(ii) Find period of oscillation



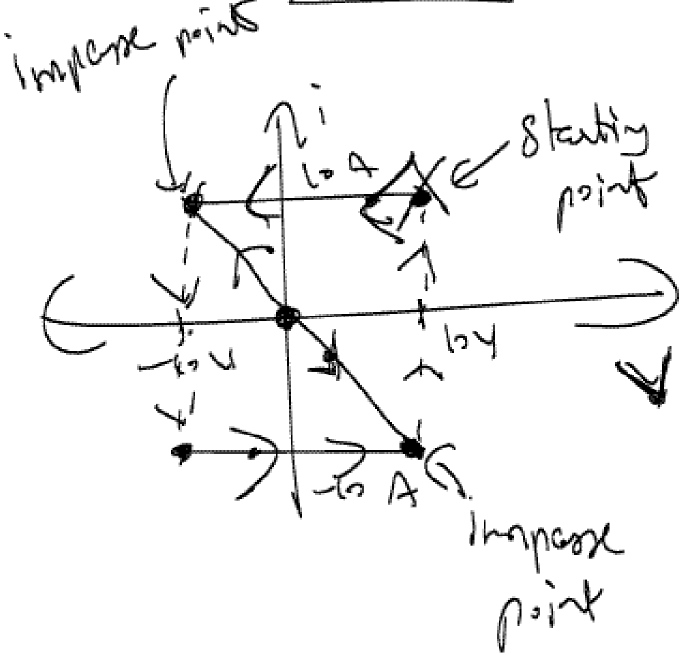
[Note: I consider this a difficult problem on the midterm.]

Assume $v(0) = 10\,V$, $i(0) = 10\,A$

Step 1: Find equilibrium points & dynamic routes.

Eq. point: $f'(t) = 0 \Rightarrow \frac{dv}{dt} = 0 \Rightarrow \boxed{i = 0}$

$\left[i = -(LF) \frac{dv}{dt} \right]$

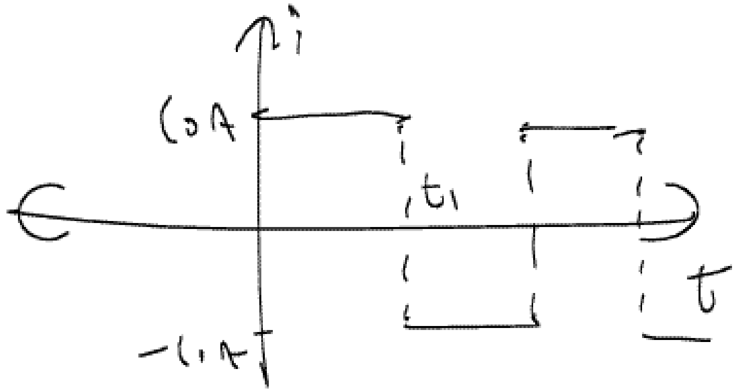


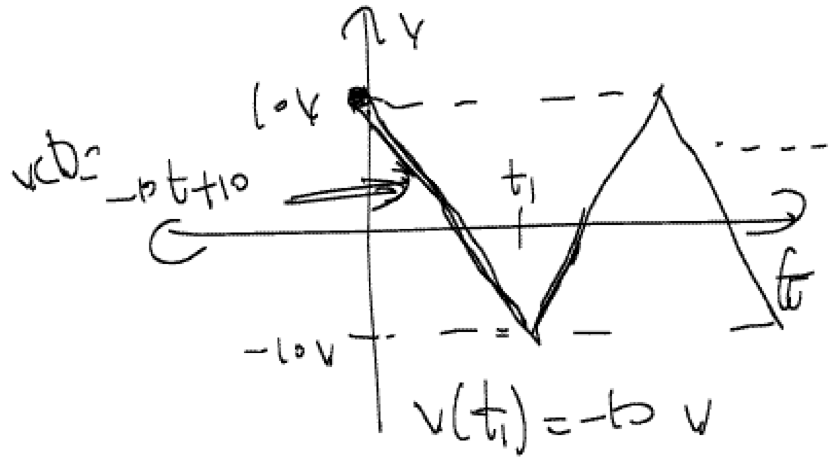
Dynamic routes:

$\boxed{\begin{matrix} i > 0, & v' < 0 \\ i < 0, & v' > 0 \end{matrix}}$

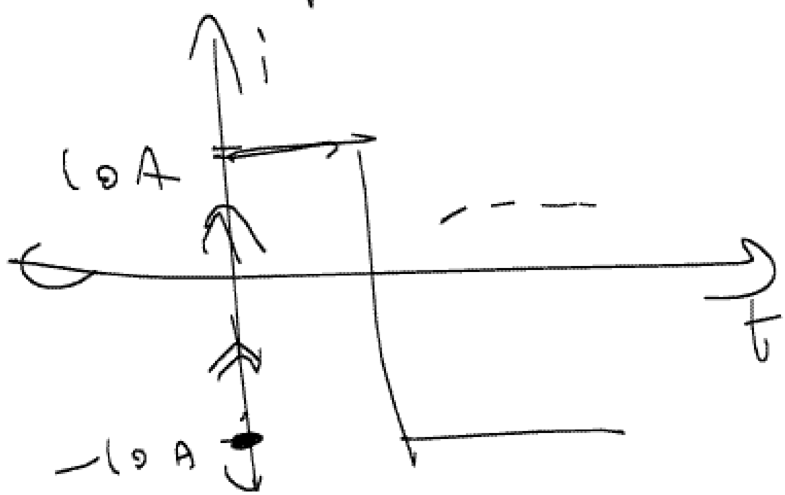
[be careful, don't make stupid mistakes]

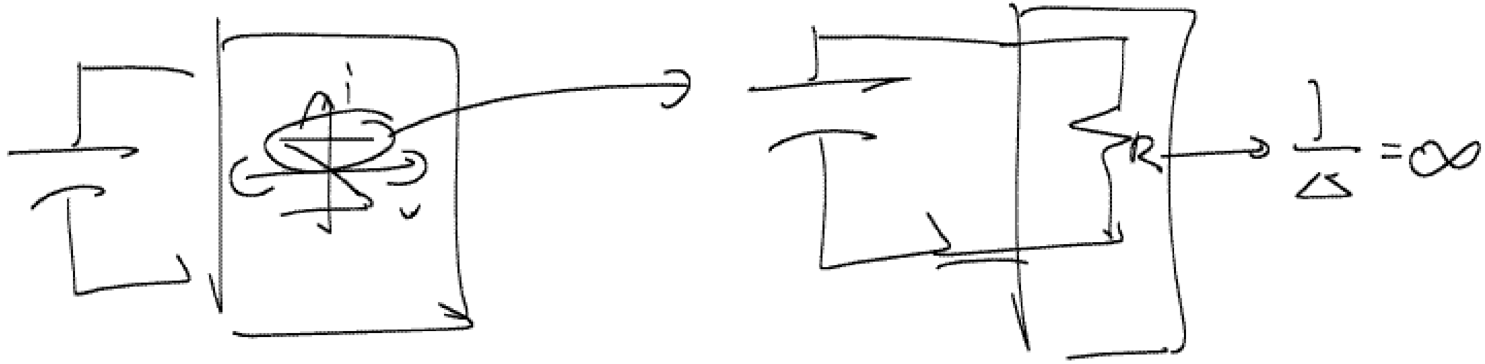
Step (2): Good idea to roughly sketch $i(t)$ & $v(t)$



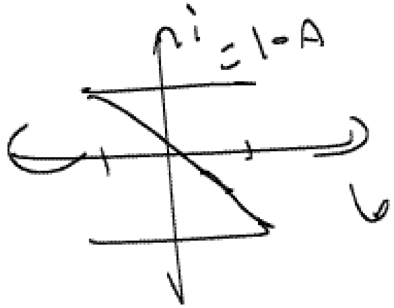


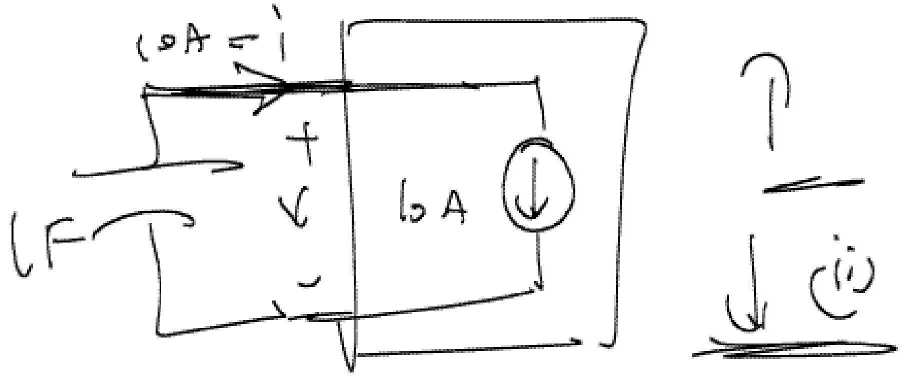
<u>Note:</u> If we started at $v(0) = 10$V, $i(0) = -10$A





This actually makes sense because in $v \in [10\,V, -10\,V]$, i is constant. In other words, the thevenin resistance of an ideal constant current source is infinity;





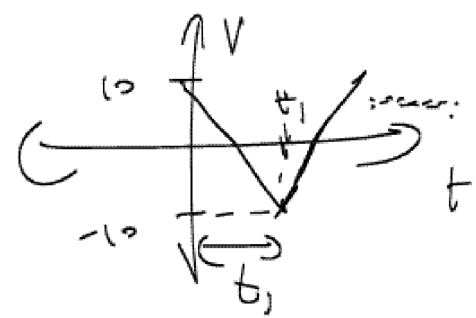
Now, $i = -C\frac{dv}{dt} \Rightarrow 10\,A = -(1\,F)\frac{dv}{dt}$

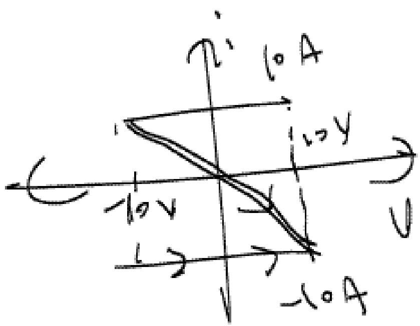
$$\Rightarrow \frac{dv}{dt} = -10\,A$$

$$\Rightarrow v(t) = -10t + V_0$$

For us, $V_0 = v(0) = 10\,V$ ∴ $\boxed{v(t) = -10t + 10\,V}$

Step 3: Find period of oscillation:





$$V(t_1) = -10$$

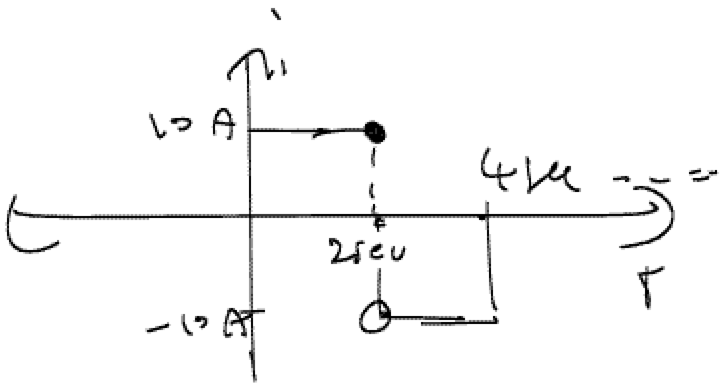
$$\Rightarrow -10t_1 + 10 = -10$$

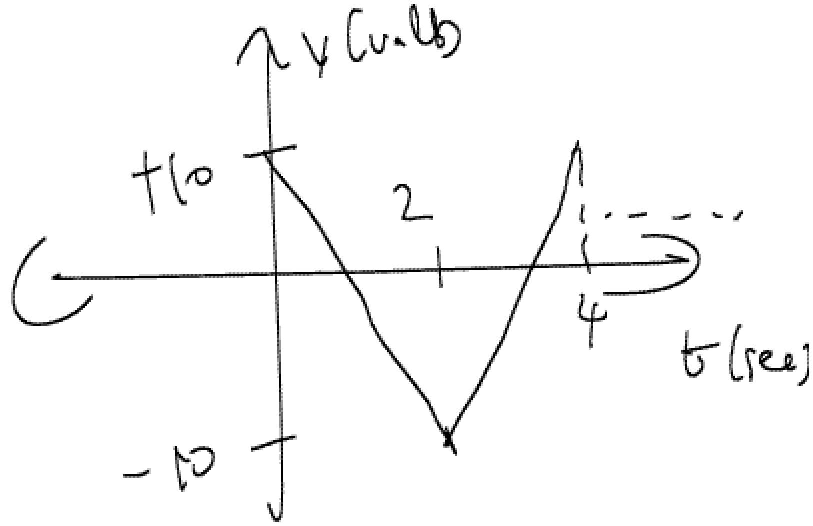
$$\Rightarrow t_1 = \frac{-20}{-10} \Rightarrow \boxed{t_1 = 2 \text{ sec}}$$

∴ $\boxed{T = 2t_1 = 4 \text{ sec}}$

(i) $i(t) = \begin{cases} 10\,A & \text{if } t \in [0, 2 \text{ sec}) \\ -10\,A \end{cases}$

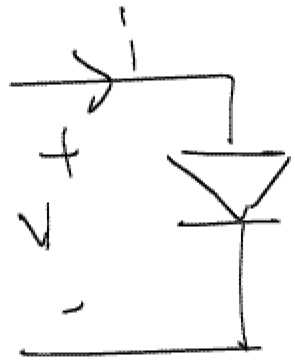
(i)





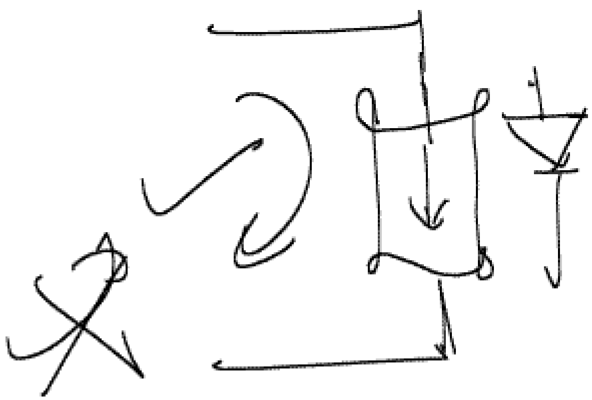
(ii) $T = 4$ sec

Finally: Diodes



circuit symbol

Diodes allow current to flow in only one direction



Mechanical Analogy

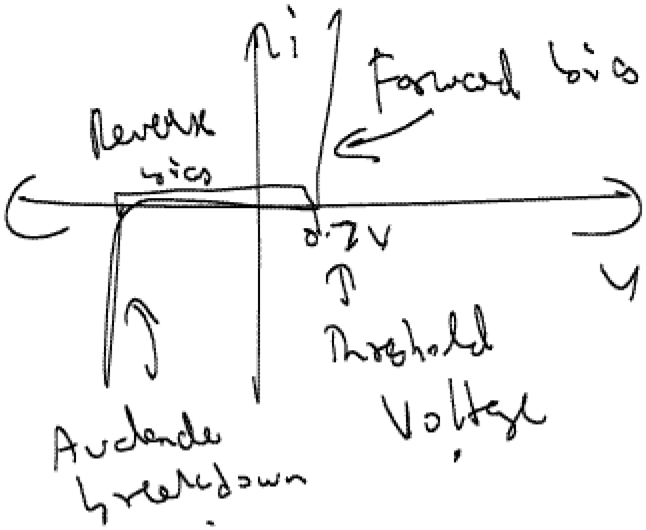
A diode is a **Check-valve**

↓

it allows water to flow in only one direction.

Ok, so whats hard about diodes ⇒ you need nonlinearity to capture the behaviour

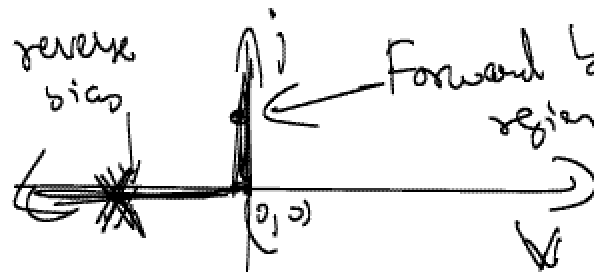
Reality:



Threshold voltage: when the diode turns "on" ⇒ forward bias

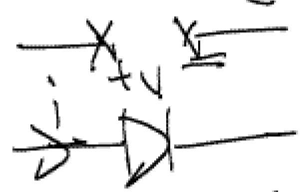
Diode off ⇒ reverse bias

For us: (Ideal diode model)



Reverse bias

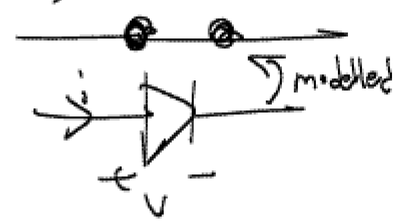
$i = 0 \quad v \leq 0$

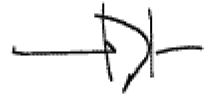


$+v = (v \leq 0)$

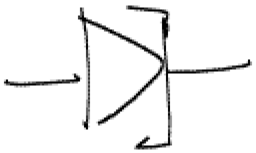
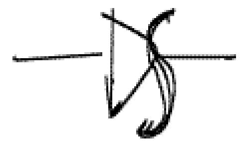
Forward bias:

$i \geq 0 \quad v = 0$



Note: many diodes exist:  : Regular switching diode

 : Zener diode

 : Tunnel diode  Schottky diode

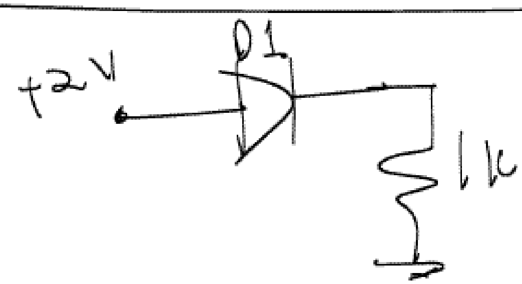
PS: You need to understand only switching diode

So, what difficult about diodes is it is difficult to spot what region of operation (i.e., is diode on (or) off) the diode is in.

Moreover: if there is 1 diode in a circuit → 2 states
on,
off

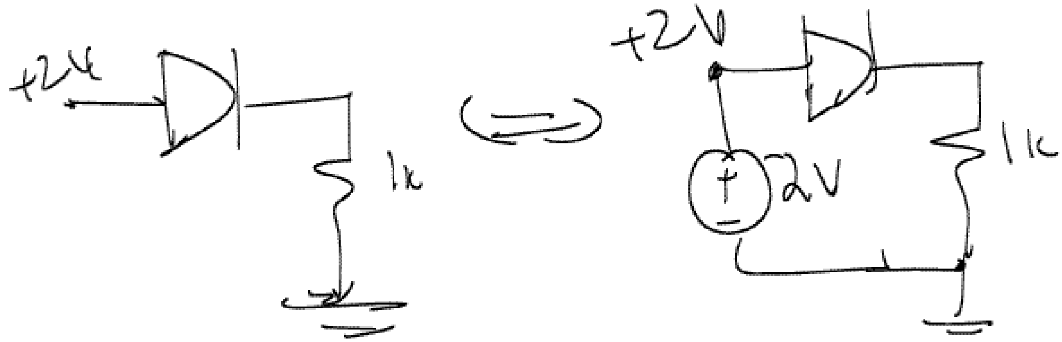
if there are 2 diodes → 4 states
on, on
off, on
on, off
off, off

In other words, if you have n diodes in a circuit, we have 2^n states, whoa, exponential ☹.

Eg: 

(Q:) Is diode on or off?
(Assume diode is ideal)

Note:



Steps in solving diode problems:

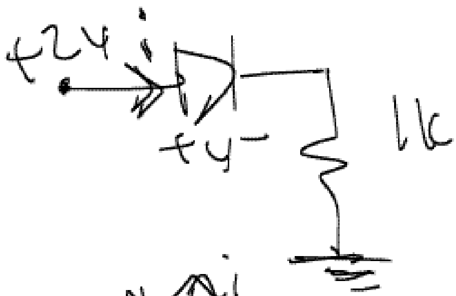
(1) Assume a state for each diode

[MAKE AN EDUCATED GUESS, IF YOU DON'T YOU WILL BE SORRY!]

(2) Solve circuit - i.e.. find Is & Vs in circuit.

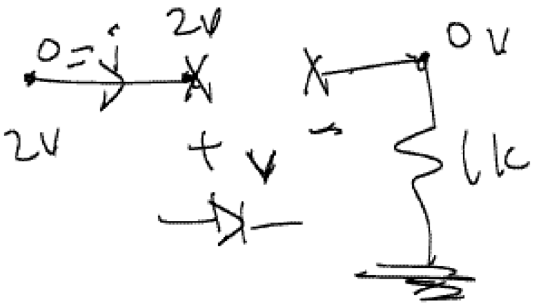
No contradictions: ☺. Solved circuit

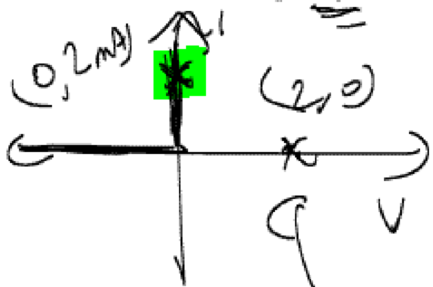
(3) If you get a contradiction, change state for diodes repeat (2



Hmm.. assume diode off [step (1)]

Step (2):



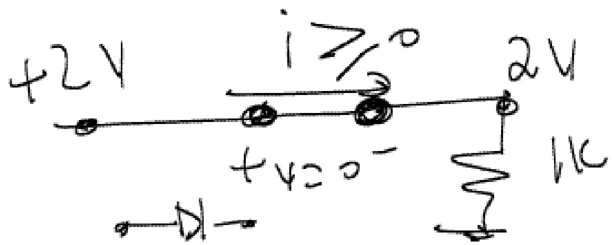


Now diode is off, $V \leq 0$

INCORRECT!

$V = 2V, \; i = 0$

=> assumption is wrong => diode is on!

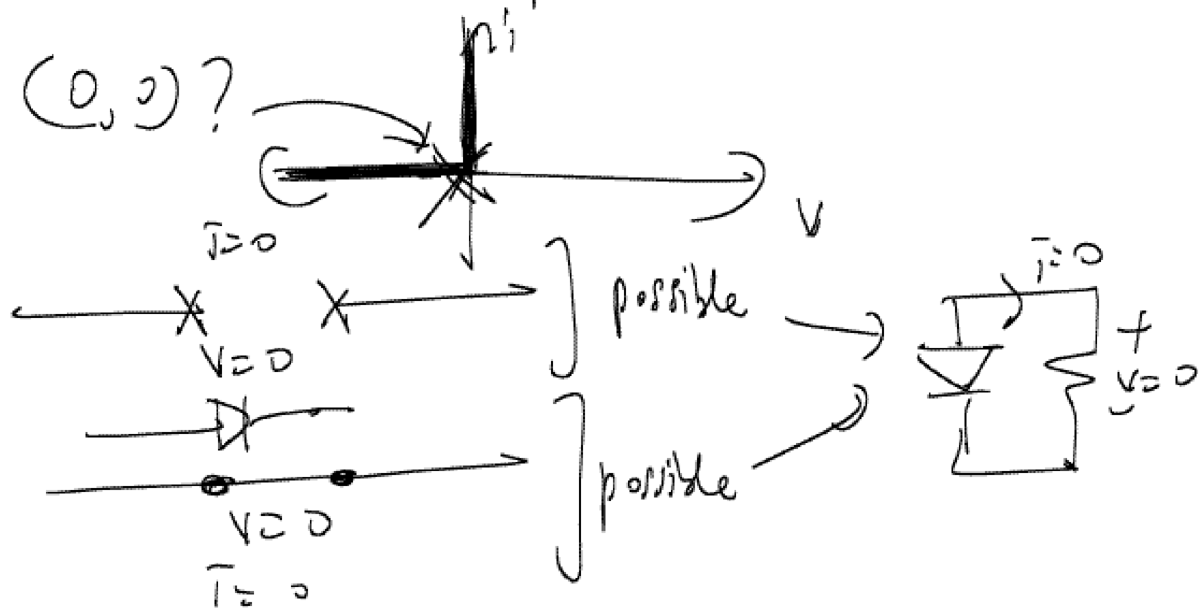


$i = \frac{2V}{1k} = 2mA$: (0 V, 2mA)

Note: (1) (0 V, 2 mA) is called the operating point (or) bias point (or) Q-point [Quiescent] point.

Important:

(2) What about (0, 0)?

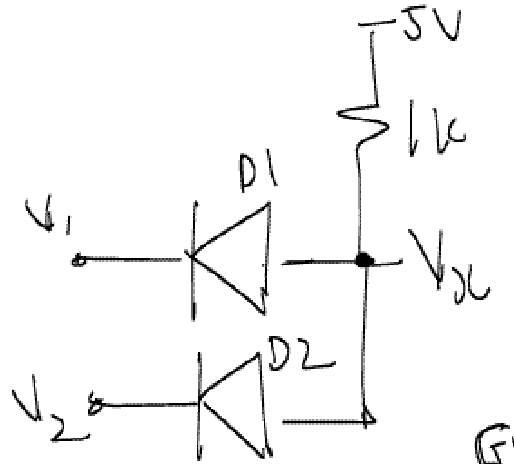


Reverse bias:

Forward bias:

Conclusion: Diode model @ (0, 0) depends on the circuit!

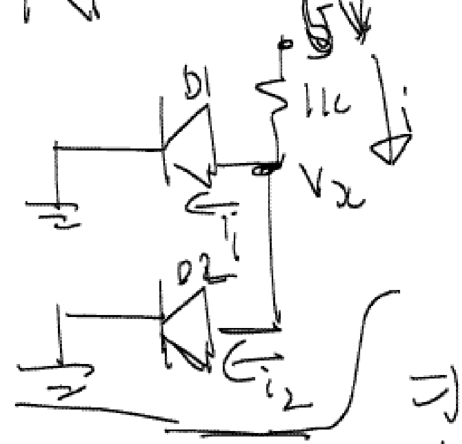
Eg 2:



V_1	V_2	V_x
0	0	0
0	5	0
5	0	0
5	5	5

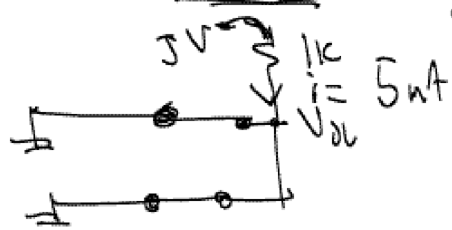
← Fill in table

Case (i): $V_1 = 0$, $V_2 = 0$



Hmm... looks like diodes are on

$\Rightarrow$ $V_x = 0$ V



Finish after mt I

Next <u>time</u>: midterm II review session.

→ look online for review problems (posted by the end of the week!)