Lecture 15 - More op-amp examples / project info

Administrivia
- → *Extra op-amp problems are up
- → HW #4 solutions are up

  BAD SCANNER, SORRY!
- → Nonlinear problem set is up (turn in with HW #5)
- → Active filters notes up ⇒ check Project section on lab page!
- → PICK UP MIDTERM, OLD HW & LABS (from lab, ask TA). I have asked TAs to email me lab scores. Start making sure online grades are correct!
- → midterm regrade deadline extended to 08/03/05

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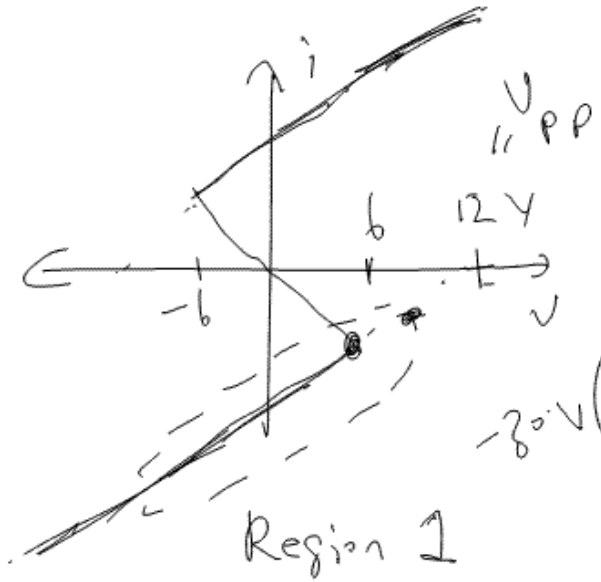
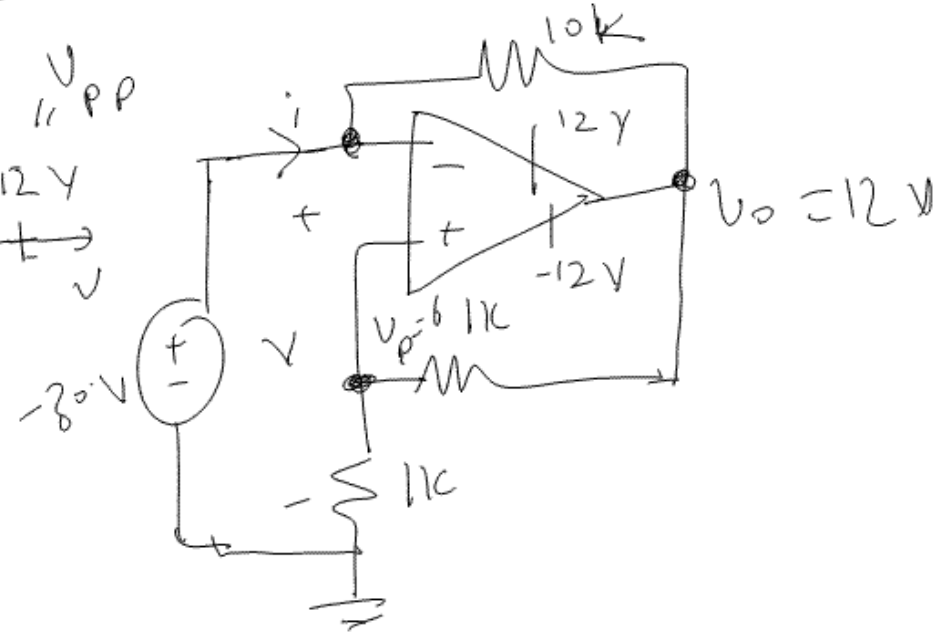
* No time to even come up with answers → talk to me in OH.

(Q. 1)





In Region 1, op-amp is positive saturated

$$\Rightarrow v_o = 12 \text{ V}$$

$$\therefore \quad v_p = 6 \text{ V}$$

Notice, $v_o = A(\overset{6\,V}{\overset{\shortparallel}{v_p}} - v_n)$ & if $v_n < v_p$

$\Rightarrow v_o = 12\,V$

If $v = 7\,V \Rightarrow v_n = 7\,V$

$\therefore v_o = A(6-7) = -A << 0$

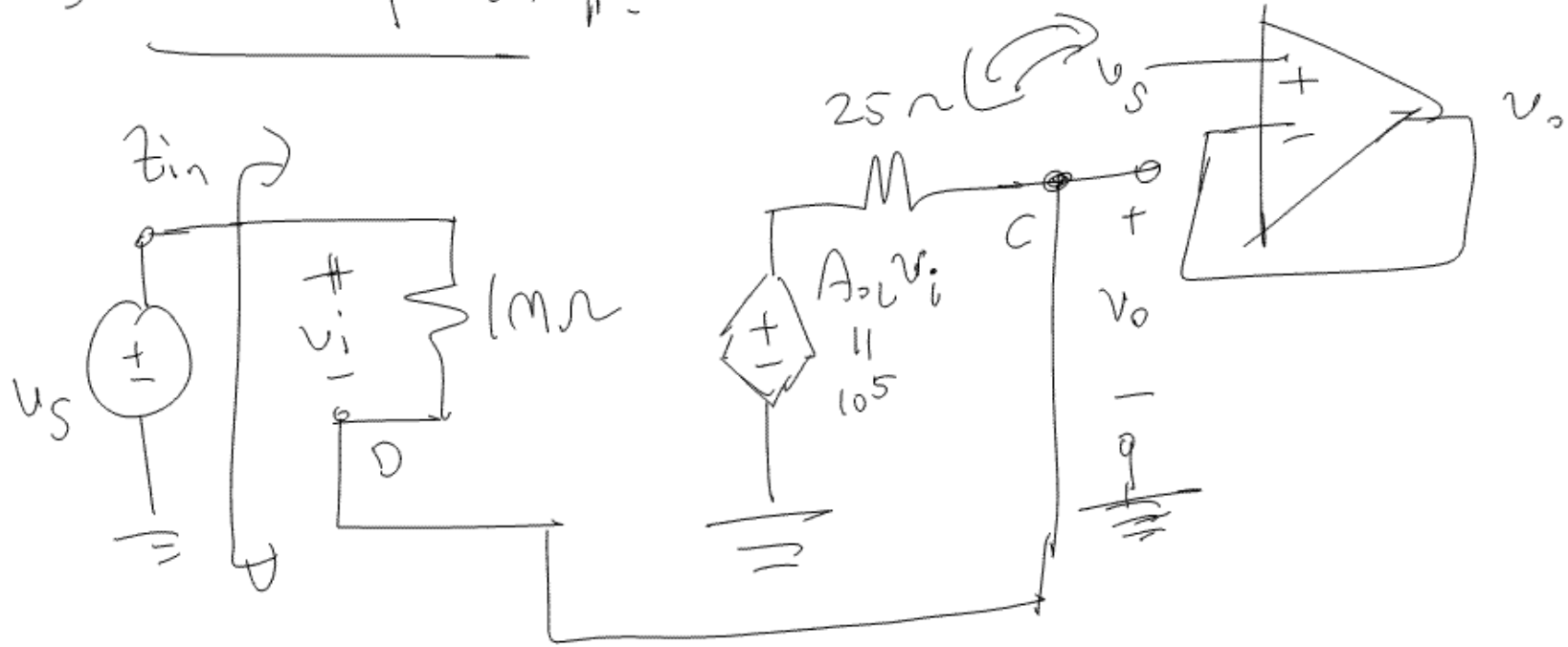
$\Rightarrow \boxed{v_o = -12\,V}$

If $v = -30\,V \Rightarrow v_n = -30\,V$, (above $v_o = 12\,V$)

$v_o = A(6 - (-30)) >>> 0$

$\Rightarrow v_o = 12\,V$ ✓

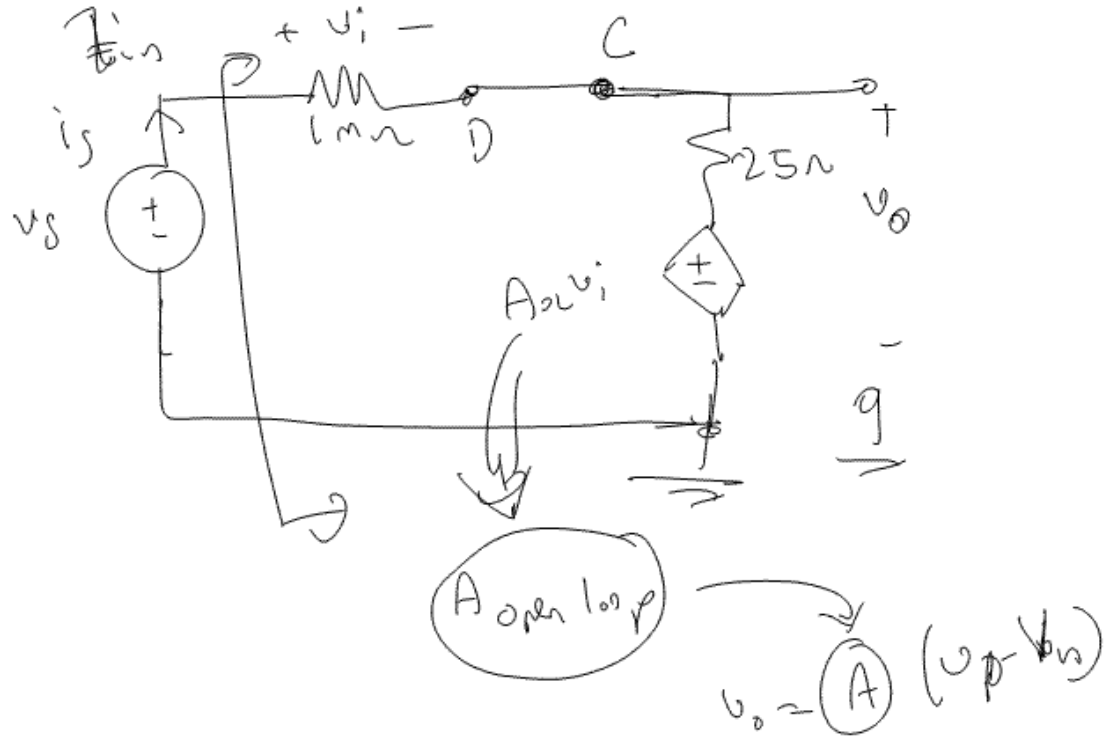
(Q.2) Problem 14-39 #:



(a) $\left.\dfrac{v_o}{v_s}\right] \rightarrow$ circuit analysis! $\left(v_o \approx 0.9999 v_s\right)$

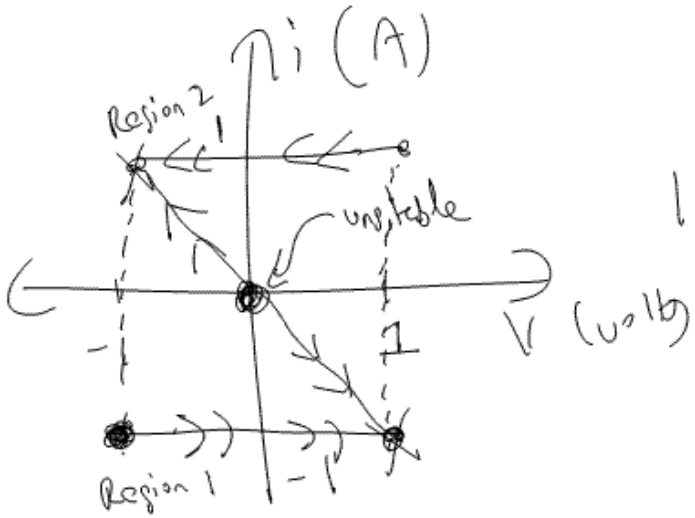
(b) $v_o \approx 1.00001 v_s$

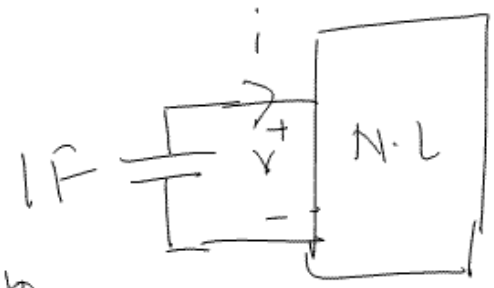
(b)



Two more nonlinear i-v examples:

(1)





Assuming $v(0) = -1$ V,

$i(0) = -1$ A

$$i(t) = i_f + (i_i - i_f)e^{-t/\tau}$$

find & sketch $i(t)$, $v(t)$?

Step (1): Find eq. points & dynamic route.

$$i = -C\frac{dv}{dt} \Rightarrow \frac{dv}{dt} = 0 \quad \text{for equilibriums}$$

$$\Rightarrow \boxed{i = 0}$$

$$\left.\begin{array}{l} i > 0,\ v' < 0 \\ \hline i < 0,\ v' > 0 \end{array}\right] \Rightarrow \text{Dynamic route}$$

<u>Step (2):</u> We find i_i, i_f, τ

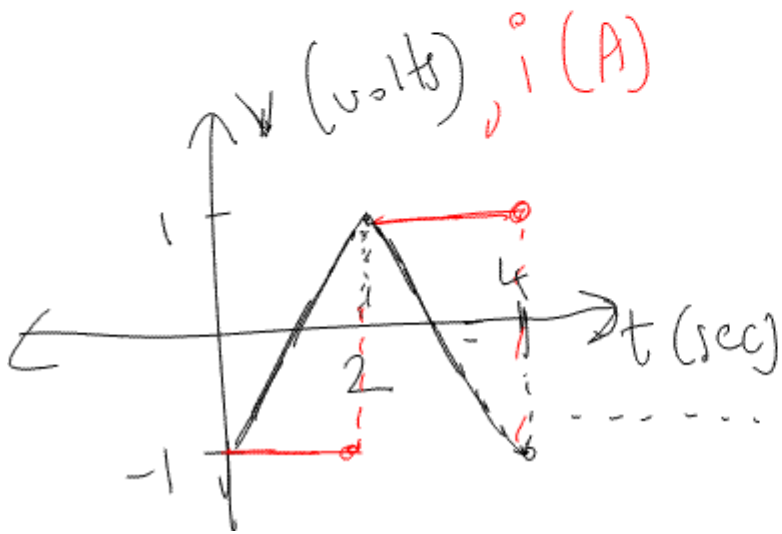
$$\left.\begin{array}{l} i_i = -1\ A, \quad i_f = -1\ A \end{array}\right] \Rightarrow \text{constant current source}$$

$\therefore$ We have to go back to first principles:

In region 1, $i = -1A$

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

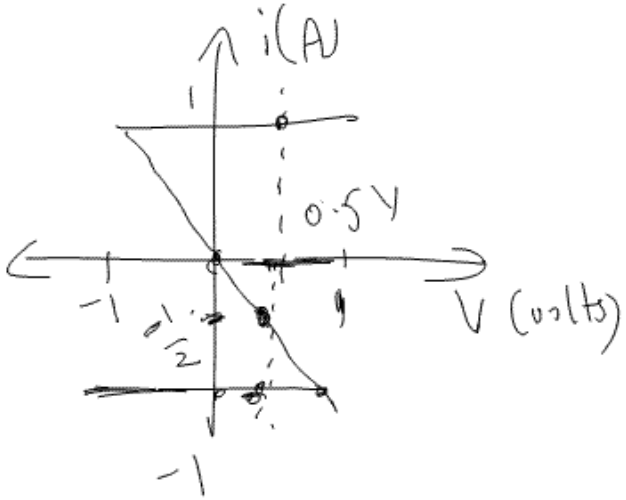
$$\Rightarrow \frac{dv}{dt} = 1\ V/sec$$

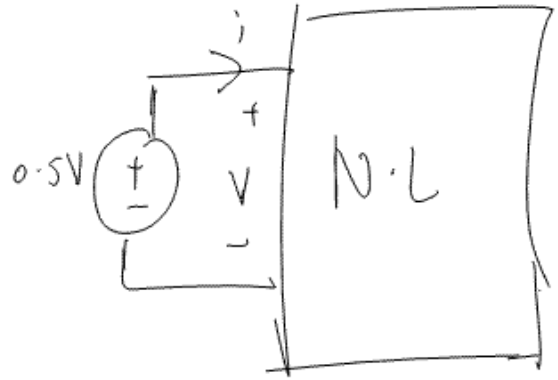


$$\Rightarrow v(t) = t + v_0$$

$$v(0) = V_0 = -1\ V$$

(2)



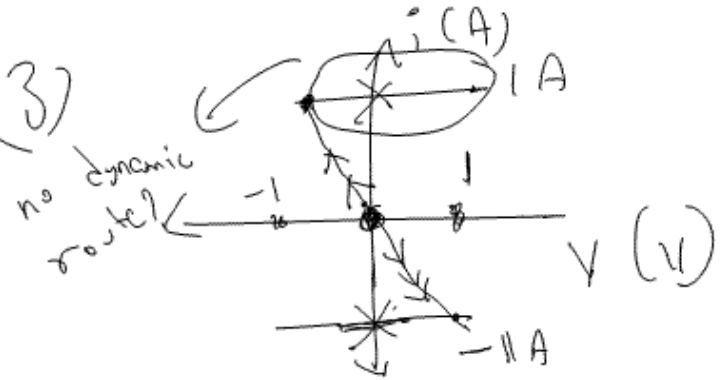


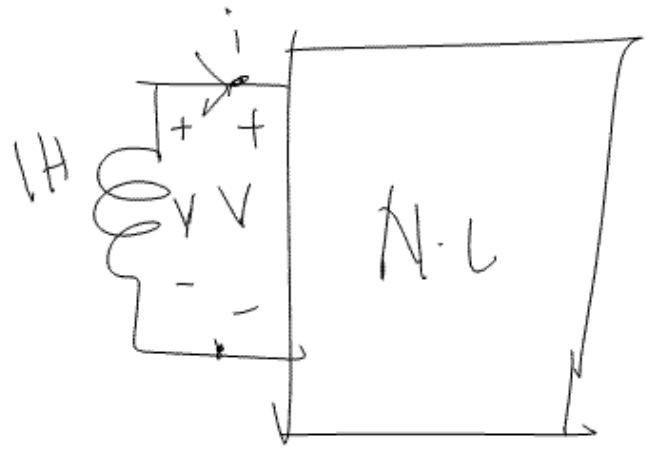
In the circuit above, find i.

(Sol): If $V = 0.5$ V, we can see from the graph $i = 1$ A, $-\frac{1}{2}$ A, -1 A.

Of course, in reality only one solution is valid, but we don't have enough info. for that!

(3)





<u>Assuming</u> $v(0) = -\delta$ (δ is a very small +ve number)

& $i(0) = \varepsilon$, (ε is a very small +ve number),

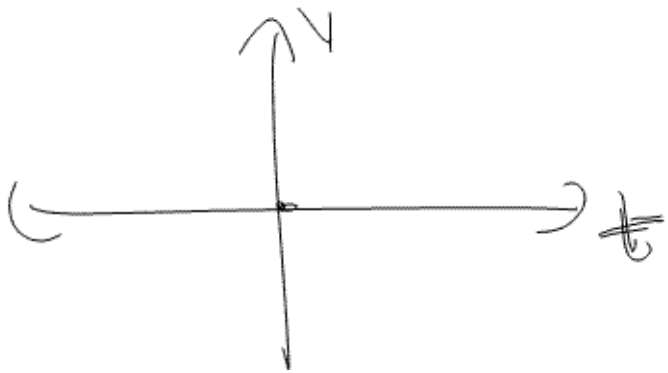
find & sketch $i(t)$, $v(t)$.

Step (1): Find eq. points & dynamic routes

Eq. points: $V = -L\frac{di}{dt} \Rightarrow \begin{cases} V>0, & \frac{di}{dt}<0 \\ V<0, & \frac{di}{dt}>0 \end{cases}$

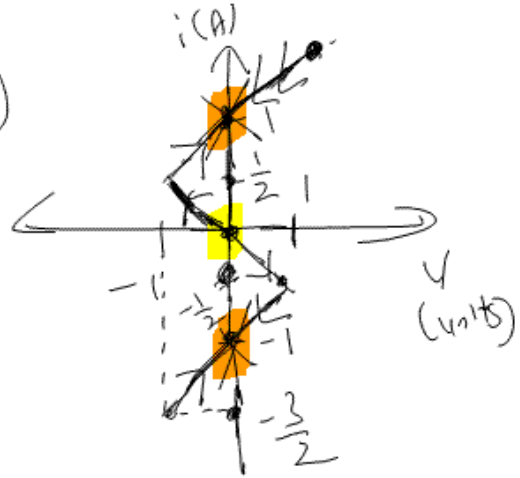
$\frac{di}{dt} = 0 \Rightarrow V = 0$

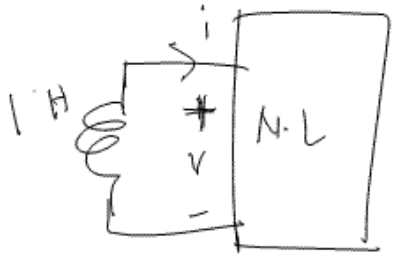
[This makes sense since at equilibrium, inductors are short circuits]



Bad problem

(3)





Assuming $v(0) = 1$ V

$i(0) = \frac{3}{2}$ A,

find & sketch

$v(t)$, $i(t)$

<u>Step (1):</u> Find eq. points & dynamic route

$$V = -L\frac{di}{dt}$$

$V > 0$, $i'(t) < 0$

$V < 0$, $i'(t) > 0$

stable $\Rightarrow$ $\boxed{V = 0}$

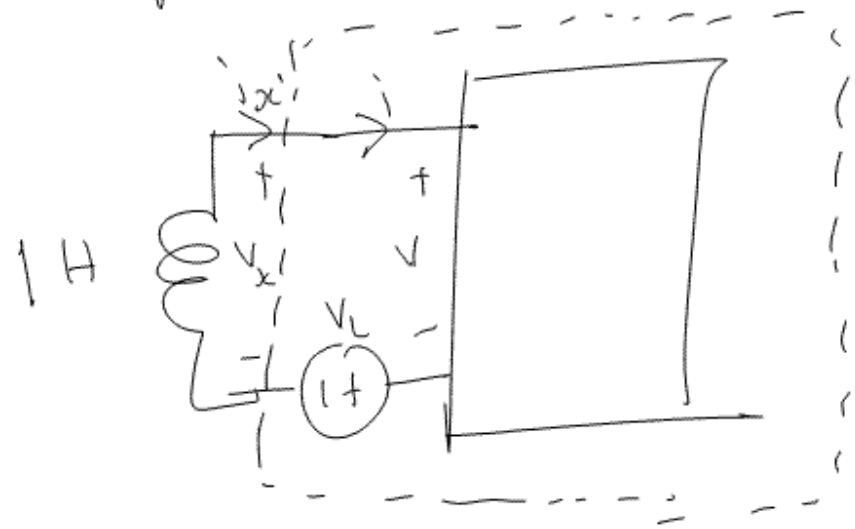
$(0, 0)$; $(0, 1)$; $(0, -1)$ stable

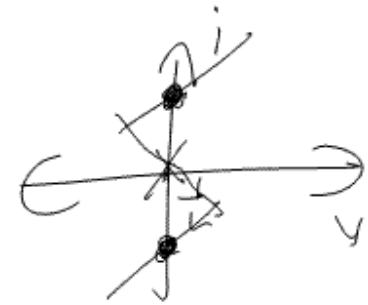
Note: This is circuit is a flip-flop because we have two stable states and they can be used to model memory.

(Q:) How do we move from one equilibrium point to another?

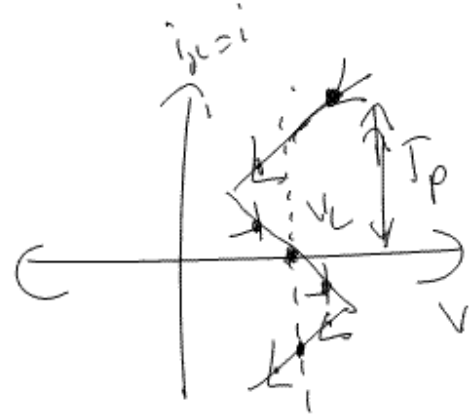
Mechanical Analogy:

In circuit, you give the system energy i.e... you apply voltage.





$V_x = -L \frac{di_x}{dt}$



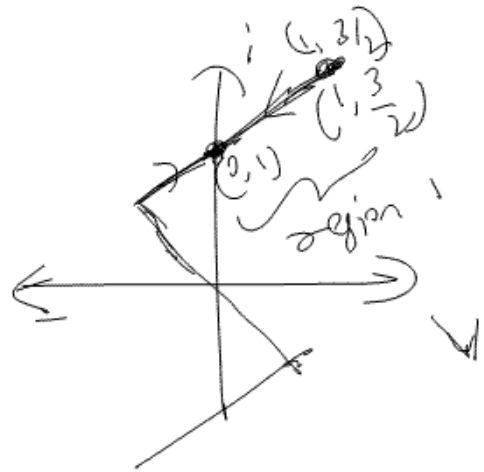
(KVL)

$V_x = V + V_L$

$(V_L > 0)$

Find $v(t)$:

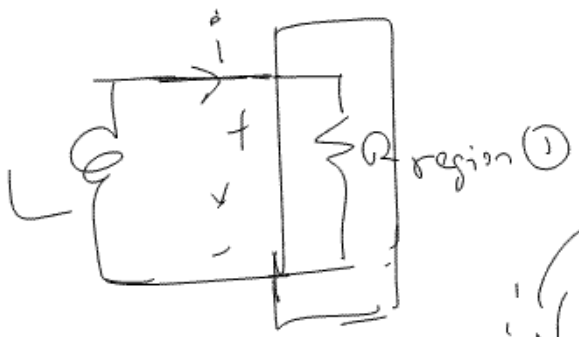
(assuming $V_L = 0$)



$$v(t) = v_f + (v_i - v_f)\, e^{-t/\tau}$$

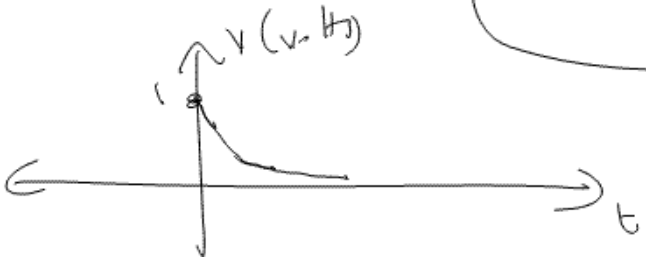
$$V_i = 1\ V$$

$$V_f = 0\ V$$



$$\tau = \frac{L}{R_{eq}} = \frac{L}{\frac{1}{\Delta i\text{-}v}} = \frac{1\ H}{\frac{1}{2}} = 2\ sec$$

$$\therefore\ v(t) = 1\, e^{-t/2\ sec}\ volt$$

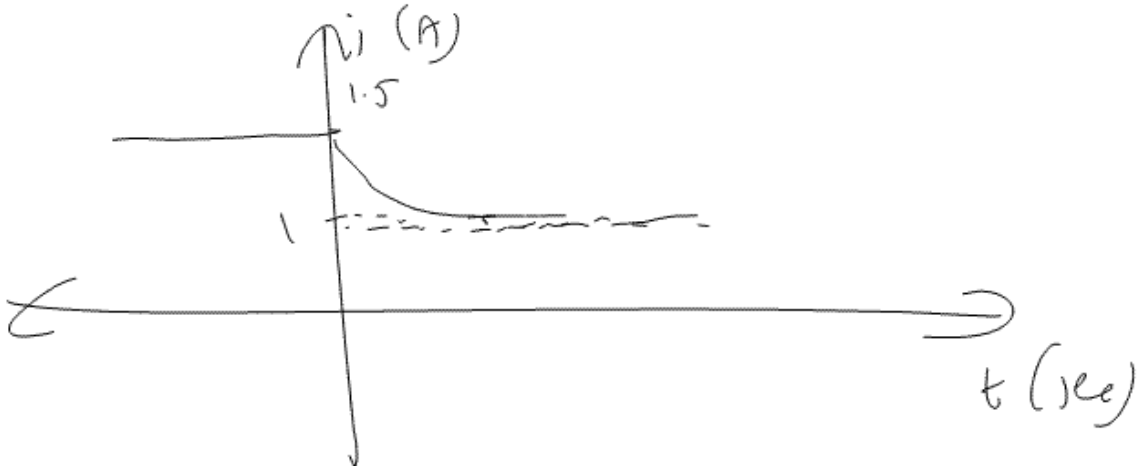


Find $i(t)$:

$$i(t) = i_f + (i_i - i_f)\, e^{-t/\tau}$$

$$= 1 + (1.5 - 1)\, e^{-t/\tau}$$

$$i(t) = 1 + 0.5\, e^{-t/2\,\text{sec}} \quad \text{Ans}$$



Friday → Finish flip-flop

→ Diodes.