*E*lectrical
*E*ngineering
*T*echnology

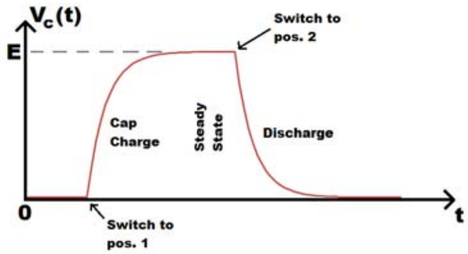
Capacitor Charge - Continued

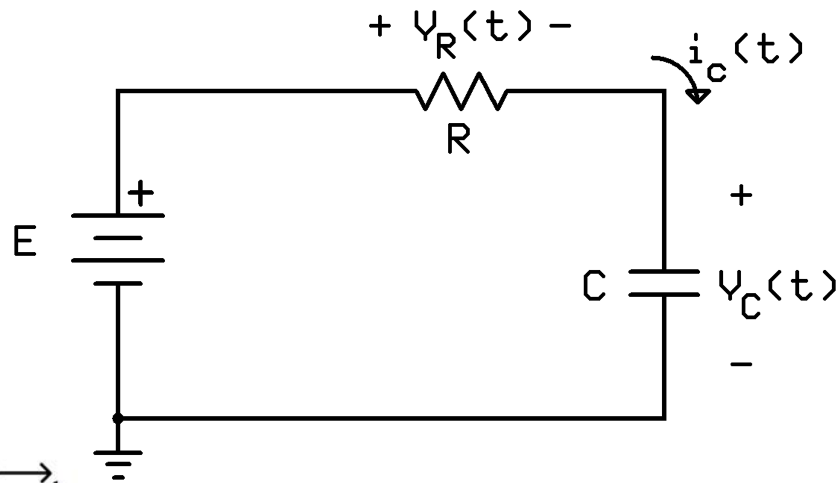
Fall 2018

Recall - Equations for the charge phase:

$$i_c(t) = \frac{E}{R} * e^{\frac{-t}{\tau}}$$

$$V_r(t) = E * e^{\frac{-t}{\tau}}$$





KVL is still true!

$$E - V_R(t) - V_C(t) = 0$$

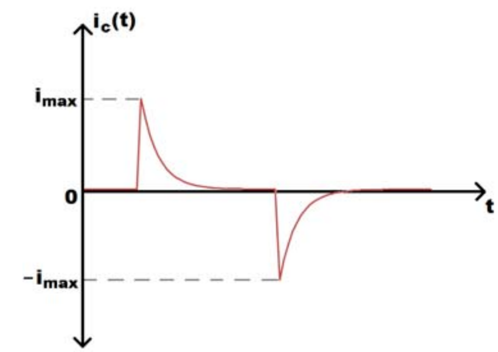
$$V_C(t) = E - V_R(t)$$

$$V_C(t) = E - E * e^{\frac{-t}{\tau}}$$

$$V_C(t) = E\left(1 - e^{\frac{-t}{\tau}}\right)$$

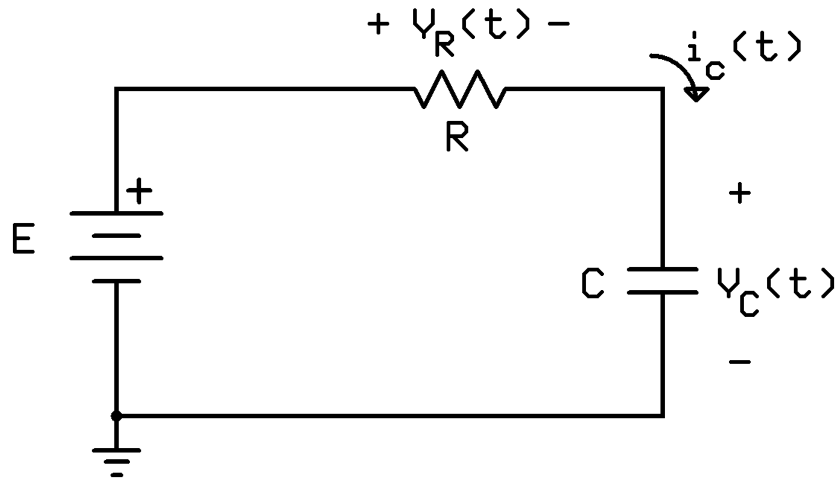
Investigating $i_c(t) = \frac{E}{R} * e^{\frac{-t}{\tau}}$

t	$i_c(t)$		
0	$\frac{E}{R}$	← Initial value	
$RC = \tau$	$\frac{E}{R}(e^{-1})$	$= 0.368\left(\frac{E}{R}\right)$	36.8% of E/R
$2RC = 2\tau$	$\frac{E}{R}(e^{-2})$	$= 0.135\left(\frac{E}{R}\right)$	13.5% of E/R
$3RC = 3\tau$	$\frac{E}{R}(e^{-3})$	$= 0.05\left(\frac{E}{R}\right)$	5% of E/R
$4RC = 4\tau$	$\frac{E}{R}(e^{-4})$	$= 0.018\left(\frac{E}{R}\right)$	1.8% of E/R
$5RC = 5\tau$	$\frac{E}{R}(e^{-5})$	$= 0.0067\left(\frac{E}{R}\right)$	0.67% of E/R



Less than 1% of max (initial) current. Considered “fully charged”.

Equations for the charge phase – ic(t) and VR(t)



$$i_c(t) = \frac{E}{R} * e^{\frac{-t}{\tau}}$$

$$V_r(t) = E * e^{\frac{-t}{\tau}}$$

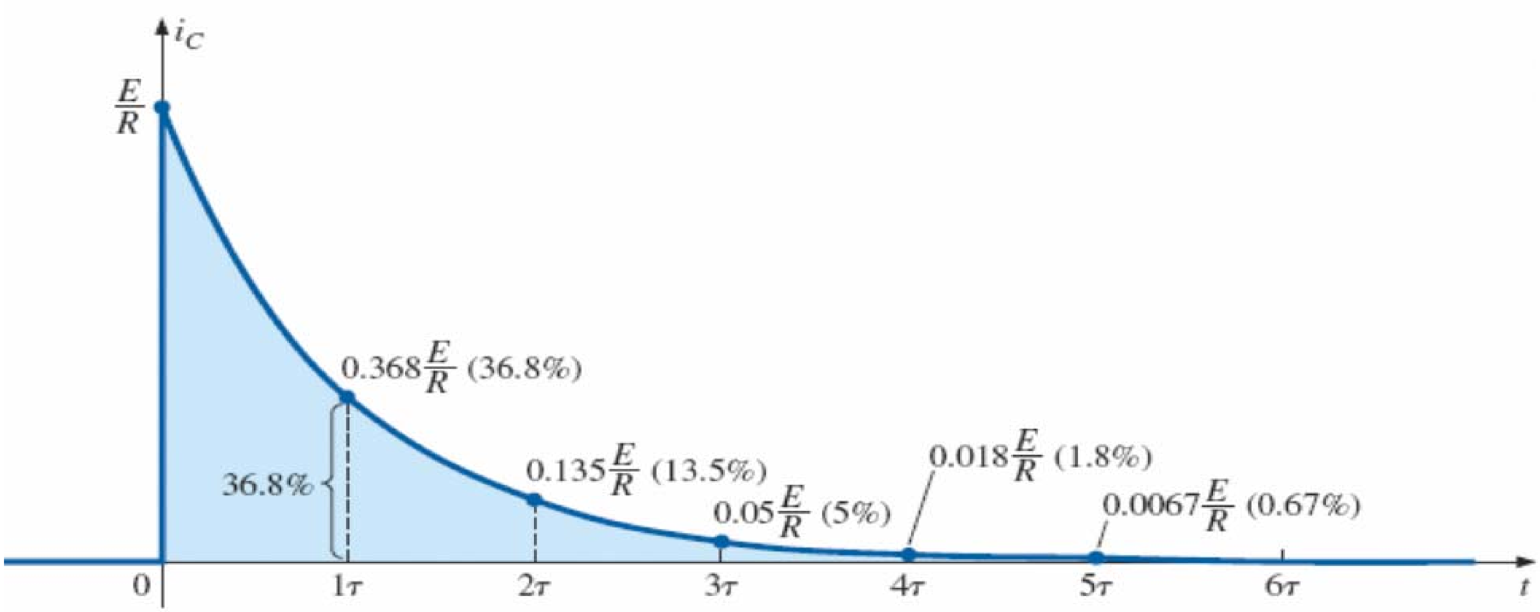
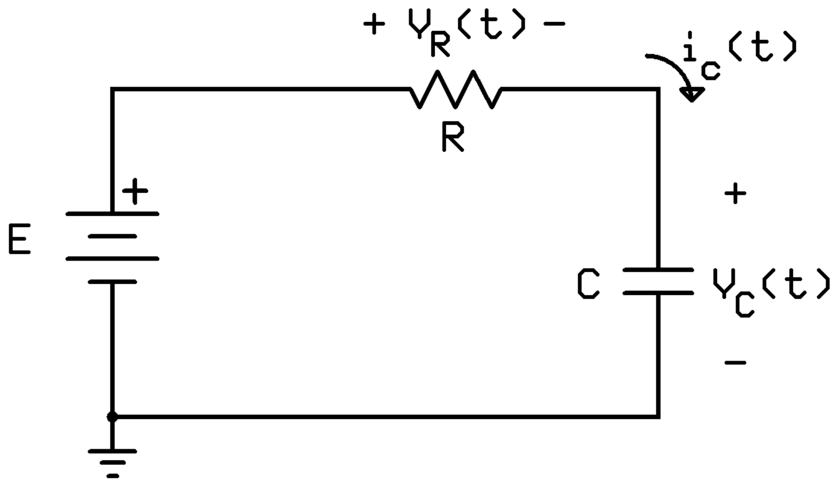


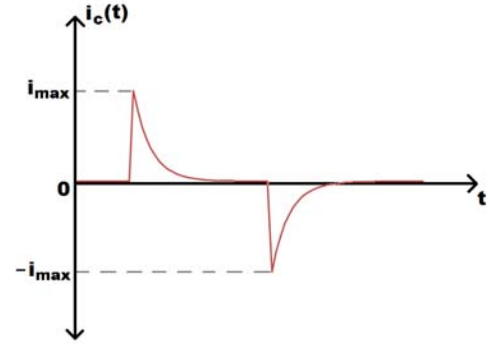
FIG. 10.30

Plotting the equation $i_C = \frac{E}{R}e^{-t/\tau}$ *versus time (t).*

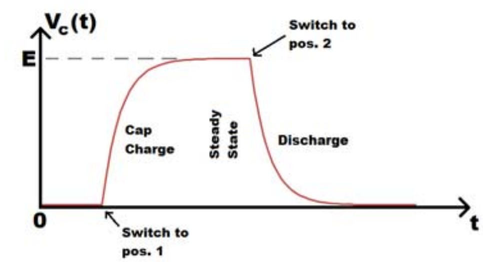
Equations for the charge phase – Vc(t)



$$i_c(t) = \frac{E}{R} * e^{\frac{-t}{\tau}}$$



$$V_C(t) = E\left(1 - e^{\frac{-t}{\tau}}\right)$$



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t	$V_C(t)$	
0	0	← Initial value

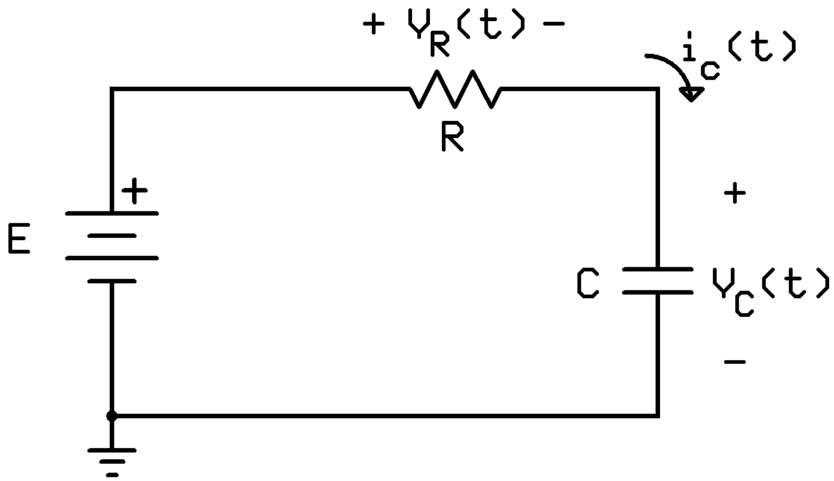
Investigating $V_C(t) = E\left(1 - e^{\frac{-t}{\tau}}\right)$

$\tau = RC$

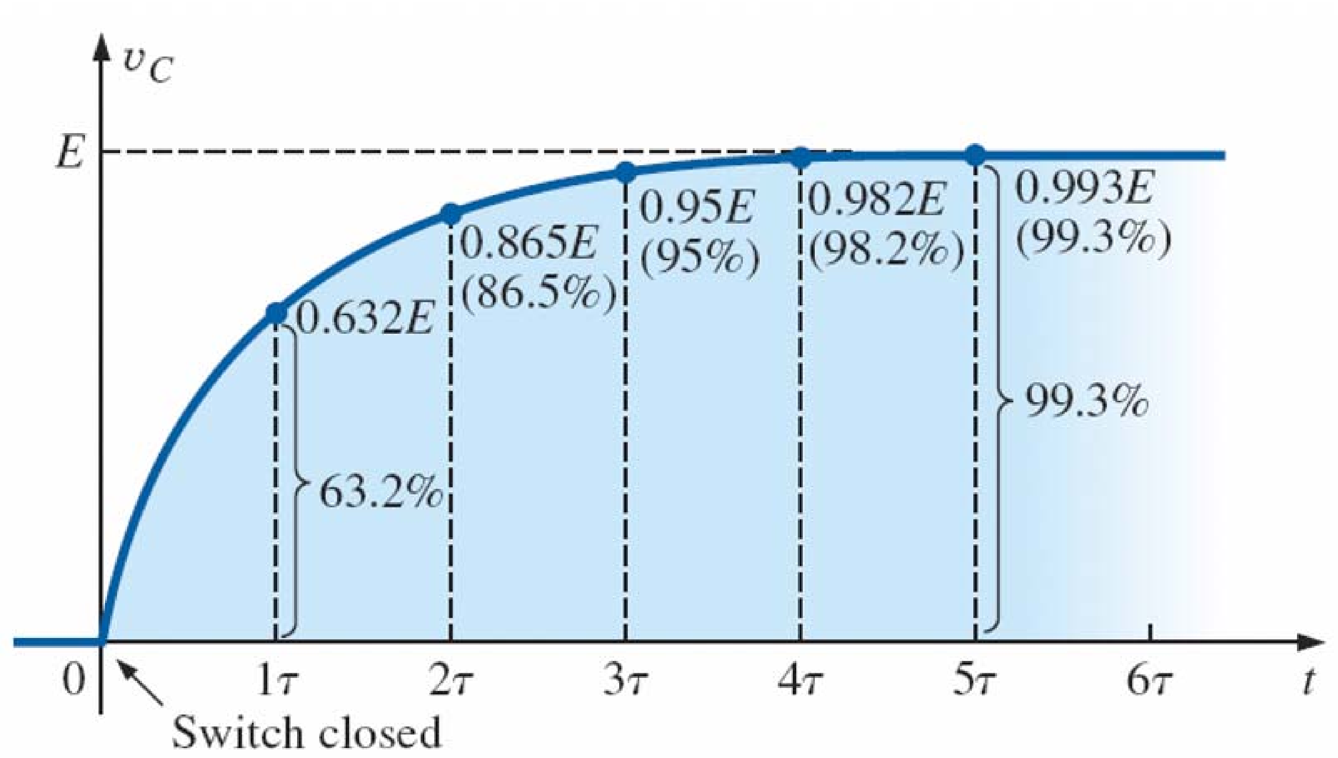
$RC = \tau$	$E(1 - e^{-1})$	$= E(0.632)$	63.2% of E
$2RC = 2\tau$	$E(1 - e^{-2})$	$= E(0.865)$	86.5% of E
$3RC = 3\tau$	$E(1 - e^{-3})$	$= E(0.950)$	95% of E
$4RC = 4\tau$	$E(1 - e^{-4})$	$= E(0.982)$	98.2 of E
$5RC = 5\tau$	$E(1 - e^{-5})$	$= E(0.993)$	99.3% of E

Less than 1% error (less than 1% from E or the **max** value). Considered "fully charged" at 5τ.

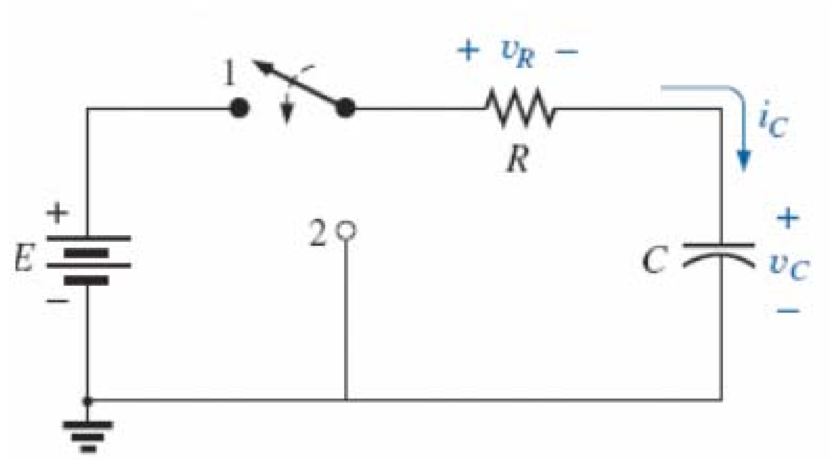
Recall - Equations for the charge phase:



$$V_C(t) = E\left(1 - e^{\frac{-t}{\tau}}\right)$$



In Class Problem



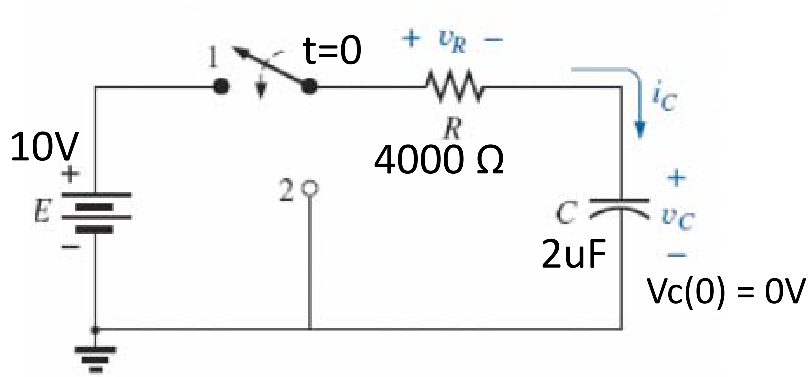
Given:

- There is no initial voltage on the capacitor, Vc(0) = 0V
- E = 10V, R = 4000 Ohms, C = 2uF
- The switch is moved to position 1 at t=0

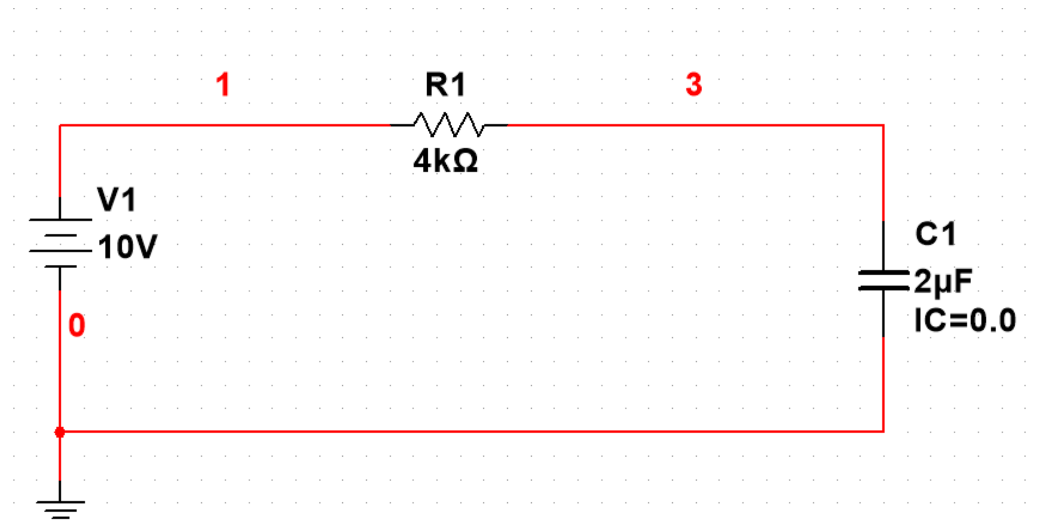
Find:

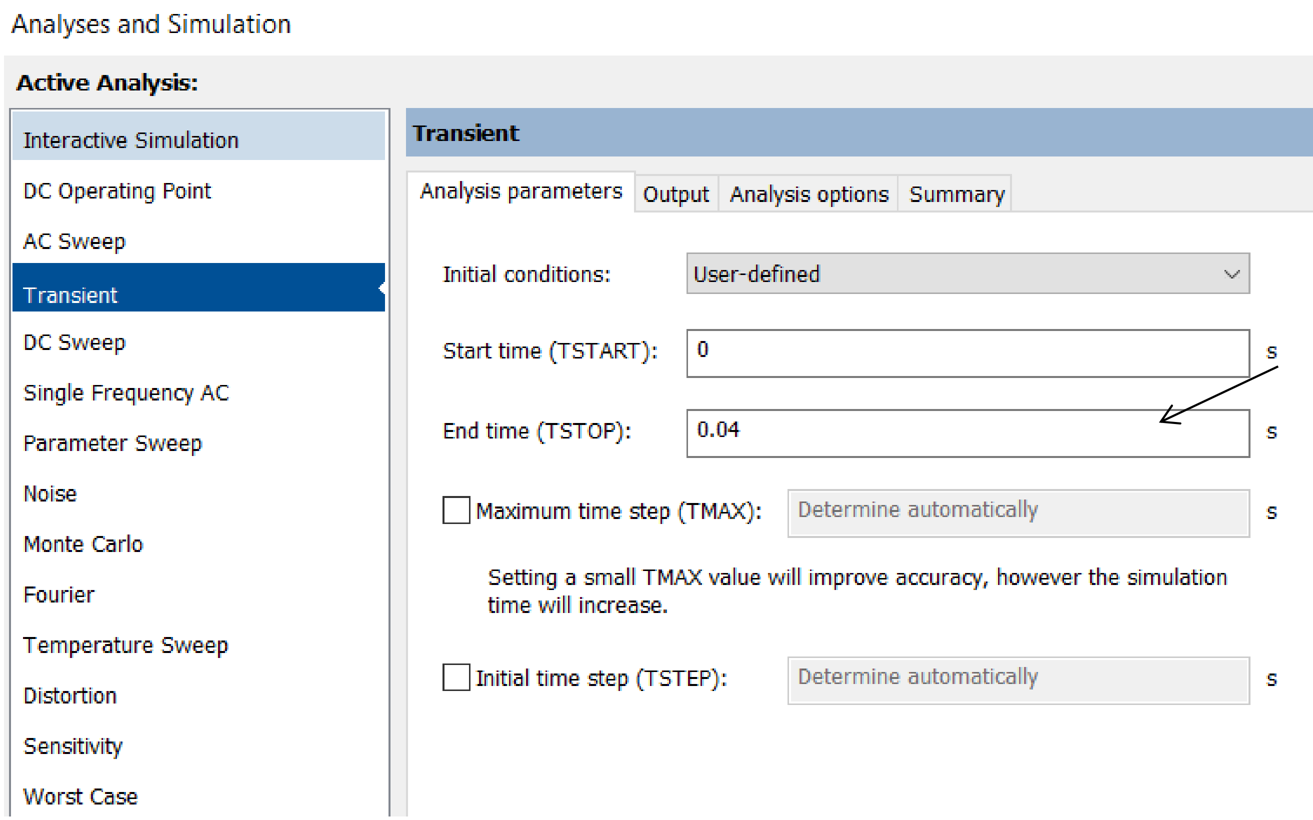
- Ic(t) and sketch
- Vc(t) and sketch
- V_R(t) and sketch
- Vc(t) at 10ms
- Ic(t) at 10ms

Multisim - Demo



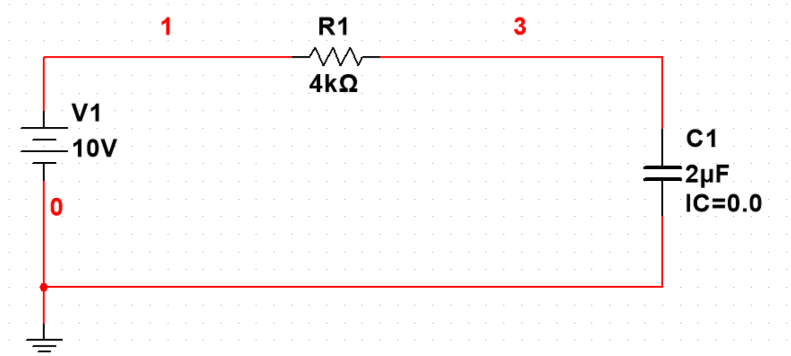
$\tau = RC$= 8ms

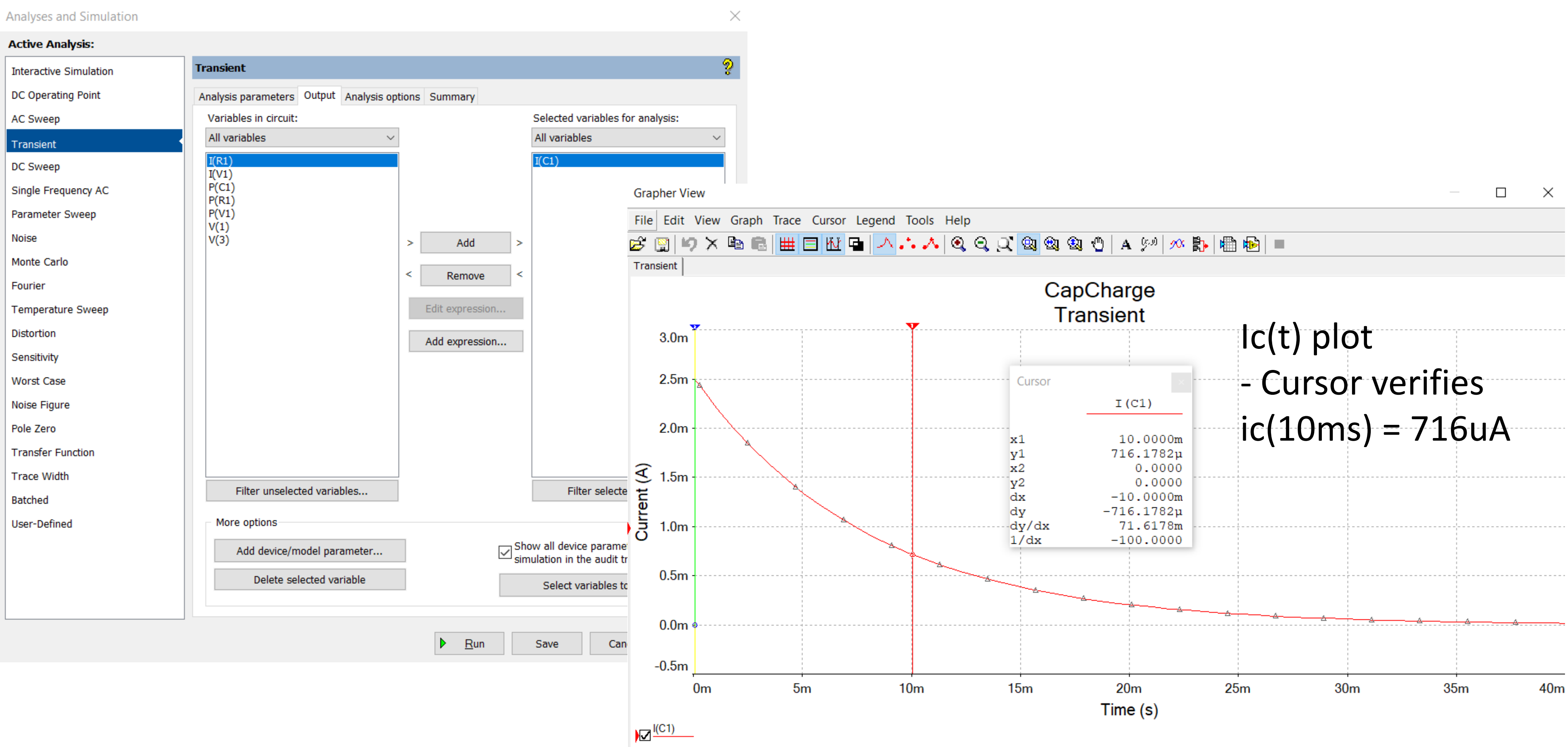




Set to 5τ to view the entire transient period

Multisim - Demo

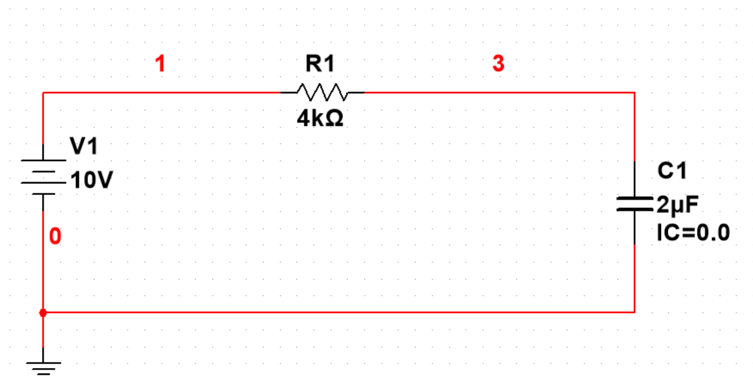


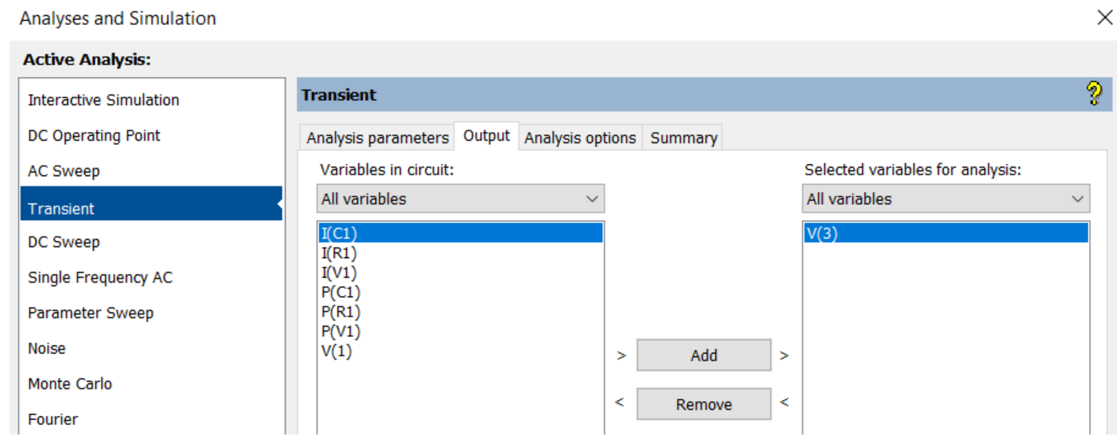


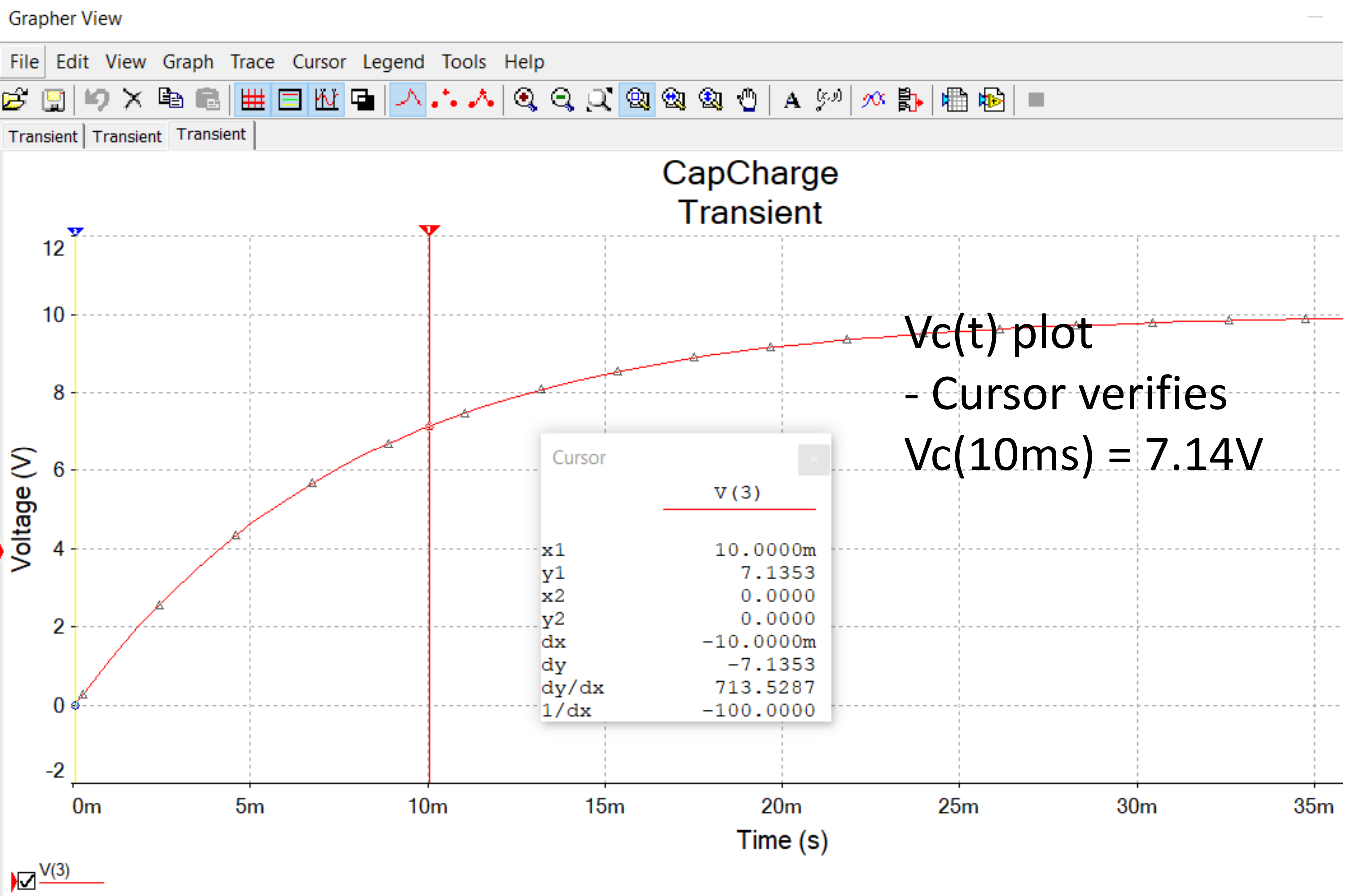
Ic(t) plot

- Cursor verifies ic(10ms) = 716uA

Multisim - Demo

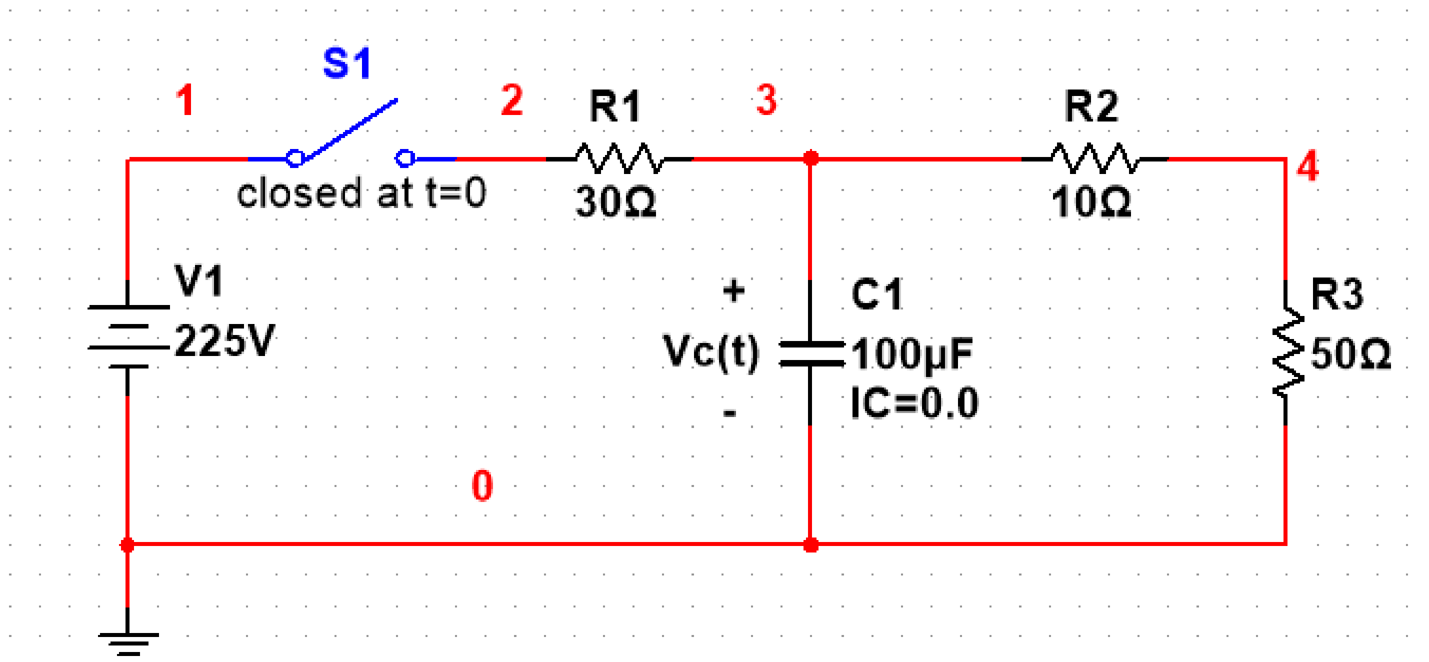






Vc(t) plot
- Cursor verifies
Vc(10ms) = 7.14V

Example – Multiple Resistors

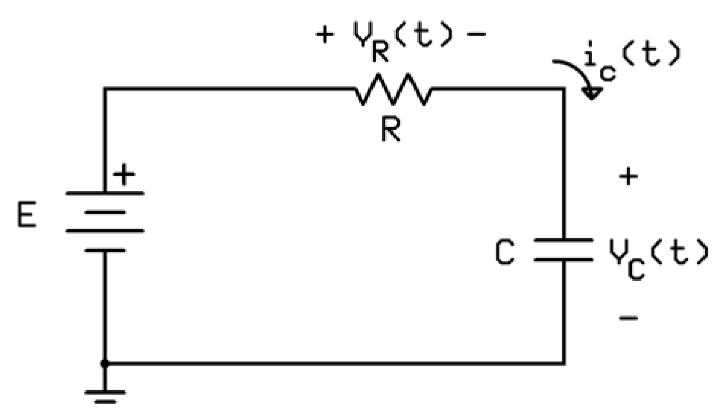


Find:

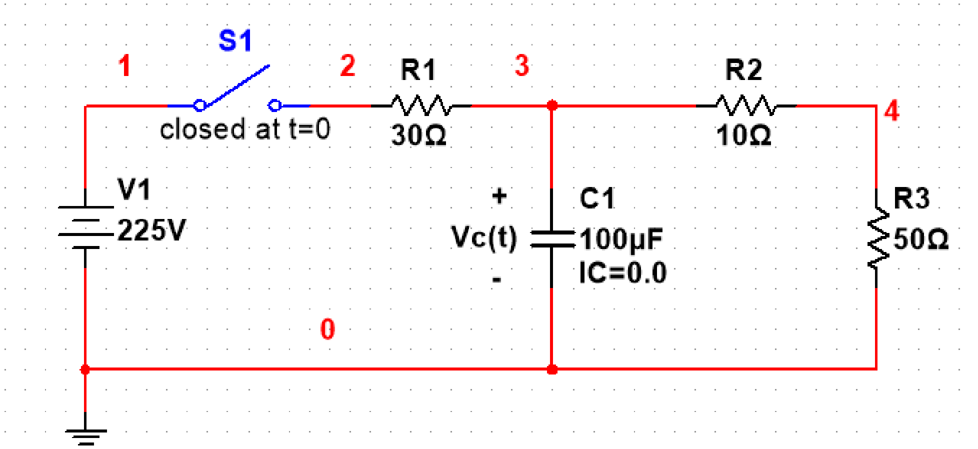
- Vc(t) and sketch for t > 0 seconds
- Estimate t for Vc(t) = 100V

Approach??

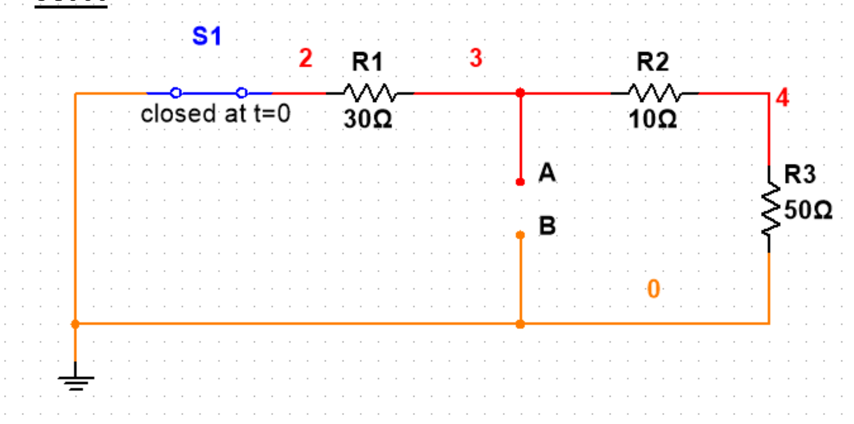
Hint – Can we handle THIS circuit?



Example – Multiple Resistors



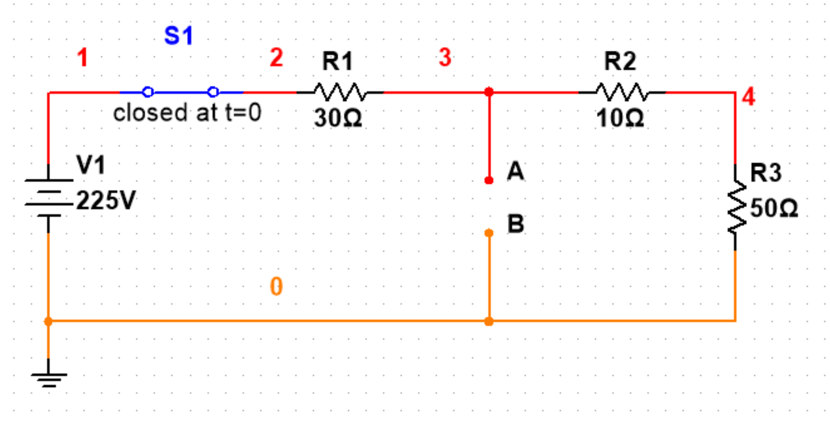
RTH



RTH

- R1//(R2+R3)
- **20 Ohms**

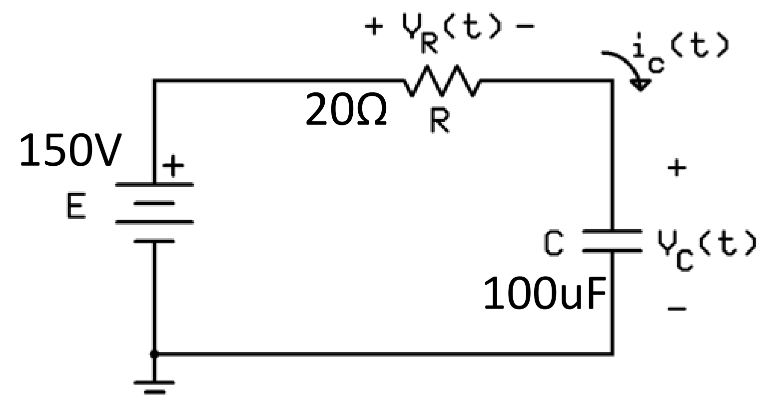
VTH



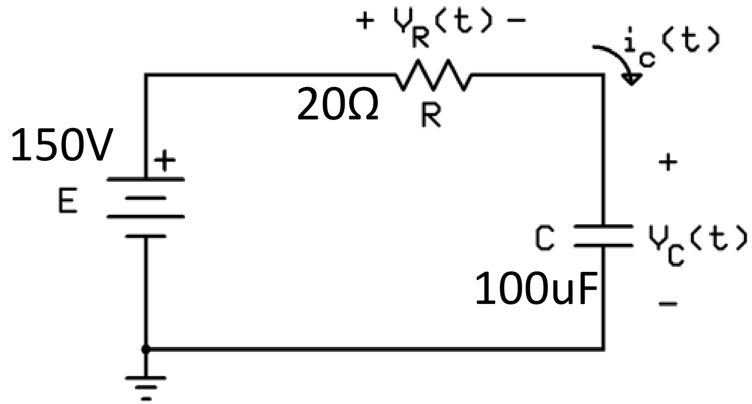
VTH

- V1*[(R2,3)/((R2,3)+R1)]
- **150V**

Analyze the Thevenin Equivalent Circuit:

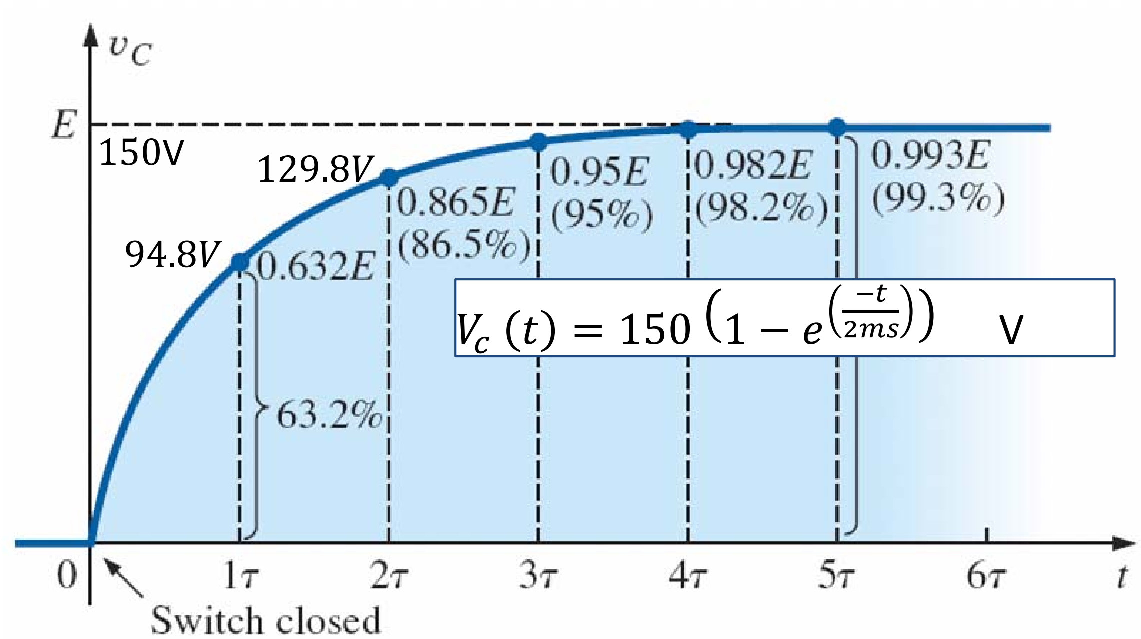


Example – Multiple Resistors



$$V_C(t) = E\left(1 - e^{\frac{-t}{\tau}}\right)$$

$$\boxed{V_c\ (t) = 150\ \left(1 - e^{\left(\frac{-t}{2ms}\right)}\right) \quad \text{V}}$$

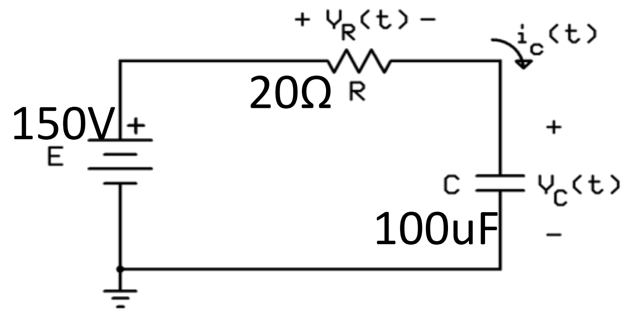


Estimate t for Vc(t) = 100V

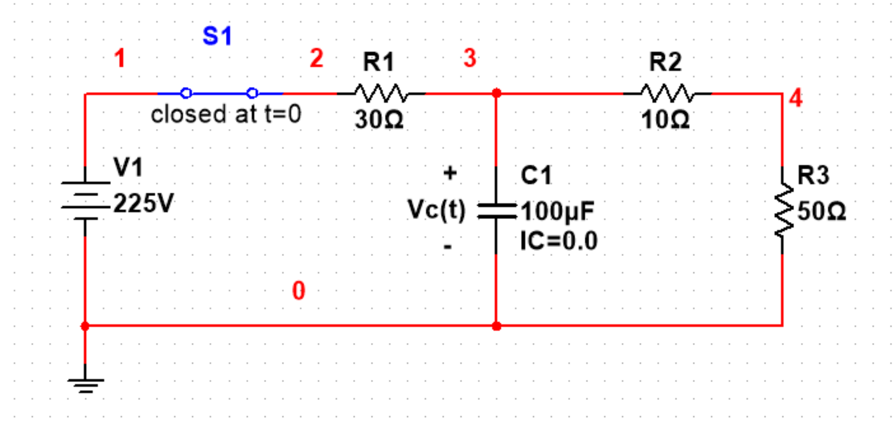
From the plot: Just over 1 time constant or ~ 2.1ms

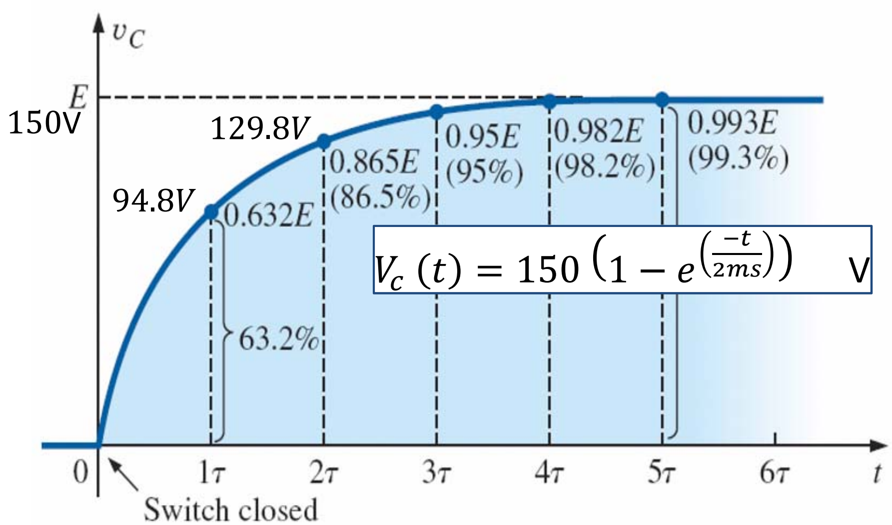
Example – Multiple Resistors

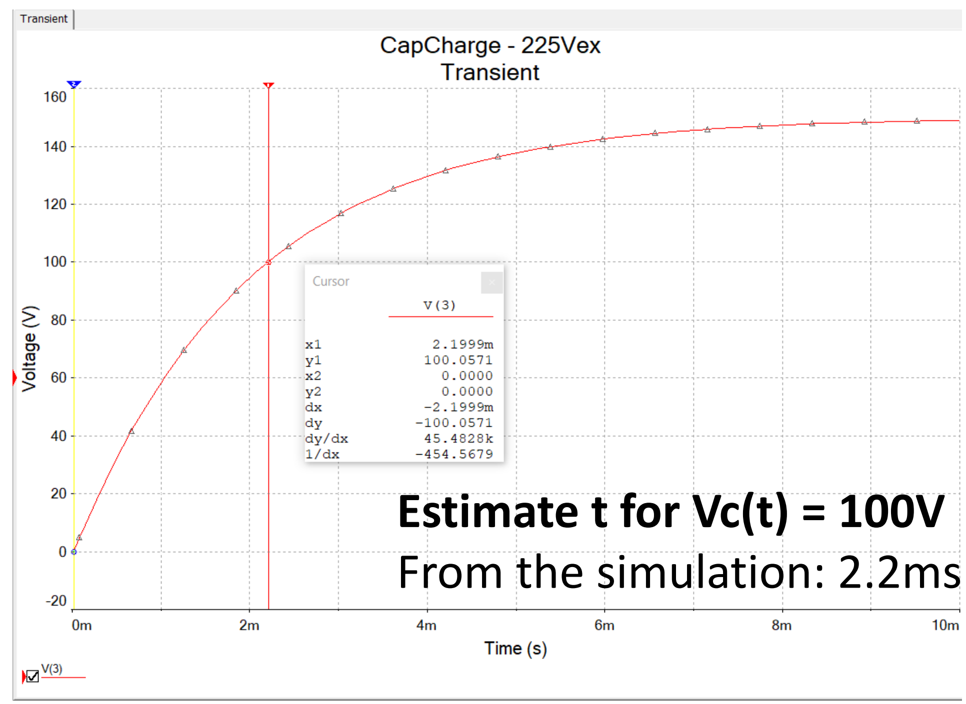
Thevenin Eq



Original Circuit







Estimate t for Vc(t) = 100V

From the plot: Just over 1 time constant or ~ 2.1ms

Estimate t for Vc(t) = 100V

From the simulation: 2.2ms