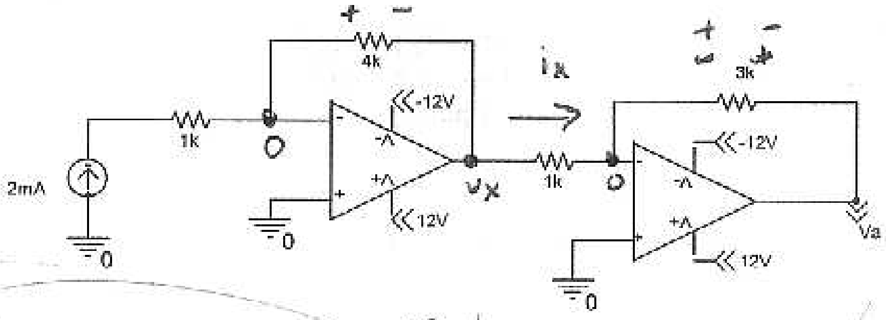
Problem 1 (25 points)

In the circuit below, find Va. **DO NOT IGNORE THE EFFECTS OF THE RAIL VOLTAGES.**



$V_{p1} = V_{n1} = 0$

$V_x = 0 - (2mA)(4k) = -8$

5pts

$V_{p2} = V_{n2} = 0$

5pts

$i_x = \frac{V_x - V_{n2}}{1k} = -0.008\,A = -8mA$

5pts

$V_A = 0 - i_x(3k)$

$= 0 - (-8mA)(3k) = +24V$

5pts

$+24V > 12V \rightarrow$ rails

$V_A = +12V$

5pts

0

Va = + 12V

Problem 2 (30 points)

In the circuit below, assume (v(0),i(0)) is (2 V, 1 mA).

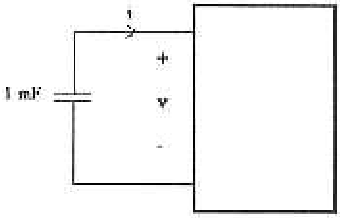
(a) Find the equilibrium points and mark them on the i-v graph provided **(2 points)**
(b) Sketch the dynamic route (on the given i-v graph) **(4 points)**
(c) Label the stability of the equilibrium points (on the given i-v graph) **(2 points)**
(d) Sketch i(t) **(5 points)**
(e) Sketch v(t) **(5 points)**
(f) Find the switching time(s) and mark them on i(t) and v(t) **(12 points)**

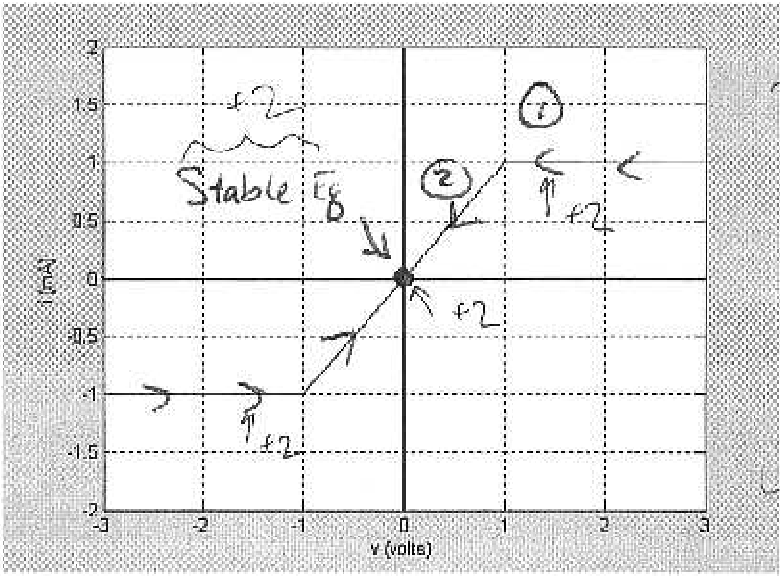
$\frac{-i}{c} = \frac{dv}{dt}$

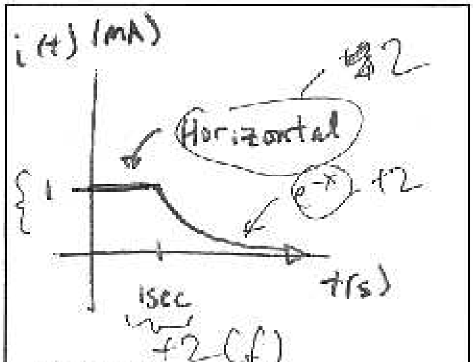
Eg @ $\frac{dv}{dt} = 0 \Rightarrow i = 0$

$i > 0 \Rightarrow v \downarrow$

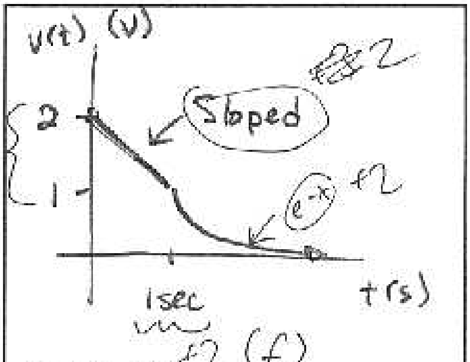
$i < 0 \Rightarrow v \uparrow$







Sketch i(t)



Sketch v(t)

Switching time(s): 1 second +8

4pts if equation not linear.

$C = 1mF$

Problem 2 EXTRA WORKSPACE

Region ①

$i = 1mA = \text{const.}$

$\frac{-i}{C} = \frac{dv}{dt} \rightarrow \int_2^v dv = \int_0^t \frac{-i}{C} dt \rightarrow v - 2 = \frac{-(.001)}{.001} t \Rightarrow v = 2 - t$

Switching Time: $t_1 \rightarrow v$ goes from $2 \rightarrow 1 \rightarrow t_1 = 2 - v \rightarrow t_1 = 1sec$

$t_1 = 1 \text{second}$

Sloped Region

$v_0 = 1V$ ~~$v_\infty = 1V$~~ $v_\infty = 0V$ $R = 1000$ $\tau = 1 \text{ sec}$

$i_0 = 1mA$ ~~$i_\infty = 1mA$~~ $i_\infty = 0 mA$ $C = 1mF$ $t_0 = 1sec$

$$x(t) = x_\infty + (x_0 - x_\infty) \exp\left[-\frac{(t - t_0)}{\tau}\right]$$

$v(t) = e^{-(t-1)} V$

$i(t) = e^{-(t-1)} mA$

$-\frac{i}{c} = \frac{dv}{dt}$

$\frac{dv}{dt} = 0$

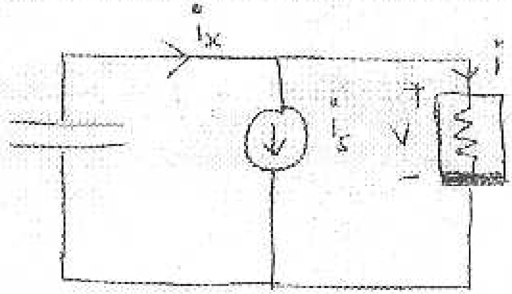
$\rightarrow i = 0$

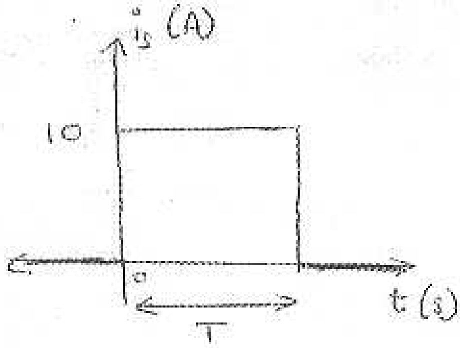
$i > 0 \rightarrow v \downarrow$

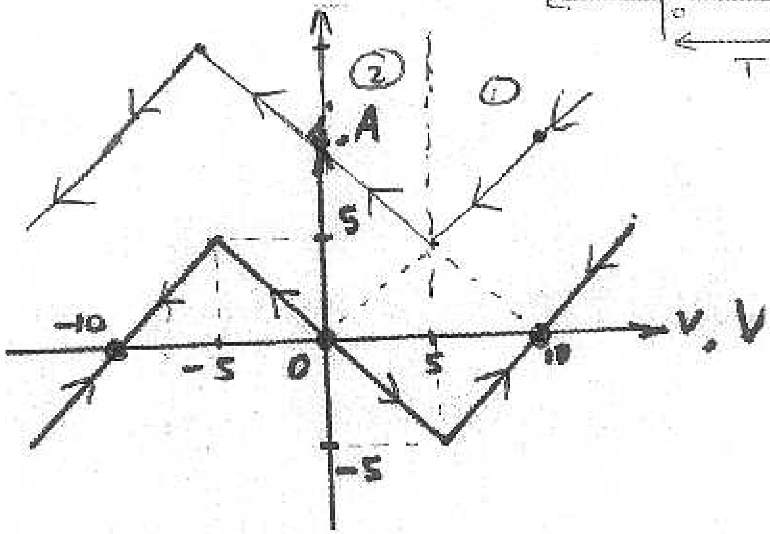
$i < 0 \rightarrow v \uparrow$

Problem 3 (30 points)

The circuit below is to be used as a flip-flop. The i-v characteristic of the nonlinear resistor is given along with a current square pulse as input.







(a) Determine the equilibrium points, classify them as stable or unstable and determine the dynamic route. **(15 points)**

(b) If the amplitude of the current pulse is 10 A as shown above, calculate the minimum T required to move from the right equilibrium point to the left equilibrium point. Use ln(2) = 0.69. **(15 points)**

Region 1: $i_0 = 10$ $R = 1$ $\tau = 1$

$i_\infty = 0$ $C = 1$ $t_0 = 0$

$i(t) = 10e^{-t}$

$i = 5 \Rightarrow 5 = 10e^{-t}$

$t_1 = \ln 2$

Region 2: $i_0 = 5$ $R = -1$ $\tau = -1s$

$i_\infty = 0$ $C = 1$ $t_1 = \ln 2$

$i(t) = 5e^{(t - \ln 2)}$

Stable equilibrium point(s): (-10, 0) (+10, 0)

Unstable equilibrium point(s): (0, 0)

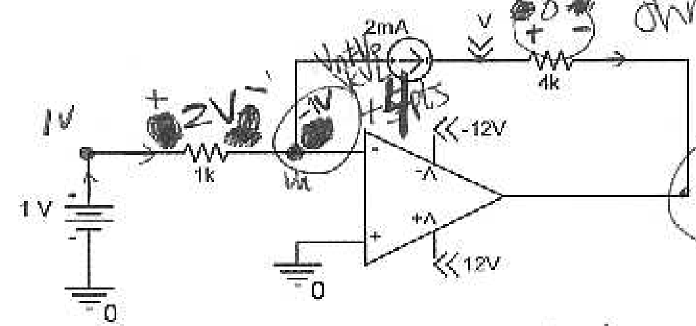
T = 1.38 seconds

regular

Problem 4 (12 points)

In the circuit below, find V. **DO NOT IGNORE THE EFFECTS OF THE RAIL VOLTAGES!**

+2pts ohm's law



+12 +3pts gain eqn → sat.

$i_p = i_n = 0$

$v_p = 0$

$\frac{1 - v_n}{1k} = 2mA$

$1 - v_n = 2$

$-1 = v_n$

$V_{out} = A(v_p - v_n)$

$= A(0 - (-1)) = A \to \infty$ Saturates

$V_{out} = +12V$

$V = 12 + (4k)(2mA)$

$= 20V$

+3 KVL

$V = V_R + V_{out}$ (+3)

$V = 4k(2mA) + V_{out}$ (+2)

total to 5 points

V = 20 V