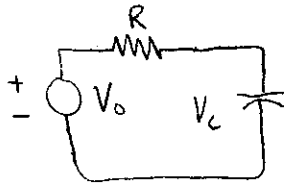
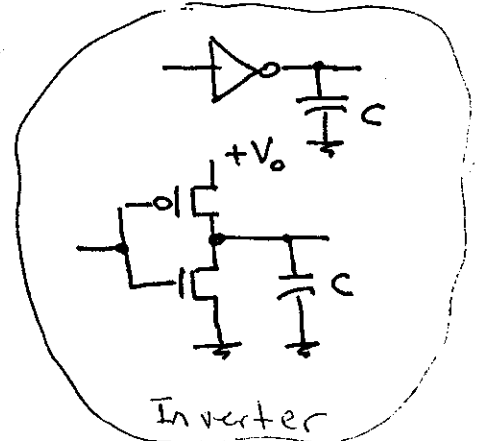
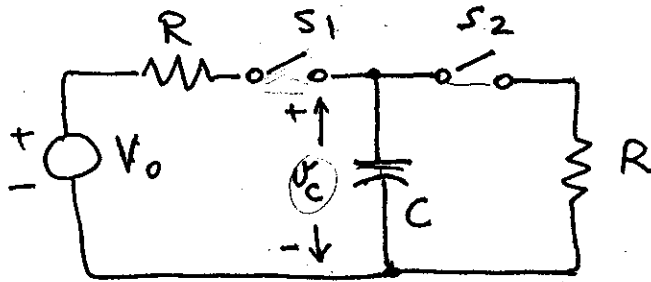


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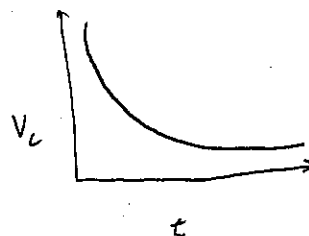
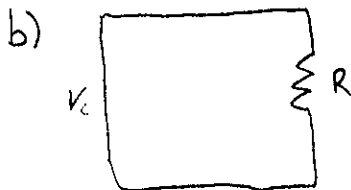
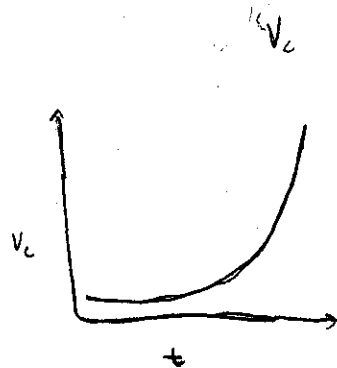
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a) $V_0 = V_c$



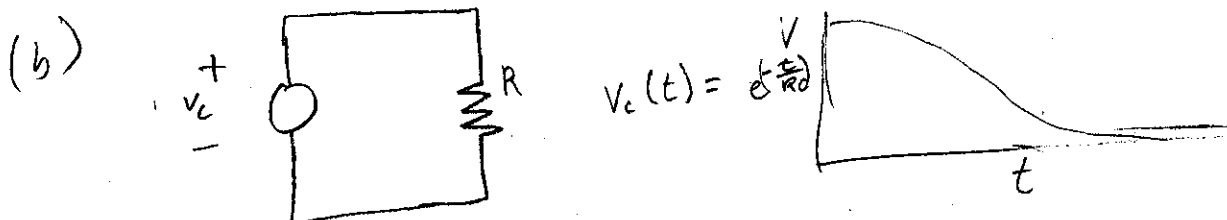
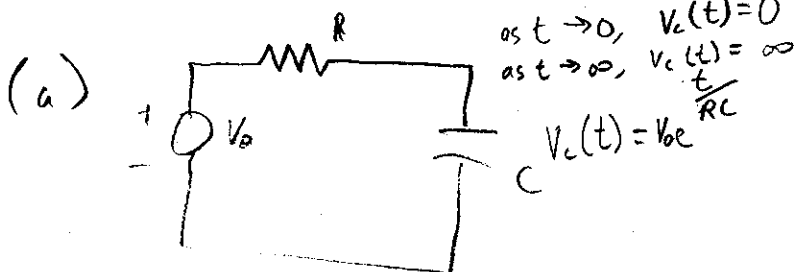
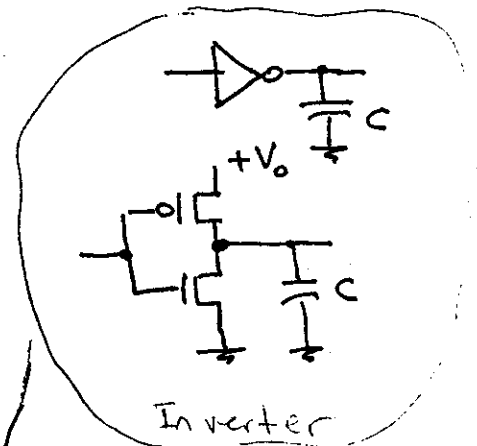
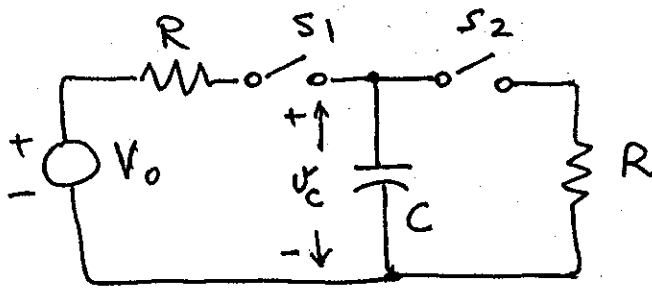
Re: Problems:

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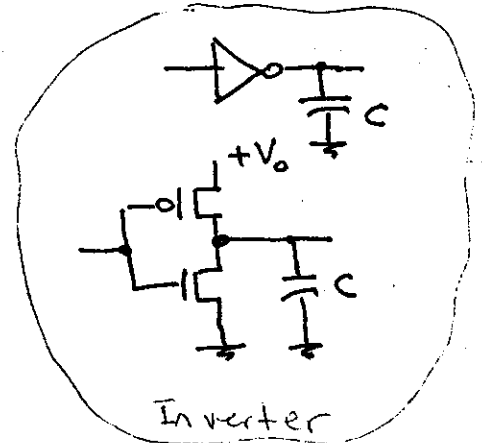
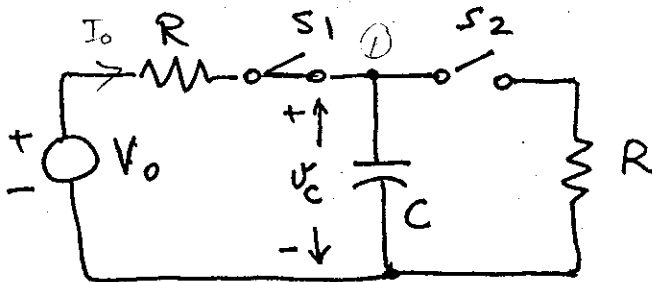
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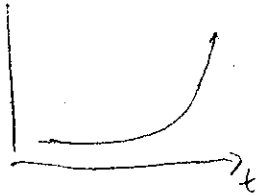
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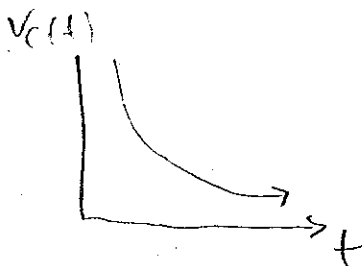
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a.) $V_c(t)$



b.)



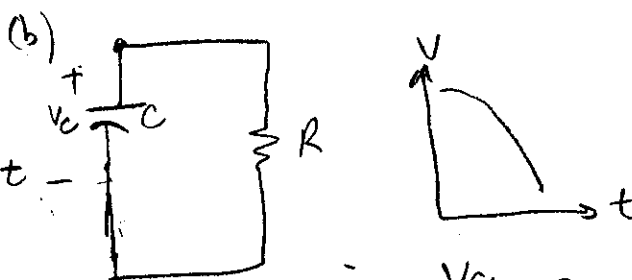
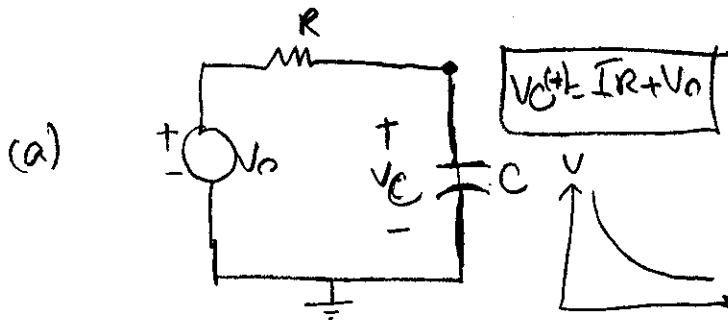
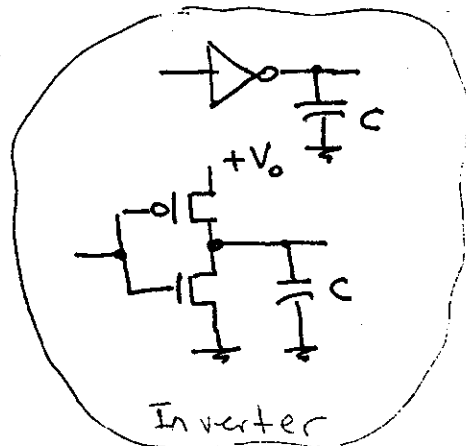
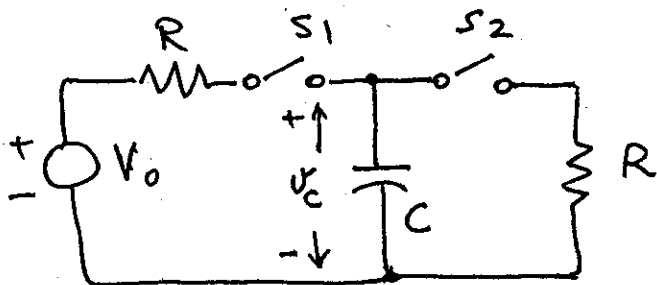
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$$\frac{V_c - V_0}{R} + V_c \cdot (j\omega C) = 0$$

$$V_c \cdot j\omega C + \frac{V_c}{R} = 0$$

$$V_c - V_0 + R V_c j\omega C = 0$$

$$V_c (1 + R j\omega C) = V_0$$

$$\Rightarrow V_c = \frac{V_0}{1 + R j\omega C}$$

$$R V_c j\omega C + V_c = 0$$

$$V_c (R j\omega C + 1) = 0$$

$$V_c = 0$$

Problems:

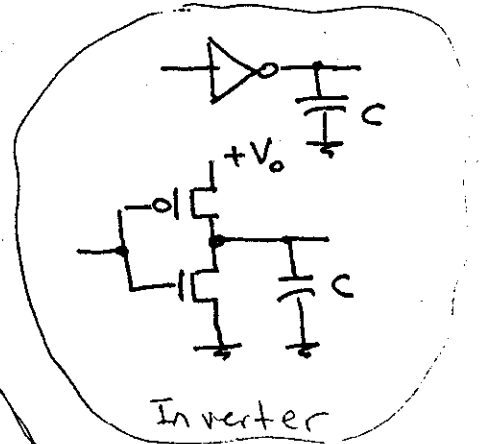
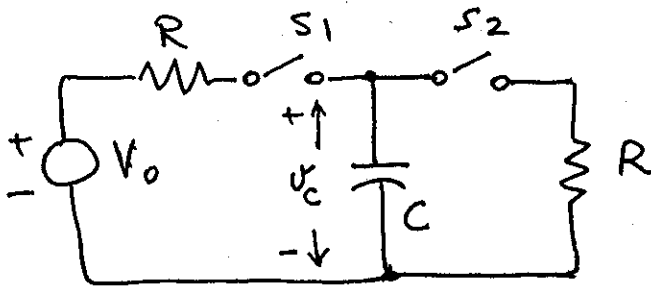
$$V_c(t) = R I + V_0$$

Your Name: _____

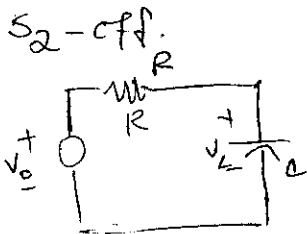
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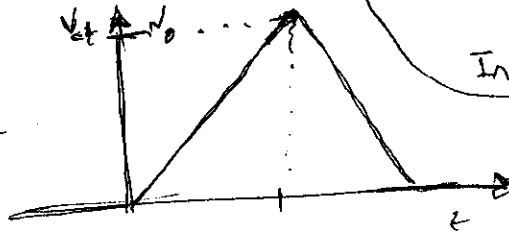
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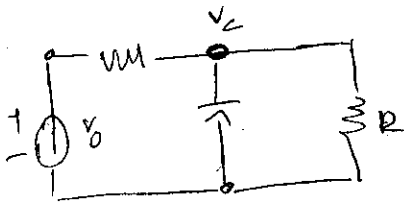
①



~~Handwritten scribbles~~



②



$$V_0 - \frac{V_c}{R} + V_c + \frac{V_c}{R} = 0$$

$$V_0 - \frac{V_c}{R} + R V_c + \frac{V_c}{R} = 0$$

$$V_0 - V_c \left[\frac{1}{R} - 1 \right] = 0$$

$$V_c = \frac{V_0}{R}$$

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③ Find Expression for: $V_c(t)$

Problems:

$$C = Q \cdot V$$

$$\frac{dQ}{dt} = C \cdot \frac{dV}{dt} \quad Q = \int i \, dt$$

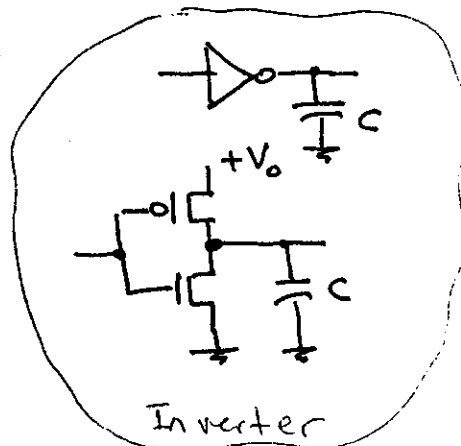
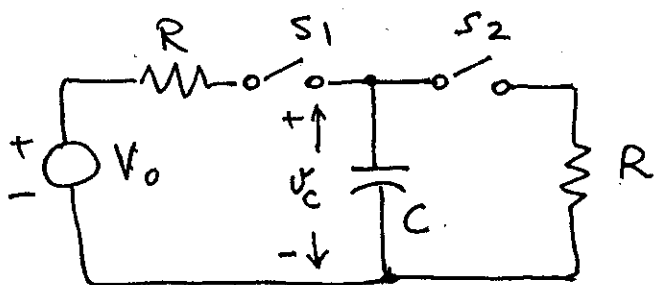
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Your Name: _____

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when S_1 is ON circuit becomes

a)

$V_c(t) = \frac{V_0 t}{R}$

b)

$V_c(t) = \frac{V_0}{Rt}$

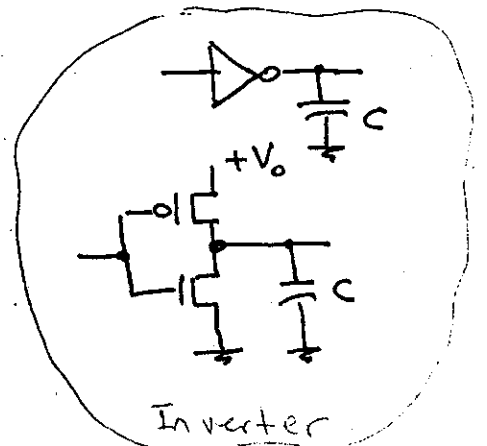
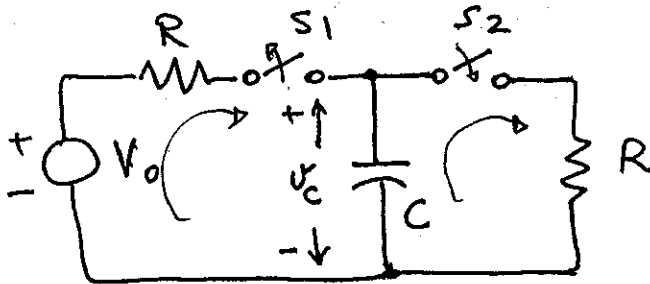
Problems:

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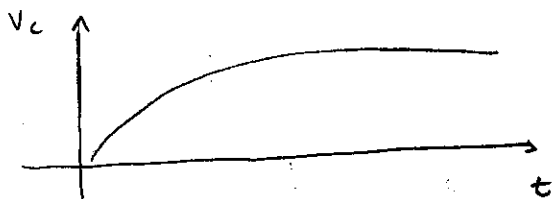
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a) KVL: $V_c(t) = V_0 + RC$



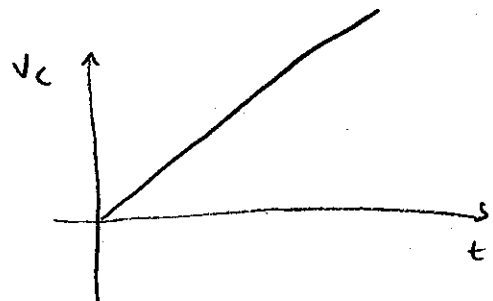
$$\text{Let } C = \frac{V}{R}$$

$$\text{or } RC = R \left(\frac{V}{R} \right)$$

Problems: = V

b)

KVL: $V_c(t) = RC$

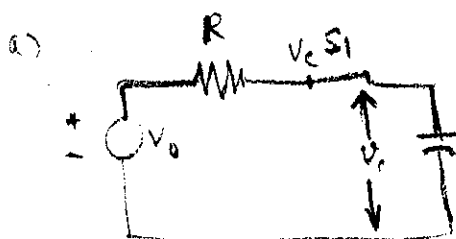
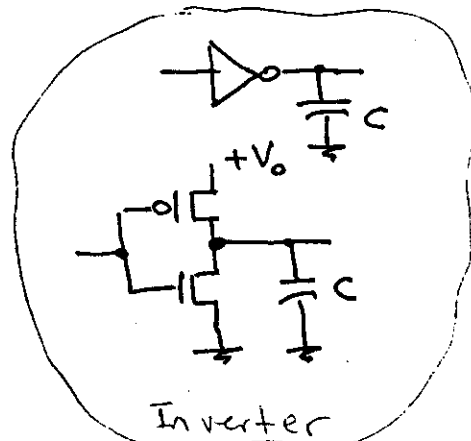
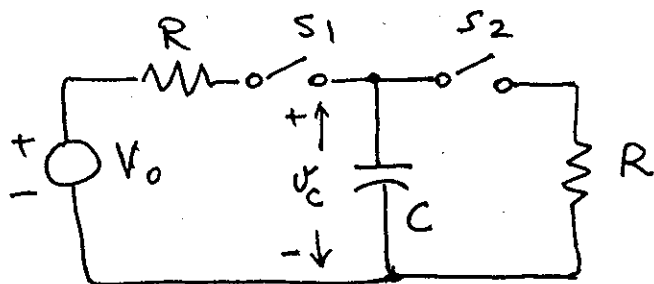


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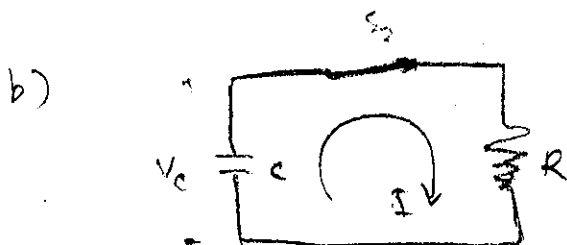
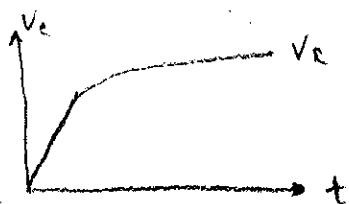
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$$I = \frac{V_0 - V_c}{R}$$

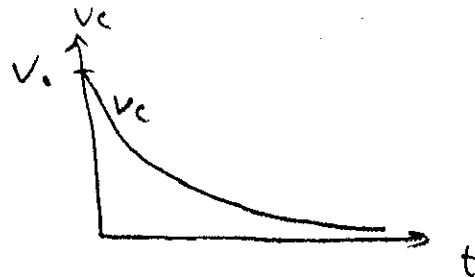
$$V_c = I_c \cdot X_c = I X_c = \frac{V_0 - V_c}{R} \cdot X_c = \frac{V_0 - V_c}{R} \cdot \frac{1}{\omega C}$$



As time elapse, V_c decreases because voltage would drop in R .

$$V_c = V_R \Rightarrow V_c = IR$$

$$\Rightarrow I = \frac{V_c}{R}$$



Problems:

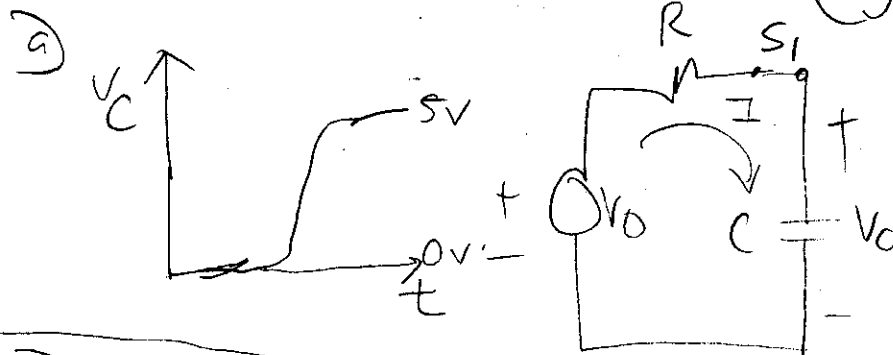
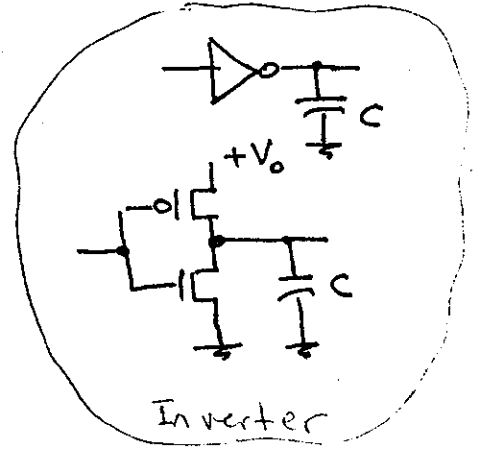
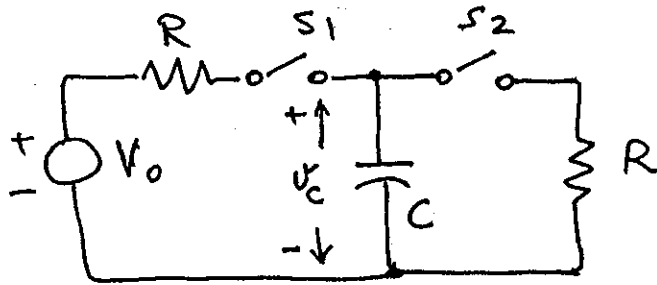
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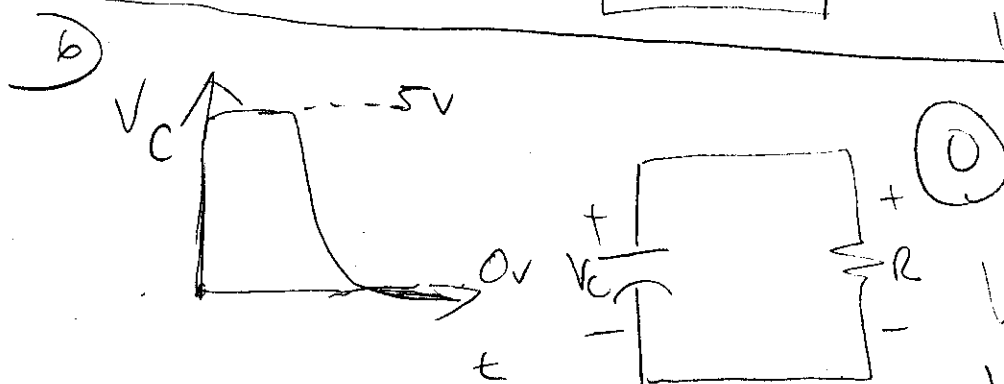
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$$I = C \frac{dV_c}{dt}$$

$$0 = RC \frac{dV_c}{dt} + V_c - V_0$$

$$V_c = e^{-t/RC} + V_0$$



$$V_c = V_R$$

$$V_c = RC \frac{dV_c}{dt}$$

$$0 = RC \frac{dV_c}{dt} + V_c$$

$$V_c = e^{-t/RC}$$

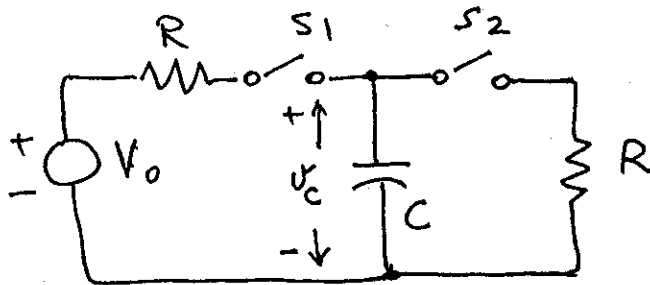
Res. Problems:

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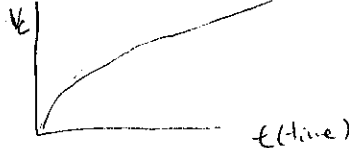
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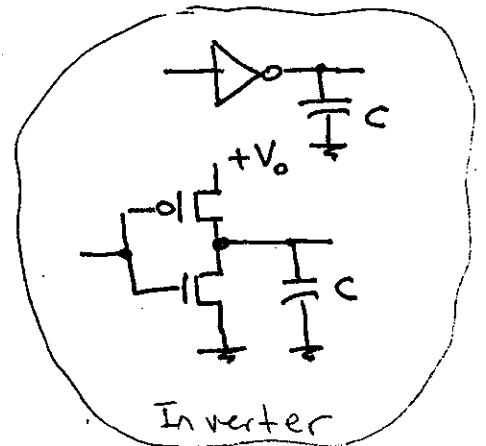
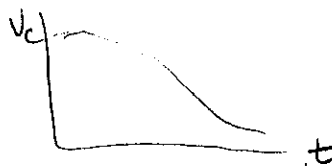
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a) $V_c = V_0 e^{-Rt/C}$



b) $V_c = V_0 e^{-Rt/C}$



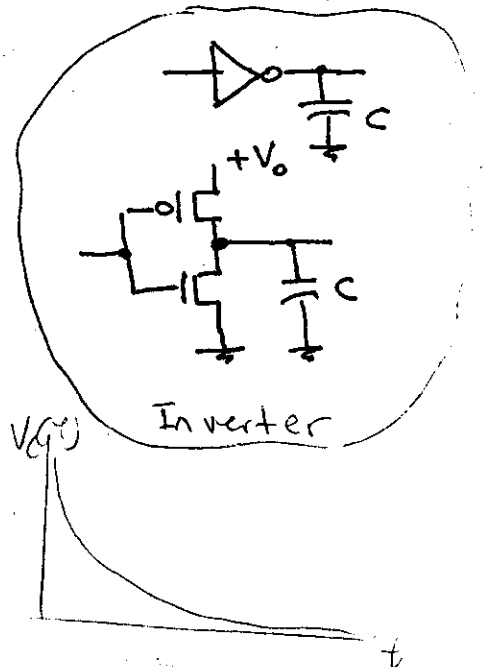
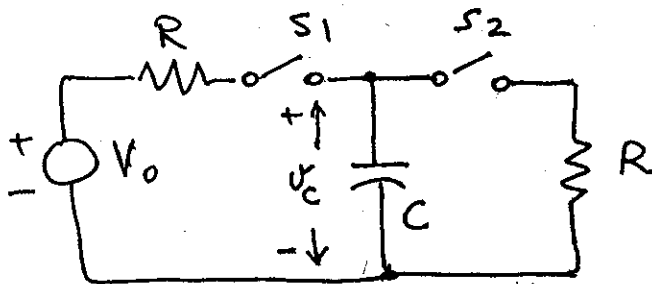
54 Problems:

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a)

S1	S2	V_c
0	0	0
0	1	0
1	0	1
1	1	1

$$V_c = \underbrace{(S1S2' + S1S2)}_{|S1|}$$

$$V_c = V_0 - iR$$

$$V_c = V_0 - RC \frac{dV_c}{dt}, \quad V_c + RC \frac{dV_c}{dt} = V_0, \quad V_c = e^{-\frac{t}{RC}} + V_0$$

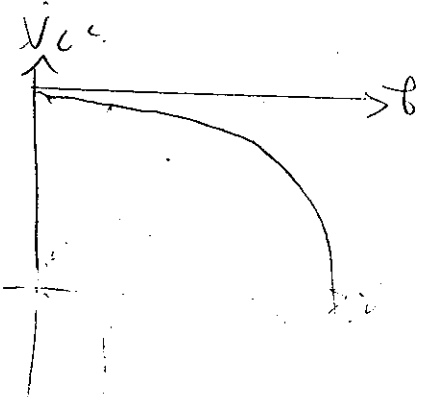
b)

S1	S2	V_c
0	0	0
0	1	0
1	0	0
1	1	0

$$V_c = iR = RC \frac{dV_c}{dt}$$

$$RC \frac{dV_c}{dt} - V_c = 0$$

$$V_c = -e^{-\frac{t}{RC}}$$



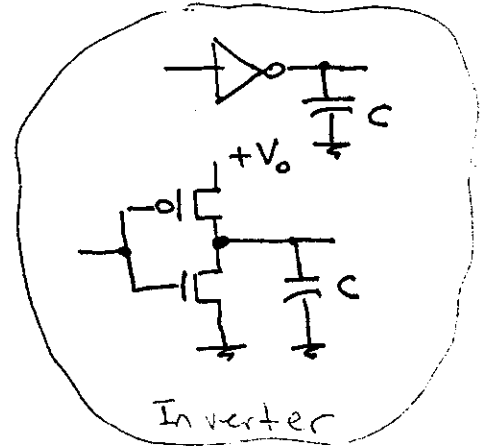
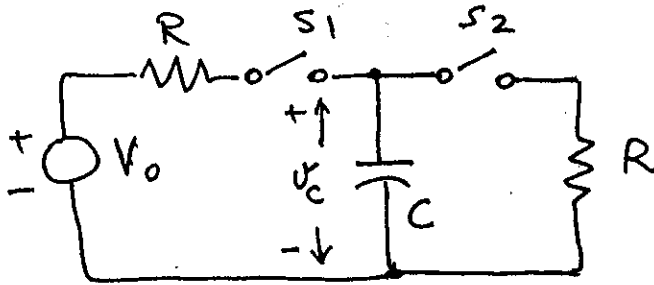
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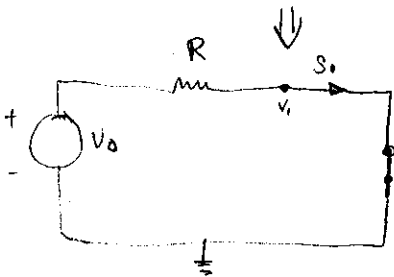
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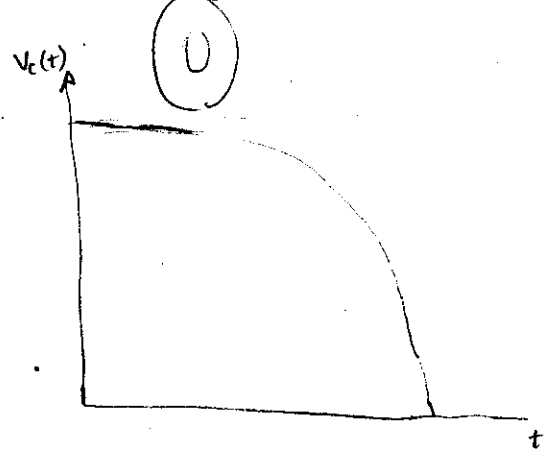
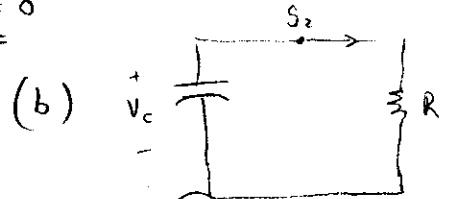
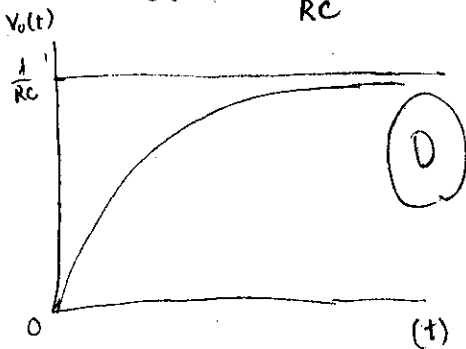


(a)



$V_c(t)$ This is RC circuit
 when $t = 0 \Rightarrow V_c(t) = 0$
 when $t = \infty \Rightarrow V_c(t) =$

$$V_c(t) = \frac{V_0}{RC}$$



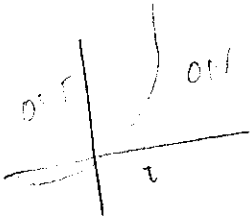
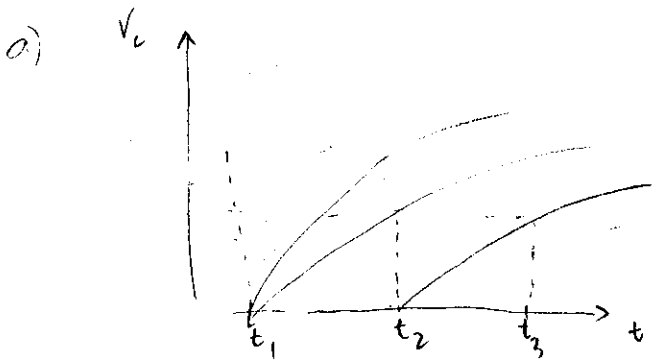
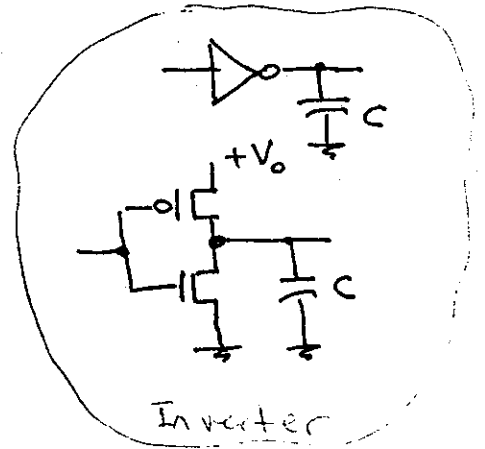
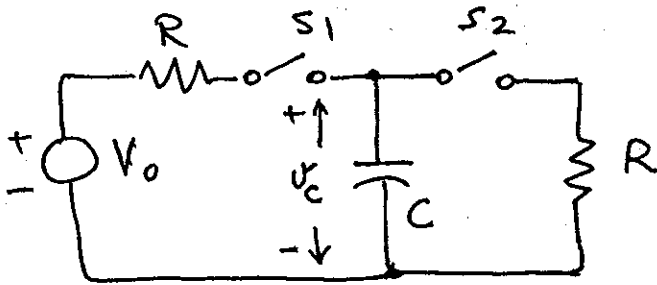
See Problems:

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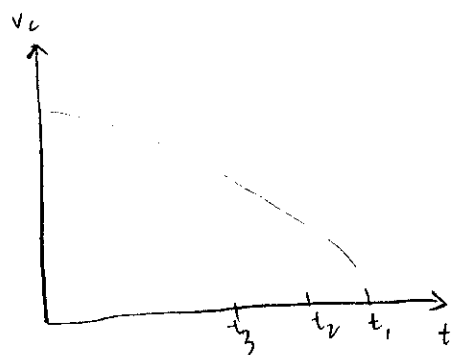
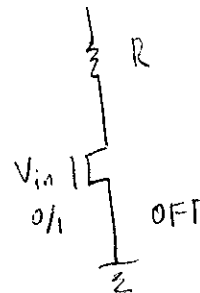
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Note: this is the first grade college physics (Sears & Zemansky) problem (for some of you perhaps a high-school problem). (12th grade)



$t_3 > t_2 > t_1 > t_0$
b)



$t_0 > t_1 > t_2 > t_3$

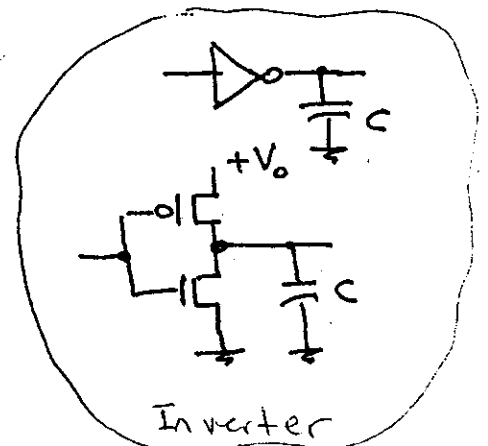
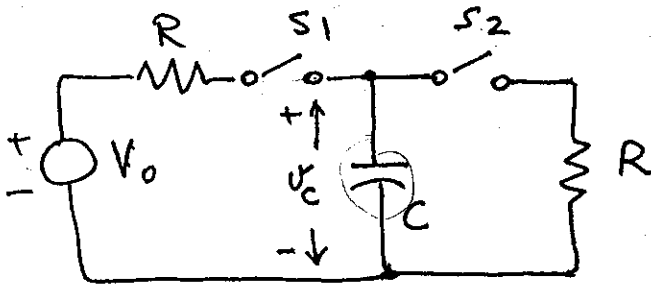
Re: Problems:

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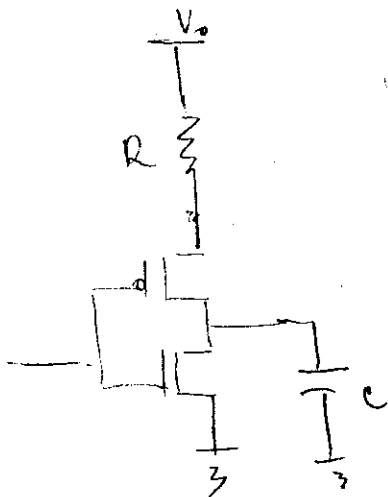
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a)



$$V_c = V_0$$

b)

$$V_c = R + \frac{1}{2} V C^2$$

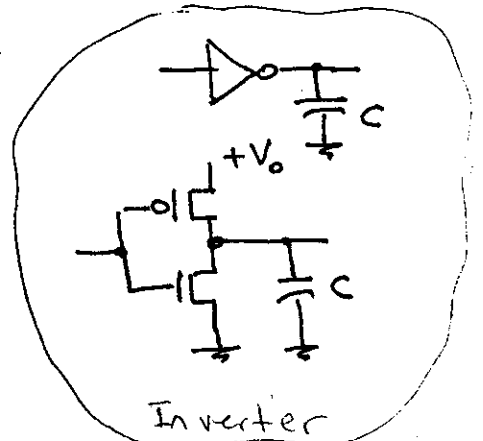
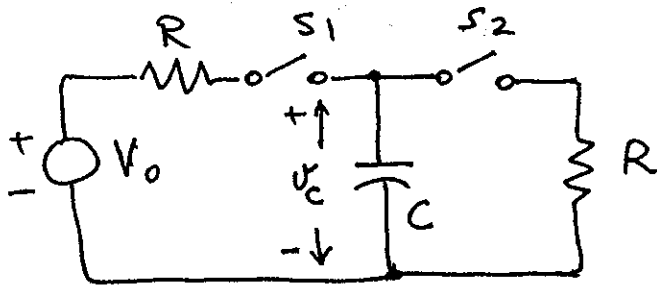
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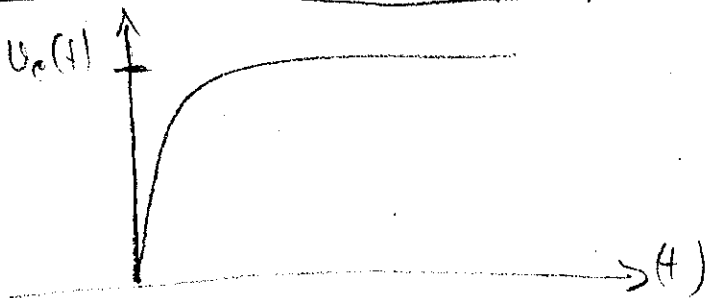
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1) $R_i = -V_c + V_0$

$V_c = V_0 - R_i$

$V_c = V_0 - R_c \frac{dR}{dt}$ (0)



$dt V_c = R_c dR \Rightarrow V_c = \frac{R_c dR}{dt}$

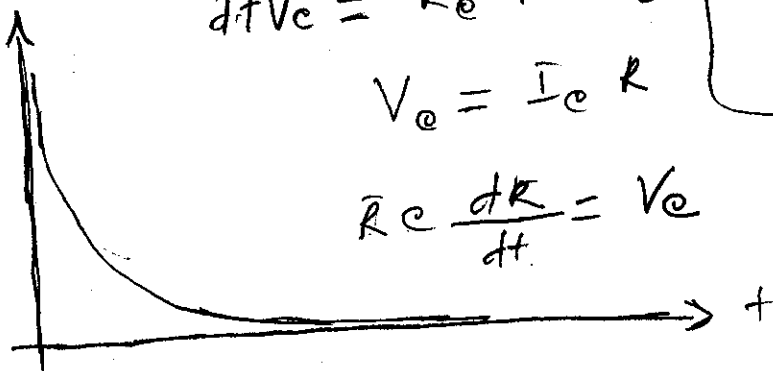
$V_c = I_c R$

$R_c \frac{dR}{dt} = V_c$

b) Problems:

$I_c = \frac{V_c}{R}$

(0)

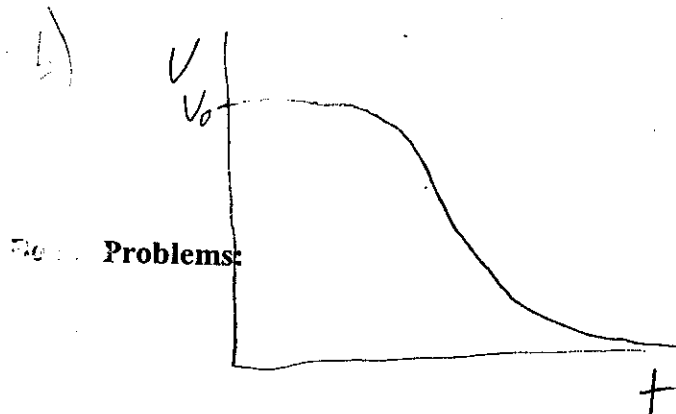
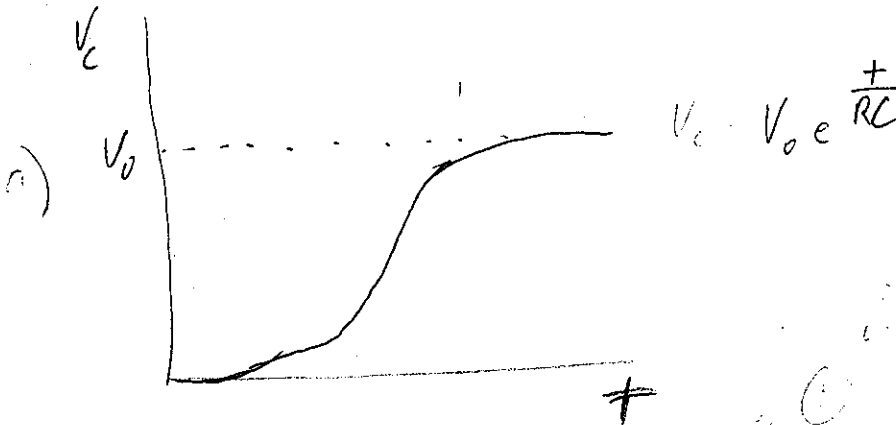
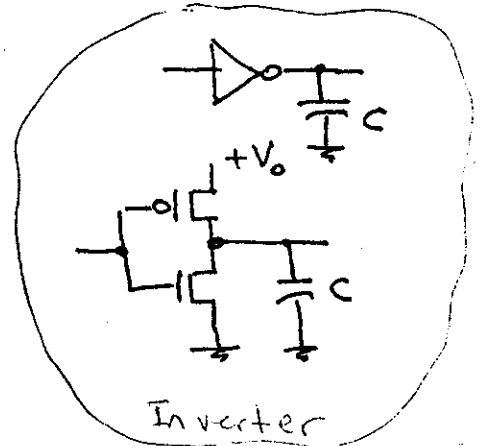
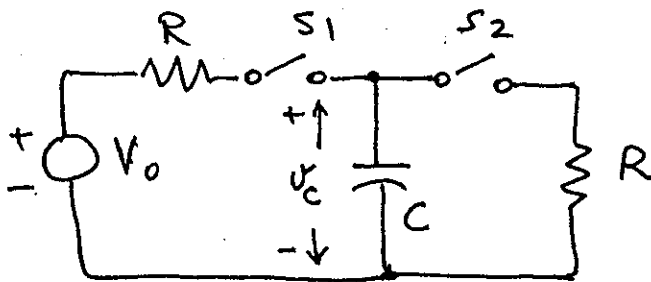


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$$V_c = V_0 - V_0 e^{-t/RC}$$

$$\frac{dV}{dt} =$$

$$I = \int_0^t \frac{1}{C} dt$$

$$I = \frac{dQ}{dt} = \frac{1}{C} \frac{dQ}{dt}$$

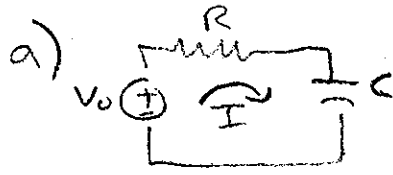
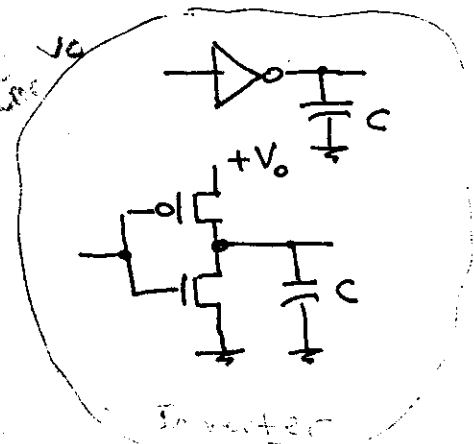
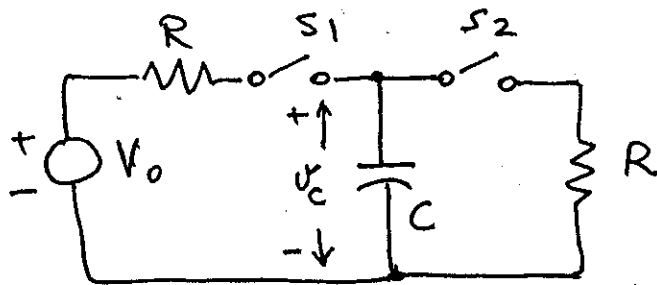


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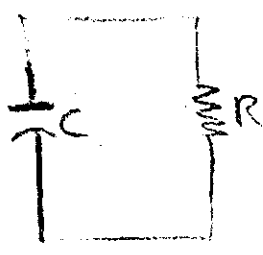
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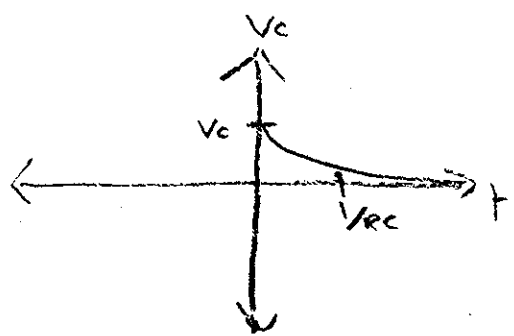
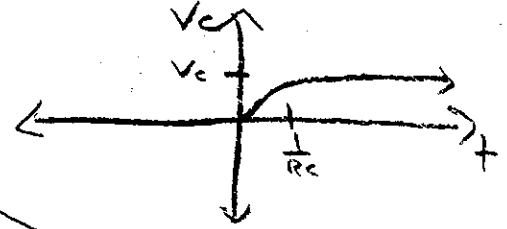


$$V_0 = RI + \frac{1}{C} \int I dt$$

$$V_c = \frac{\frac{1}{C} \int_0^t I dt}{\frac{1}{C} \int_0^t I dt + R} V_0$$



$V_c =$



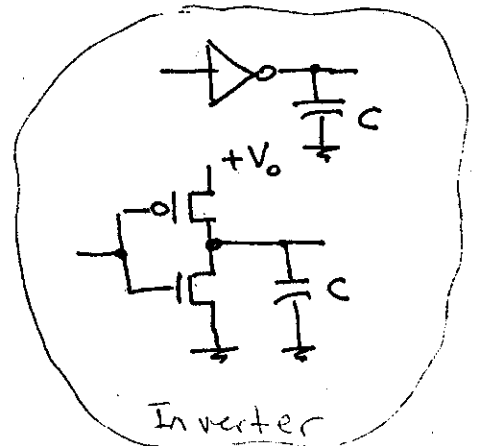
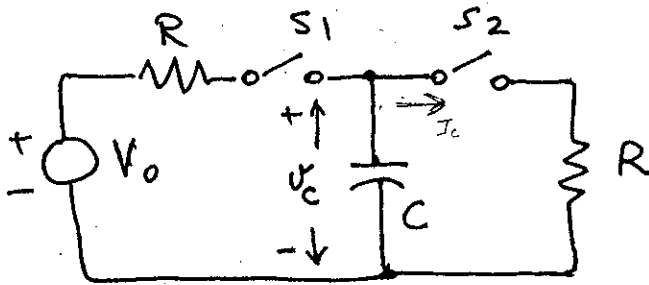
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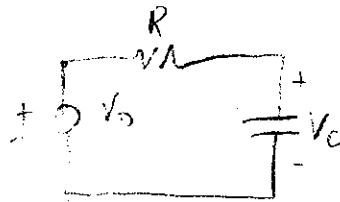
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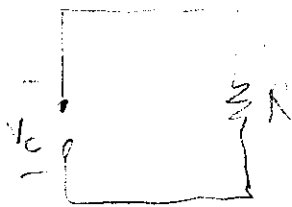
a/
$$V_c = \frac{SC}{R+SC} V_0$$

$$V_c(t) = V_0 + V_c$$

$$V_c =$$



c/



$$V_c = I_c R$$

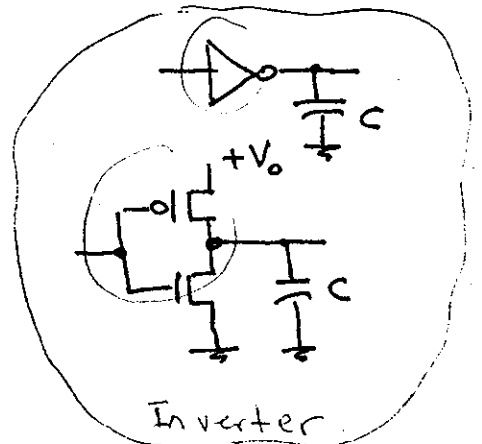
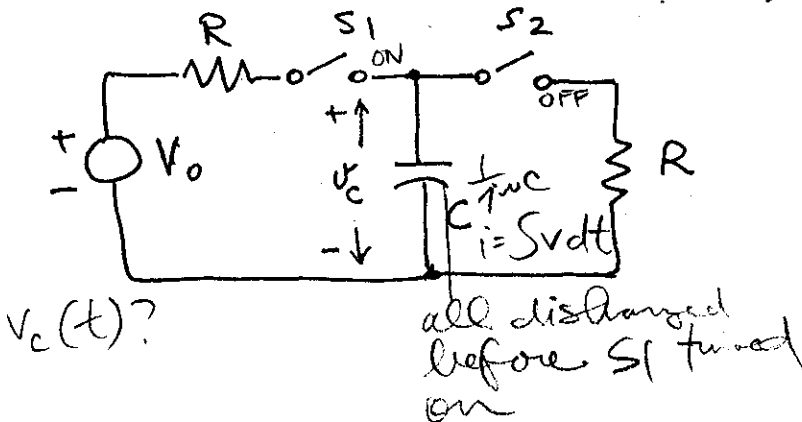
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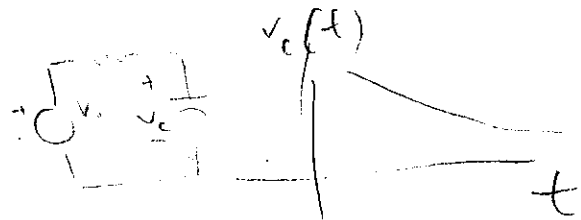
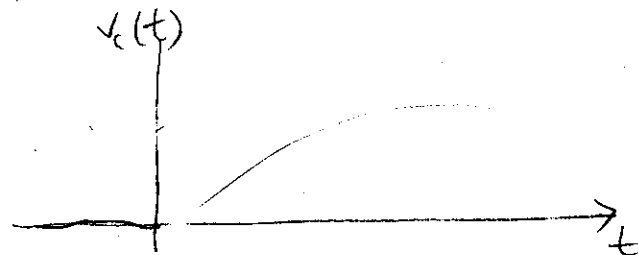
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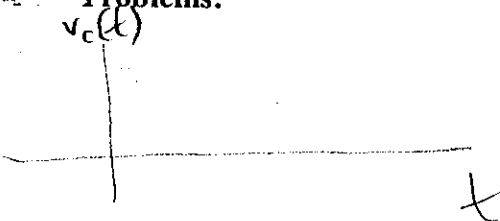


a) $V_0 - V_c + iR = 0 \Rightarrow V_0 - V_c + S v dt R = 0$
 $V_c = V_0 + R S v dt$



b) $V_c + S v dt = 0$
 $V_c(t) = -S v dt$

Problems:

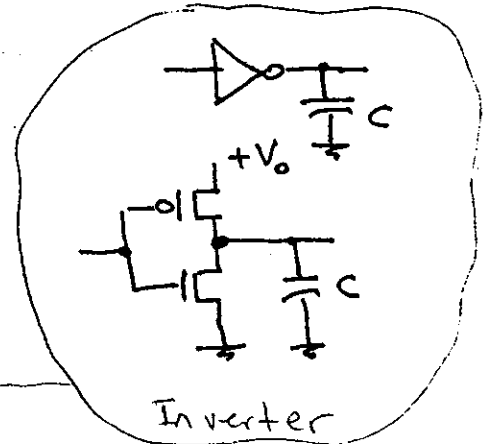
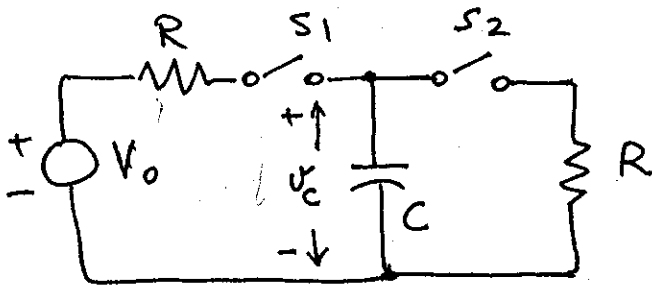


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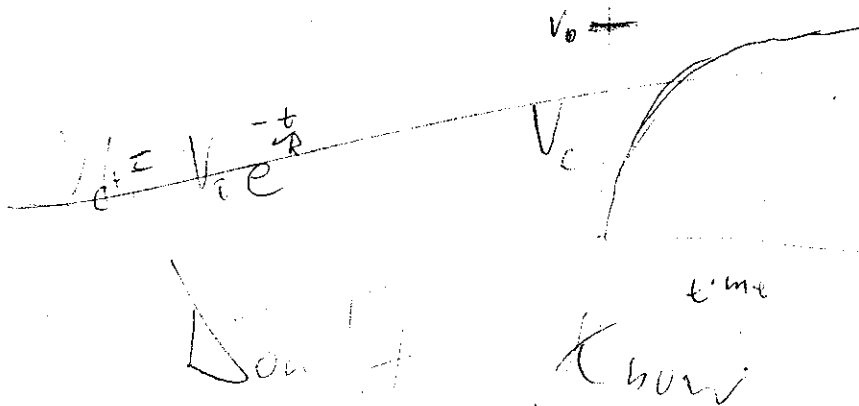
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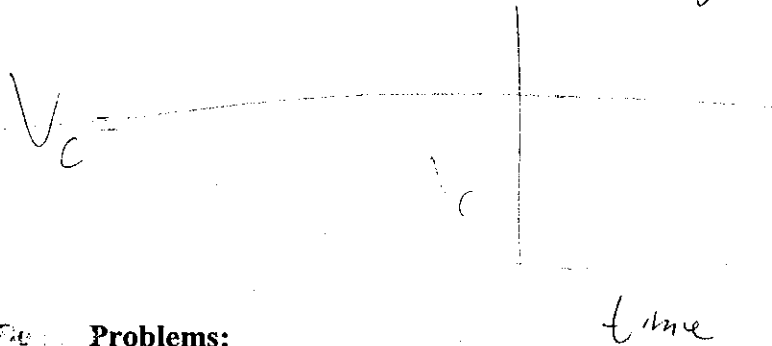
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a)



b)



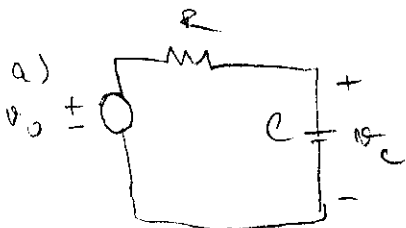
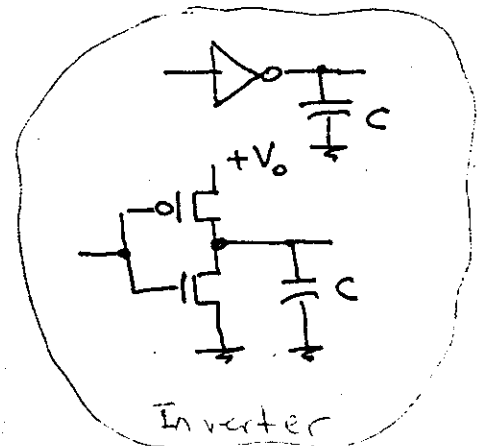
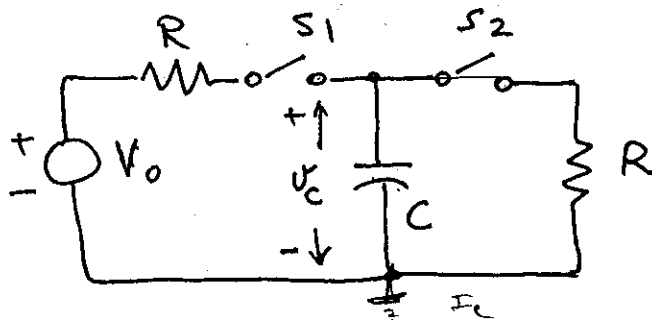
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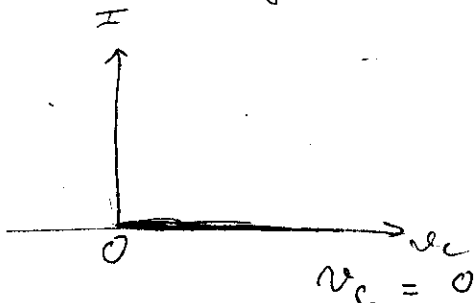
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$$V_c = V_0 \frac{\frac{1}{j\omega C}}{\frac{1}{j\omega C} + R} = V_0 \frac{1}{Rj\omega C + 1}$$

b)



$$\frac{\frac{1}{j\omega C} \cdot R}{\frac{1}{j\omega C} + R} = \frac{R}{1 + Rj\omega C}$$

$$V_c = I_c \frac{R}{1 + Rj\omega C}$$

Problems:

Your Name: _____

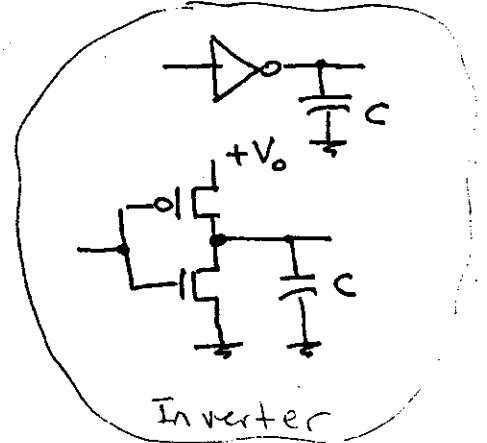
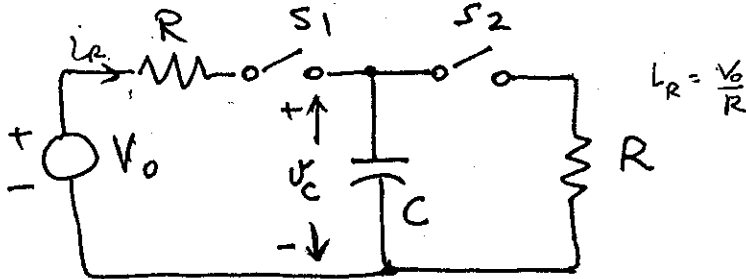
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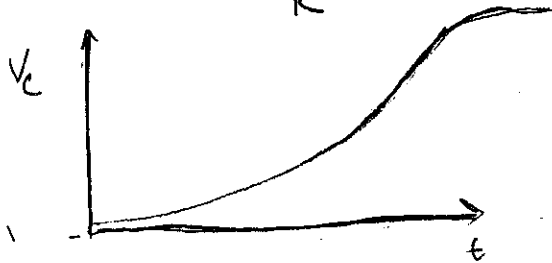
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KVL (1):

$$0 = \frac{V_0}{R} + V_C$$



a)
$$V_C(t) = -\frac{V_0}{R} + V_0(1 + e^{-t/\tau})$$

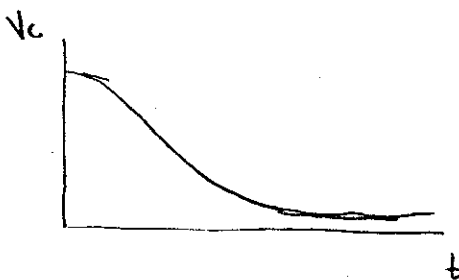


KVL (2):

$$V_C + \frac{V_0}{R} = 0$$

$$V_C = -\frac{V_0}{R}$$

b)
$$V_C(t) = -\frac{V_0}{R}(1 + e^{-t/\tau})$$



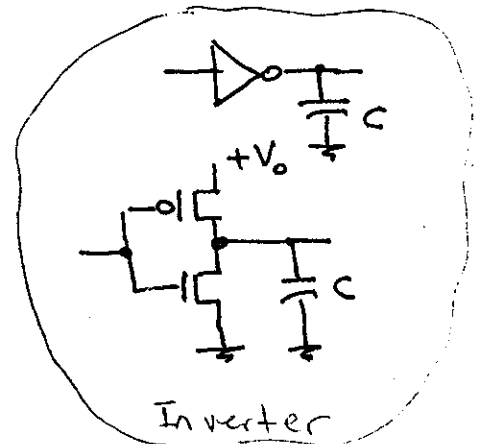
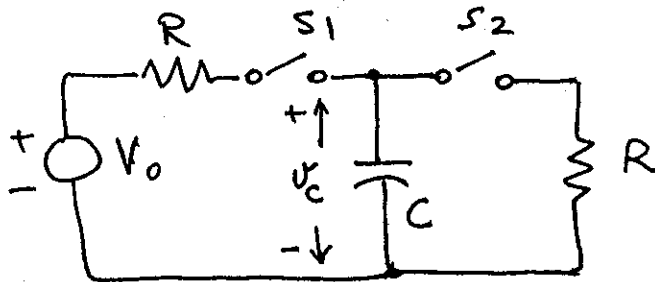
Do Problems:

Your Name: _____

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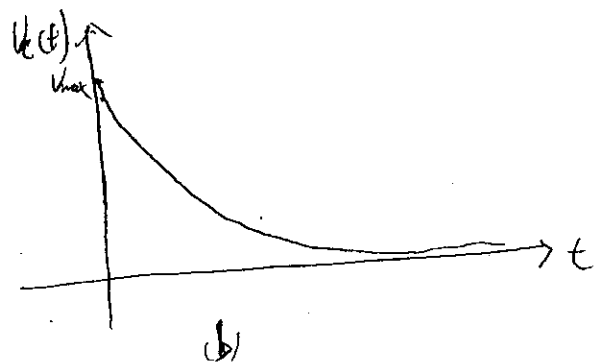
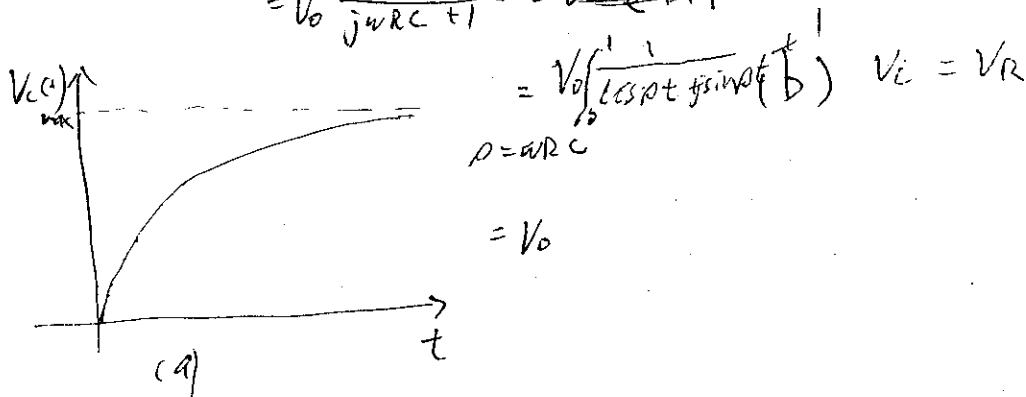
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$$(a) V_c(t) = \frac{\frac{1}{j\omega C}}{\frac{1}{j\omega C} + R} V_0 = \frac{1}{Rj\omega C + 1} V_0$$

$$= V_0 \frac{1}{j\omega RC + 1} = \cancel{V_0 \frac{1}{j\omega RC + 1}}$$



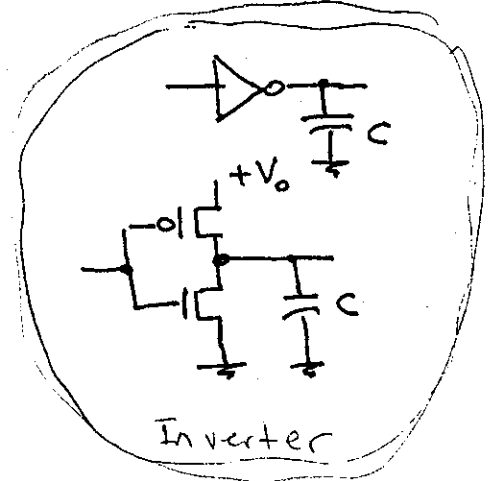
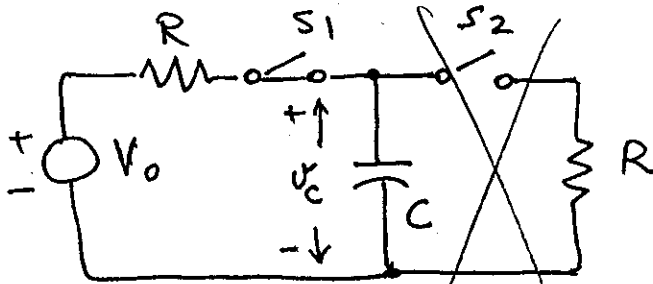
Problems:

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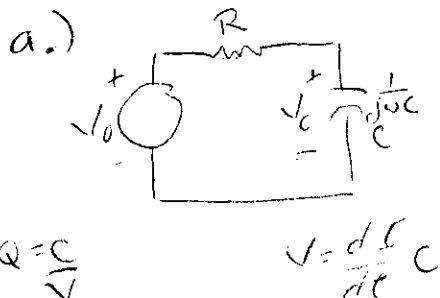
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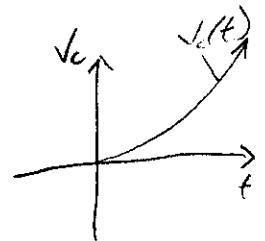
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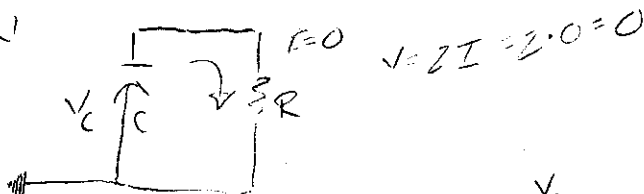
NOTE: Assuming ON = closed and OFF = open



$$V_c = \frac{j\omega C}{j\omega C + R} (V_0) = \frac{1}{1 + j\omega CR} V_0$$

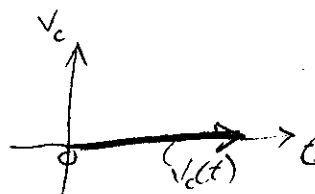


b.) $S_1 = \text{OFF}$
 $S_2 = \text{ON}$



Problems:

$V_c(t) = 0$

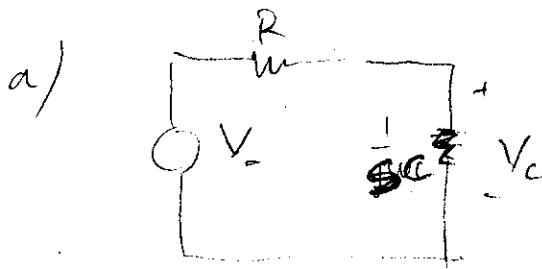
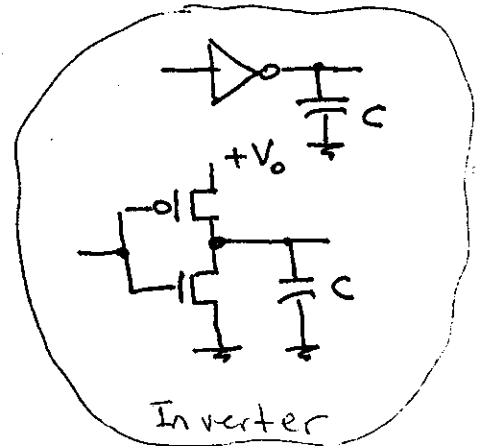
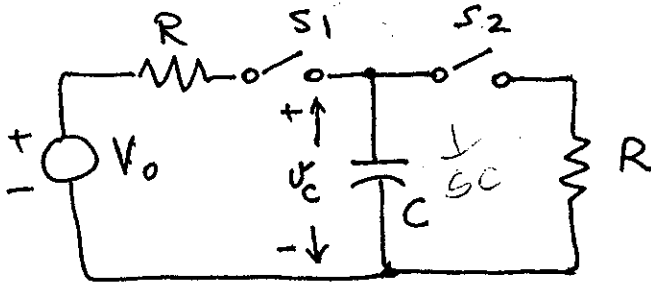


Your Name: < _____ >

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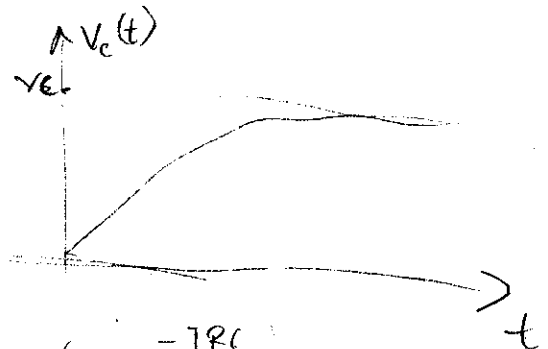


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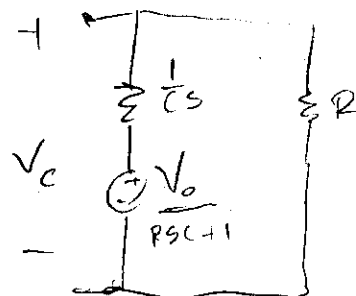
$$V_c = \frac{V_0 \frac{1}{sC}}{R + \frac{1}{sC}}$$

$$V_c = \frac{V_0}{R s C + 1}$$

$$V_c(t) = \left(V_0 e^{-t/RC} \right) u(t)$$

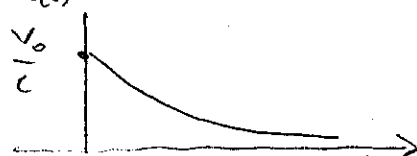


b/



$$V_c = \frac{1}{sC} + \frac{V_0}{R s C + 1}$$

$$V_c(t) = \left(\frac{1}{C} e^{-t} + V_0 e^{-t/RC} \right) u(t)$$



Problems:

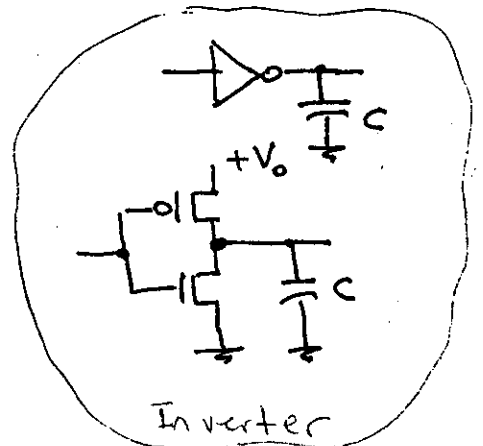
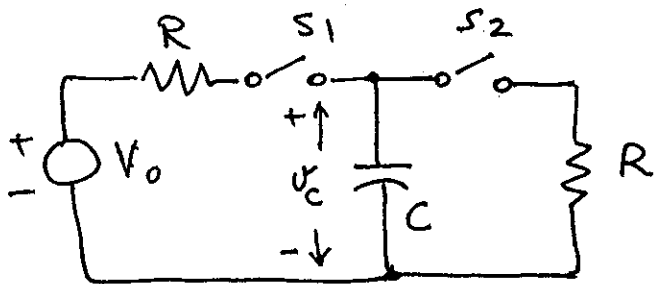
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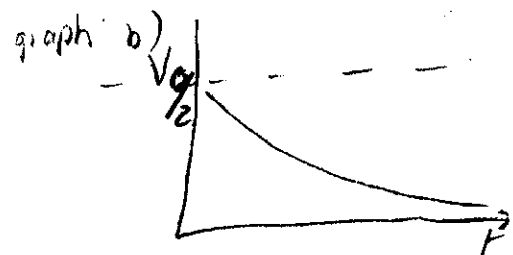
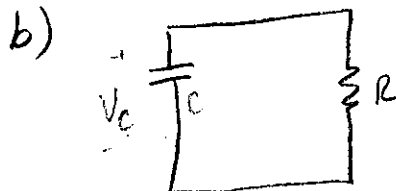
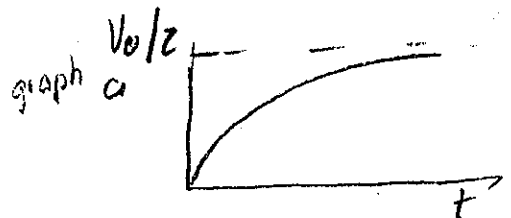
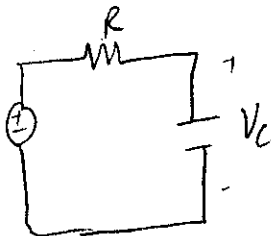
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a) $V_c = \frac{\frac{1}{sC}}{\frac{1}{sC} + R} V_0 = \frac{1}{1 + R s C} V_0(t)$



jw

Problems:

$V_c - i_c R = 0$

$V_c = I_c R$

$I_c = C \frac{dV_c}{dt} = C$

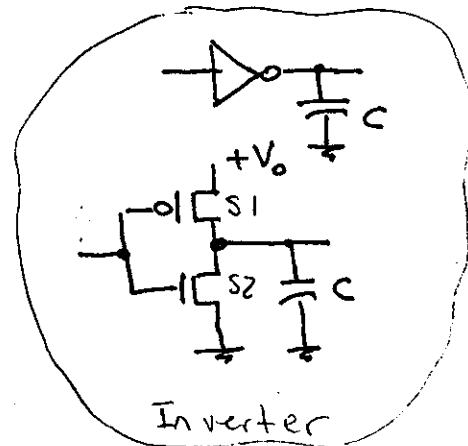
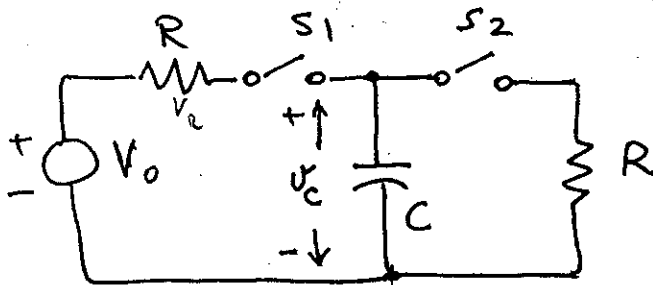


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a)

$$V_0(j\omega) = \frac{R + \frac{1}{j\omega C}}{R + \frac{1}{j\omega C} + R}$$

$$V_0(t) = \frac{R j\omega C + 1}{j\omega C}$$

$$V_0 j\omega C = R j\omega C + 1$$

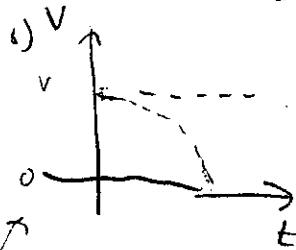
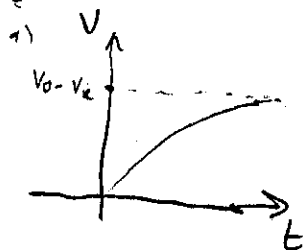
$$j\omega C (V_0 - R) = 1$$

$$j\omega C = \frac{1}{V_0 - R}$$

$$\omega = \left(\frac{1}{V_0 - R} \right) \frac{1}{C j}$$

b) $V_c = R + \frac{1}{j\omega C}$

$$\omega = \left(\frac{1}{V_c - R} \right) \frac{1}{C j}$$



Problems: Note To TAs this whole quiz is an UNREASONABLE judge of our knowledge of DIGITAL CIRCUITS

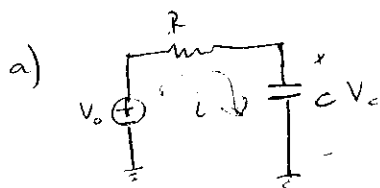
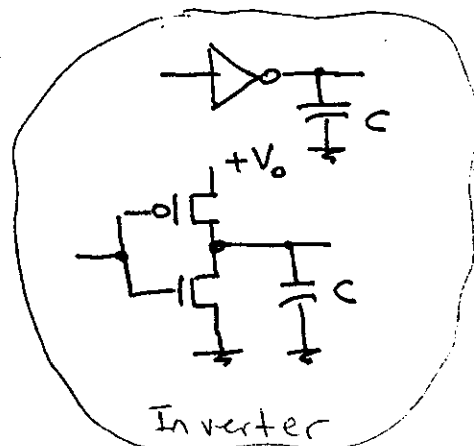
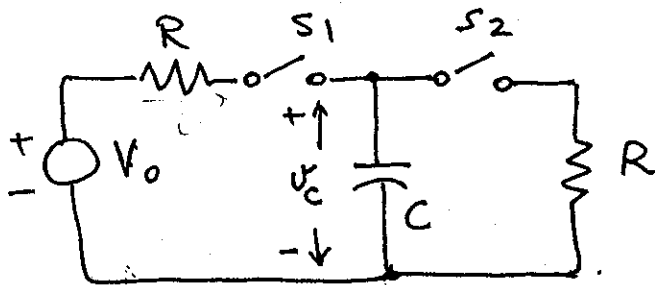
Why should we need to know analog. I'm a Computer Science student This is an EE course and this is a quiz of basic knowledge. You should complain about your degree.

Your Name: _____

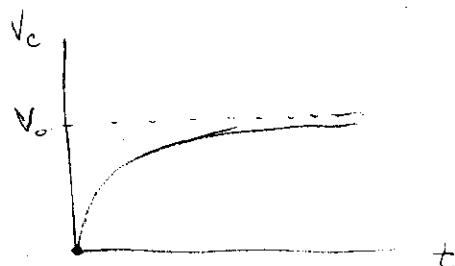
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$$V_c = \frac{\frac{1}{sC}}{\frac{1}{sC} + R} V_0 = \frac{V_0}{1 + sCR}$$



b) on back

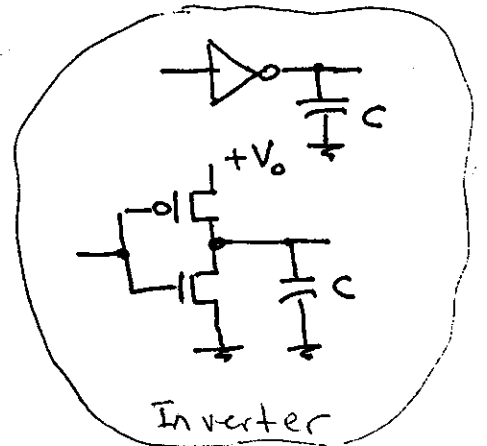
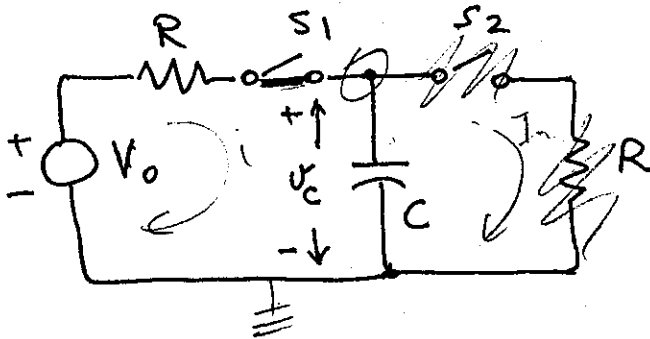
Problems:

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$\frac{V}{R} = I$

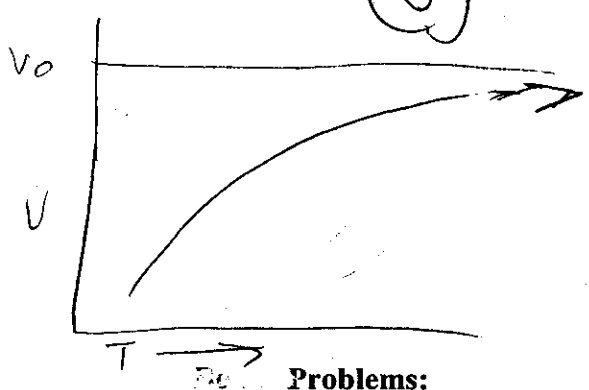
$\frac{1}{C} \int_0^\infty V_c - V_0 = I(t) R$

$V_c = RC \int I(t) dt$

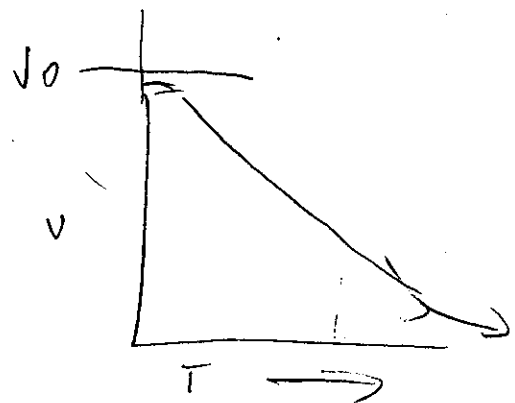
(B)

$R \int I(t) dt = - \frac{1}{C} \int_0^\infty V_c dt$

$C \int R I(t) dt = -V_c$



Problems:

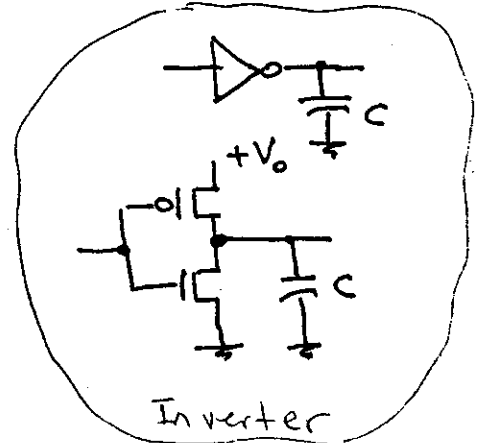
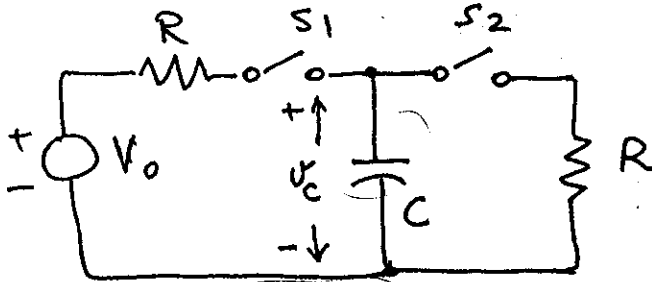


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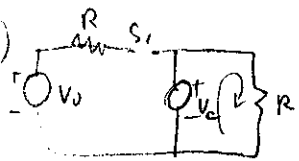
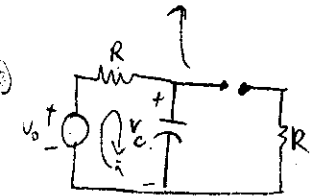
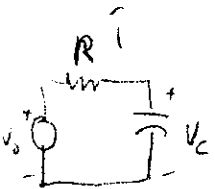
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$$V_c = C \frac{di}{dt}$$



$$V_c = C \frac{di}{dt}$$

$$I = L \frac{dv}{dt}$$

(a) $V_0 = IR + V_c$

$$V_c = V_0 - IR$$

$$V_c = V_0 - \frac{V_c}{C} t R$$

$$V_c + \frac{V_c}{C} t R = V_0$$

$$V_c (1 + \frac{tR}{C}) = V_0$$

$$V_c = \frac{V_0}{1 + \frac{tR}{C}} = \frac{V_0}{\frac{C + tR}{C}} = V_0 \cdot \frac{C}{C + tR}$$

$$V_c(t) = \frac{V_0 \cdot C}{C + tR}$$

$$V_c(t) = C \frac{di(t)}{dt}$$

$$V_c = C \frac{di}{dt}$$

$$\int \frac{V_c}{C} dt = \int di(t)$$

$$\int V_c dt = i(t)$$

$$i(t) = \frac{1}{C} V_c t$$

$$i(t) = \frac{V_c}{C} t$$

$$i(t) = \frac{V_0}{R + \frac{dV_c}{dt}}$$

$$V_c =$$

become voltage source

$$C = V_0 \quad i(t) = \frac{V_c(t)}{R}$$

$$t = IR$$

$$V_c = i(t) R$$

$$V_c = \frac{V_c}{C} t R$$

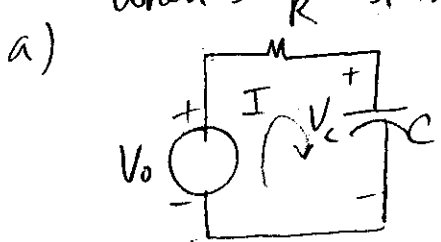
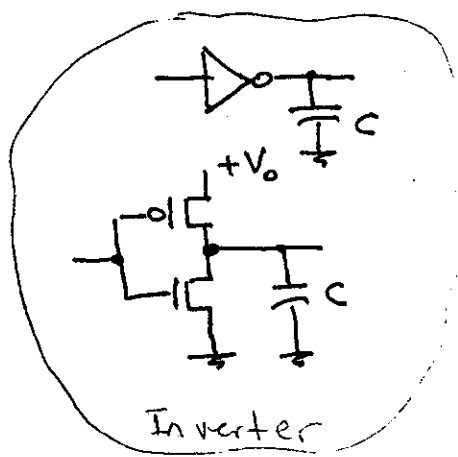
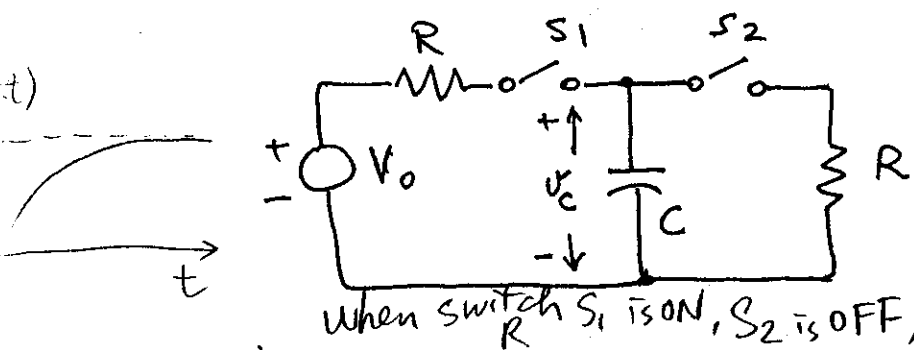
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$$-V_0 + I(2R) = 0$$

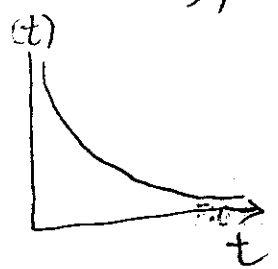
where $I = \frac{V_0}{2R}$

$$-V_0 + IR + V_c(t) + C \frac{dV_c}{dt} = 0$$

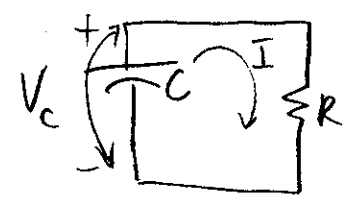
$$V_c(t) = V_0 - IR - C \frac{dV_c}{dt}$$

Voltage + current mixed units

- b) When switch S_1 is OFF, S_2 is ON,



Problems:



$$V_c(t) = C \frac{dV_c}{dt} + IR$$

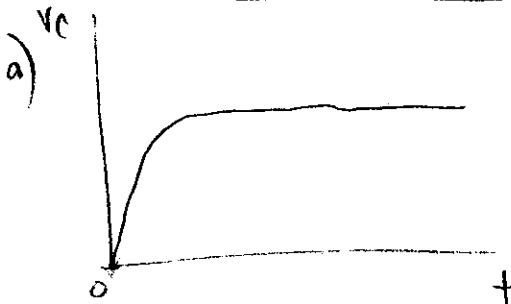
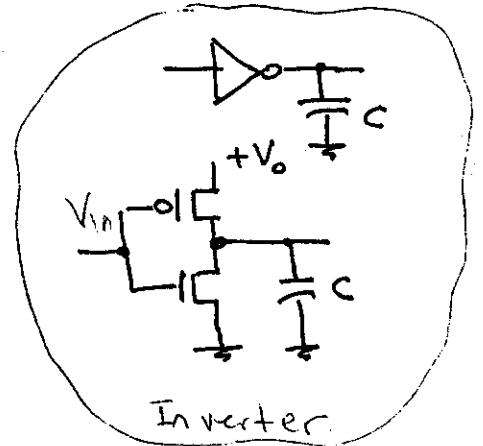
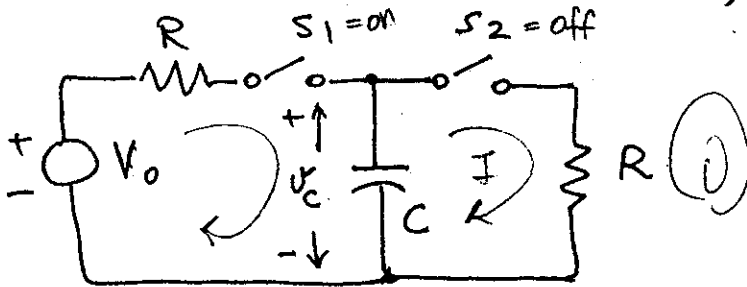
\uparrow Current thru cap \uparrow Voltage across resistor

Your Name: _____

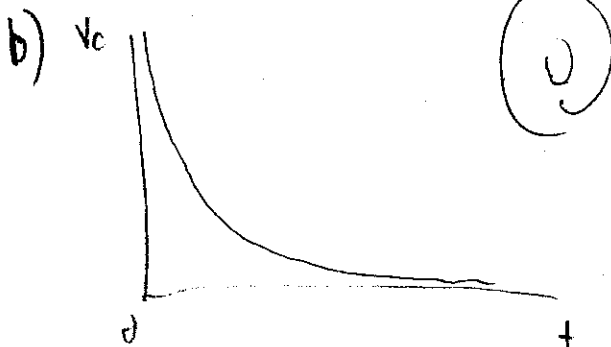
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$$V_c(t) = \frac{V_0 t R C}{\frac{1}{\omega C} + R} V_0$$

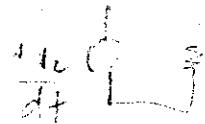


$$V_c = IR$$

$V_c =$ changing voltage

$$V_c = \frac{C dV_c/dt}{R}$$

$$\frac{1}{RC} + R$$



Problems:

$$\frac{dV_c}{dt} = IR$$

$$V_c = \int IR$$

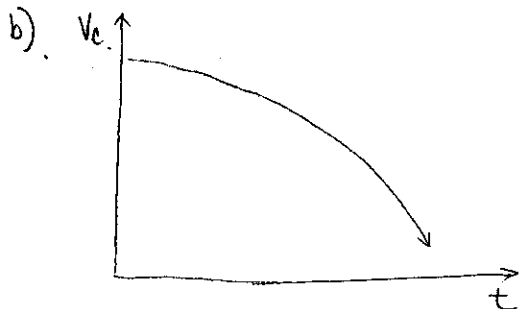
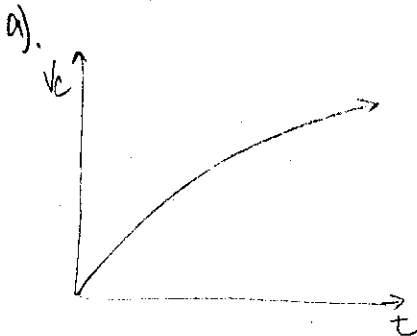
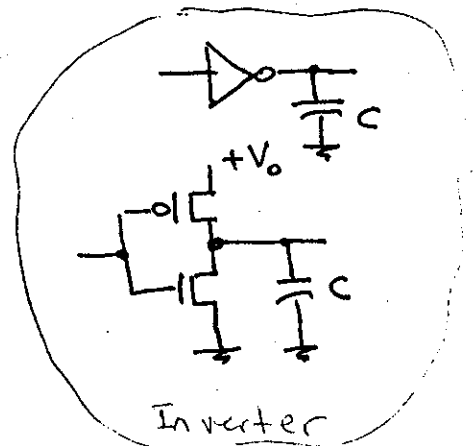
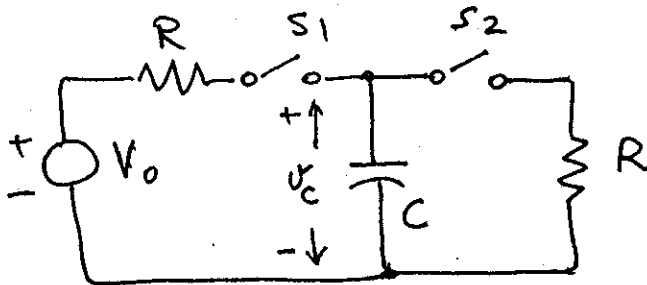
$$V_c = V_{c, \text{initial}} - \int_0^t IR$$

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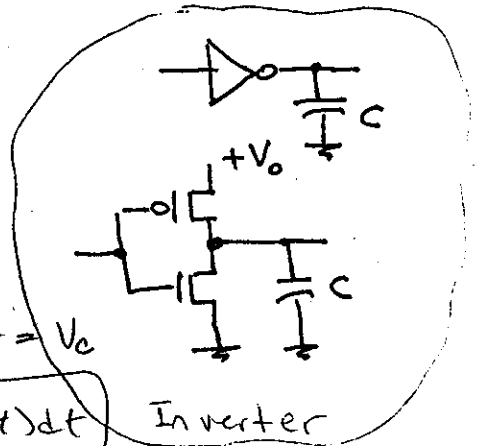
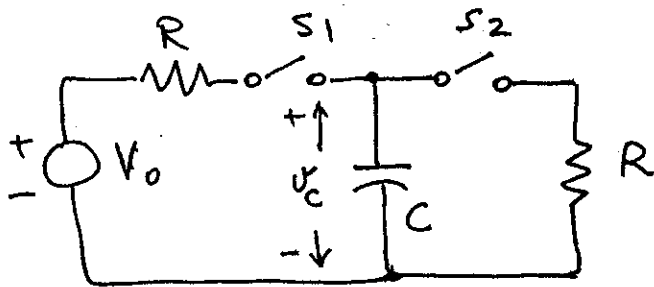
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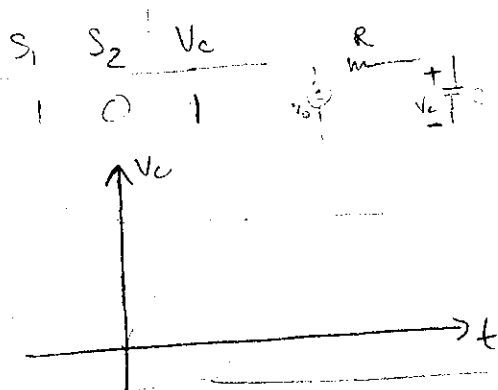
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a.)



$$-V_0 + Ri(t) + \frac{1}{C} \int i(t) dt = V_c$$

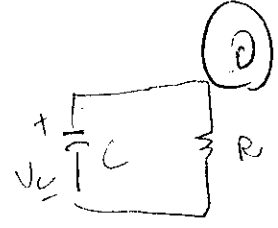
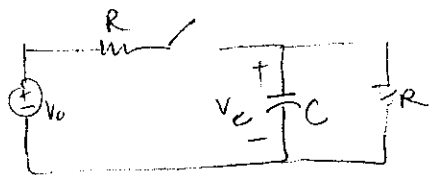
$$V_c = Ri(t) - V_0 + \frac{1}{C} \int_0^t i(t) dt$$

$$\lim_{t \rightarrow \infty} V_c = \infty - V_0 + \infty = \infty$$

0

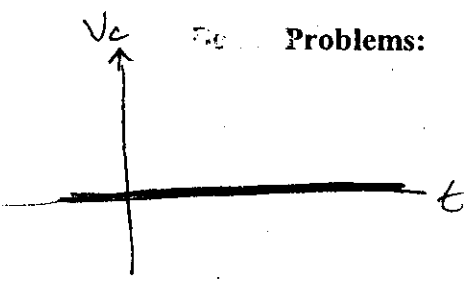
S_1	S_2	V_c
0	1	0

since the switch 1 is off, there is no V_0 going through the capacitor C .



$$V_c = \frac{1}{C} \int i(t) dt + Ri(t) = 0$$

$$\therefore V_c = 0 \text{ volts.}$$

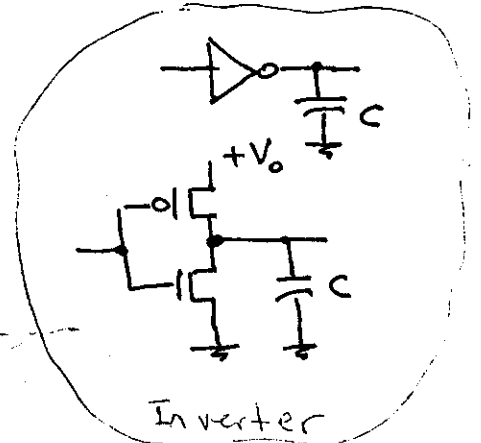
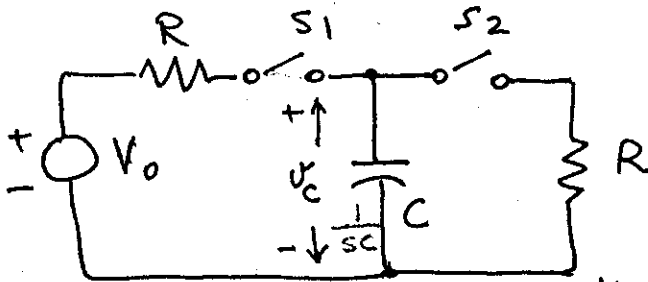


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- (b.) find the expression for the voltage V_c (as a function of time t) when (after sufficient time has elapsed to charge the capacitor C fully) the switch S_1 is turned off and switch S_2 is turned on. Draw a graph: $V_c(t)$

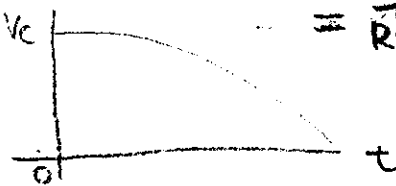
Note: this is the first grade college physics (Sears & Zemansky) problem (for some of you perhaps a high-school problem). (12th grade)



(a) $V_c(t) = \frac{\frac{1}{sC}}{R + \frac{1}{sC}} V_0$

(b) $V_c(t) = \frac{V_0}{RCs + 1} = \frac{V_0}{RC(j\omega + \frac{1}{RC})} = \frac{V_0}{RC} \cdot \frac{1}{s + \frac{1}{RC}}$

(b)



(c)

$$V_c(t) = V_0 - \frac{R}{C} \cdot t$$

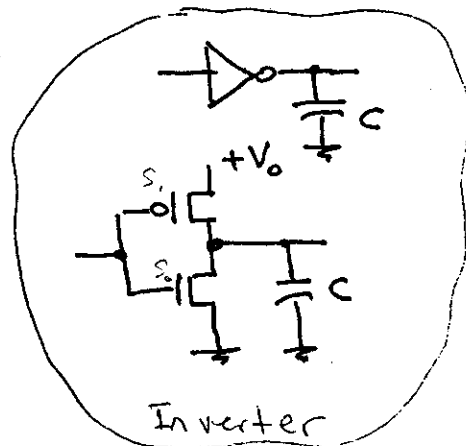
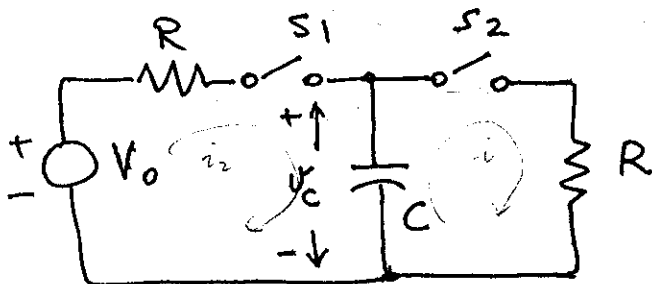
Re. Problems:

Your Name: _____

Problem #1: Digital CMOS inverter can be approximated as a circuit given in the figure.

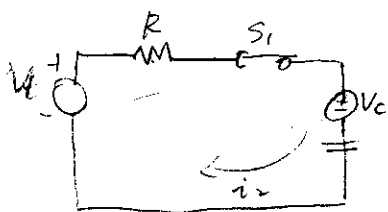
- (a.) find the expression for the voltage V_c (as a function of time t) when switch S_1 is ON and S_2 is off. Assume that the capacitor C was completely discharged before S_1 was turned ON. Draw a graph of $v_c(t)$
- (b.) find the expression for the voltage V_c (as a function of time t) when (after sufficient time has elapsed to charge the capacitor C fully) the switch S_1 is turned off and switch S_2 is turned on. Draw a graph: $v_c(t)$

Note: this is the first grade college physics (Sears & Zemansky) problem (for some of you perhaps a high-school problem). (12th grade)



a)

0



$$V_c = iR = C \cdot \frac{dv}{dt} R$$

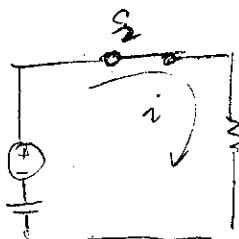
$$V_0 - V_c + i_2 R = 0$$

$$V_0 = -i_2 R + V_c = \frac{1}{j\omega C} - i_2 R$$

b) $V_c = \frac{1}{j\omega C} + iR$

$$= \frac{1}{j\omega C} + \frac{dv}{dt} R$$

0



$$V_0 = V_c \quad (S_1 = \text{off})$$

$$V_0 = 0 \quad (S_1 = \text{on})$$

Problems: