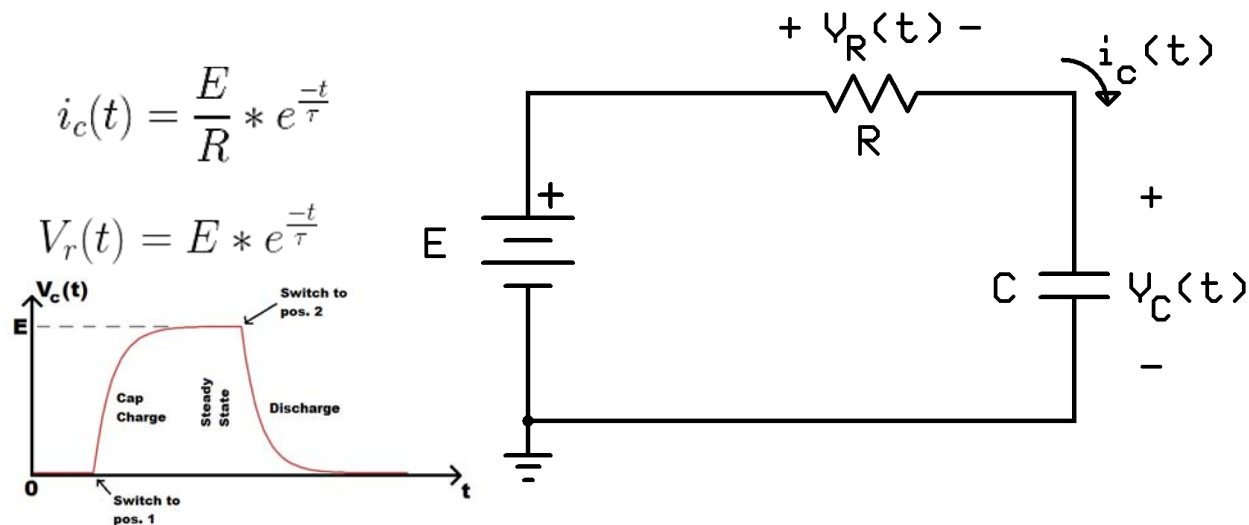


Electrical Engineering Technology

Capacitor Charge - Continued

Fall 2018

Recall - Equations for the charge phase:



KVL is still true!

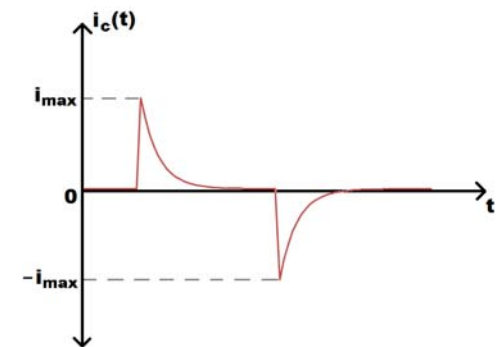
$$E - V_R(t) - V_C(t) = 0$$

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

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

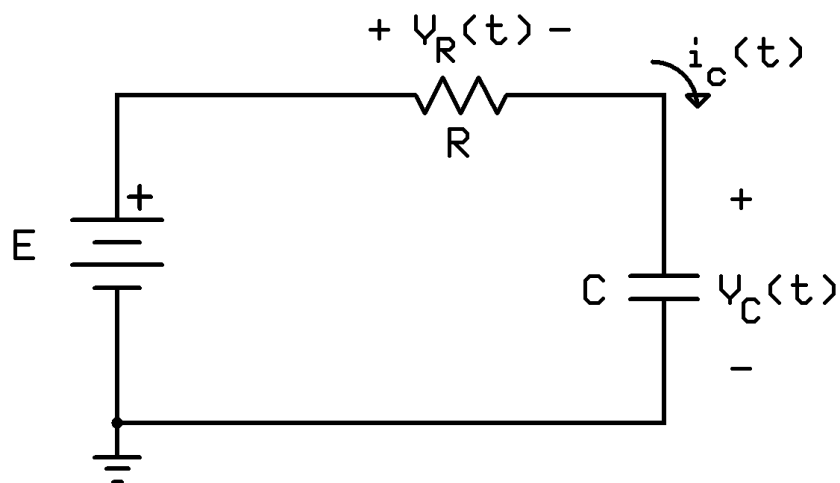
$$V_C(t) = E \left(1 - e^{\frac{-t}{\tau}} \right)$$

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



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

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

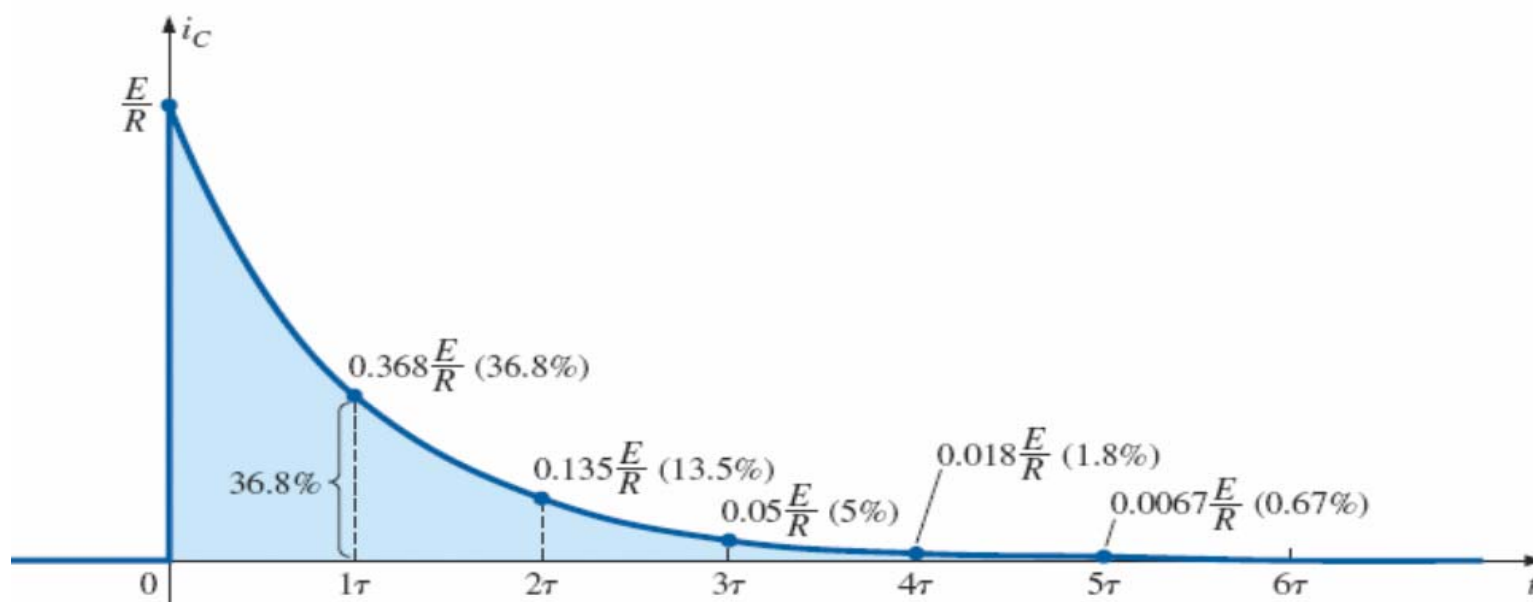
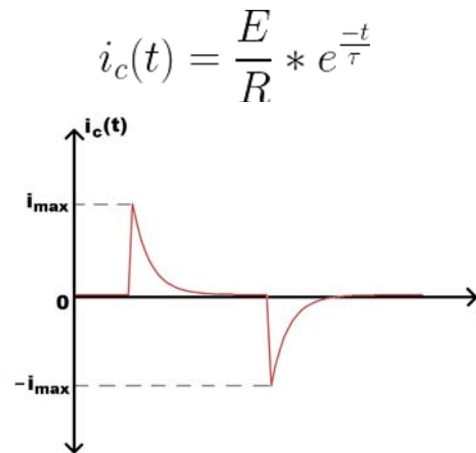
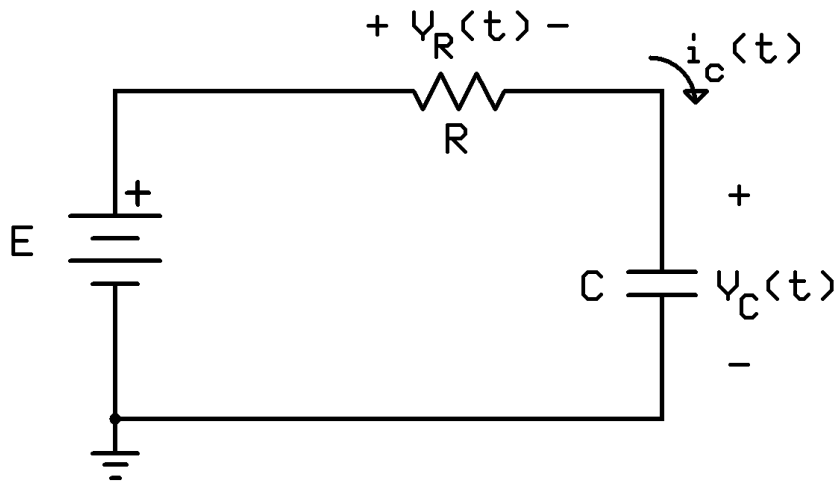


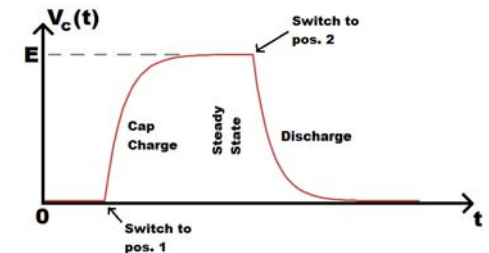
FIG. 10.30

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

Equations for the charge phase – $V_C(t)$



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

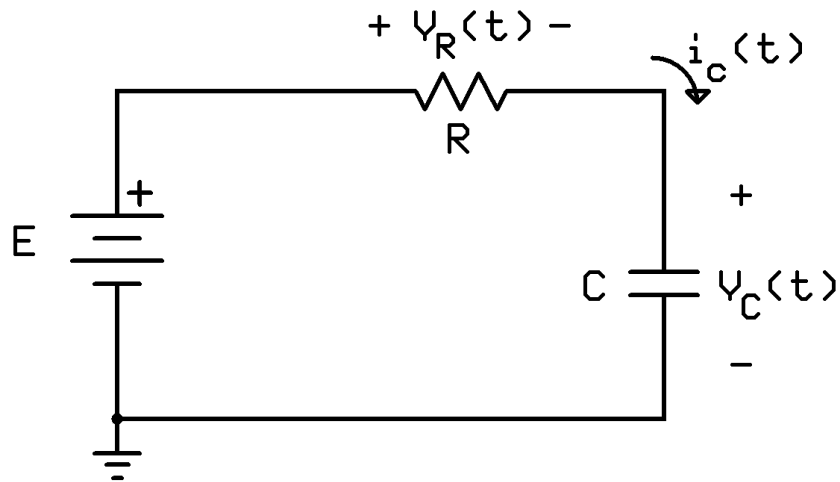


t	$V_C(t)$	Investigating $V_C(t) = E \left(1 - e^{\frac{-t}{\tau}} \right)$	
0	0	← Initial value	$\tau = RC$

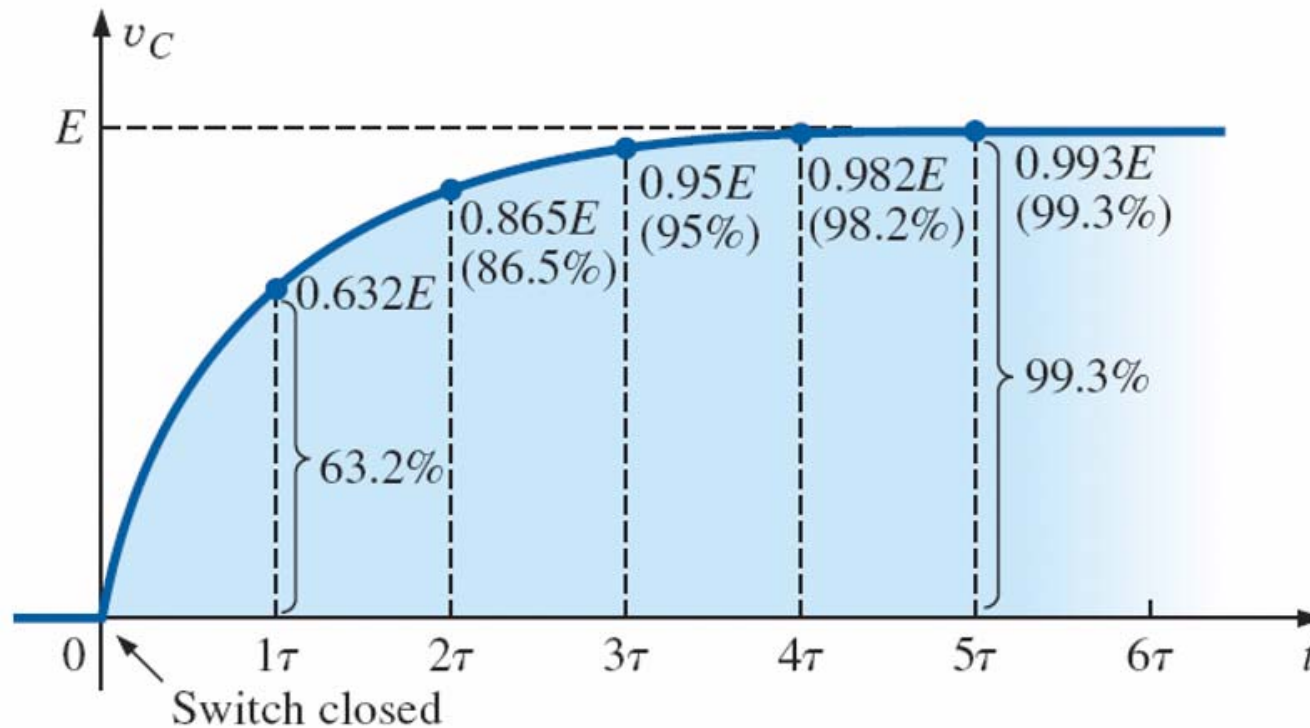
$RC = \tau$	$E(1 - e^{-1})$	$= E(0.632)$	63.2% of E
$2RC = 2\tau$	$E(1 - e^{-2})$	$= E(0.865)$	86.5% of E
$3RC = 3\tau$	$E(1 - e^{-3})$	$= E(0.950)$	95% of E
$4RC = 4\tau$	$E(1 - e^{-4})$	$= E(0.982)$	98.2 of E
$5RC = 5\tau$	$E(1 - e^{-5})$	$= E(0.993)$	99.3% of E

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

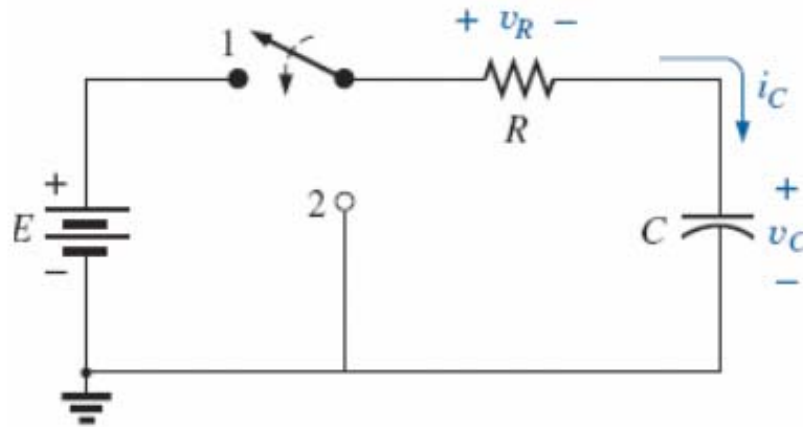
Recall - Equations for the charge phase:



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



In Class Problem



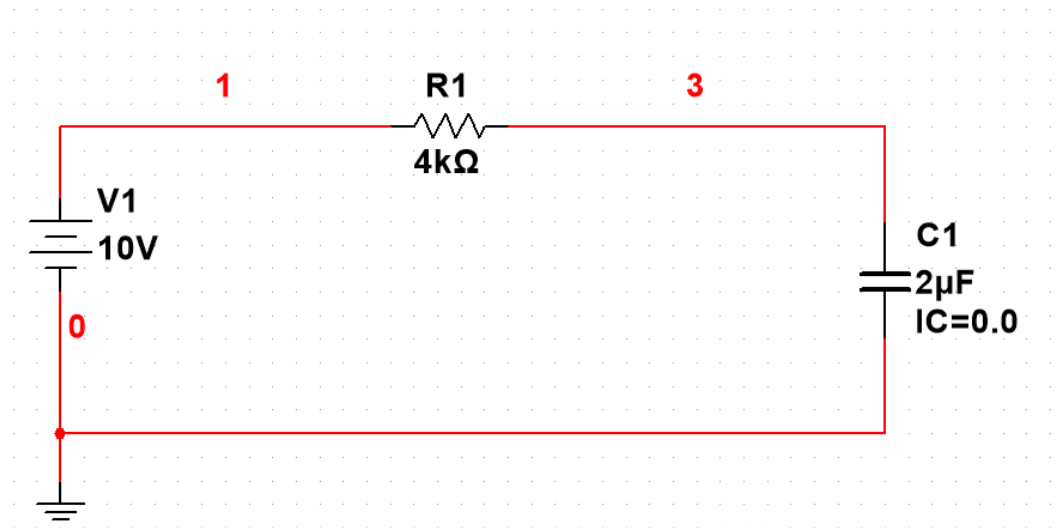
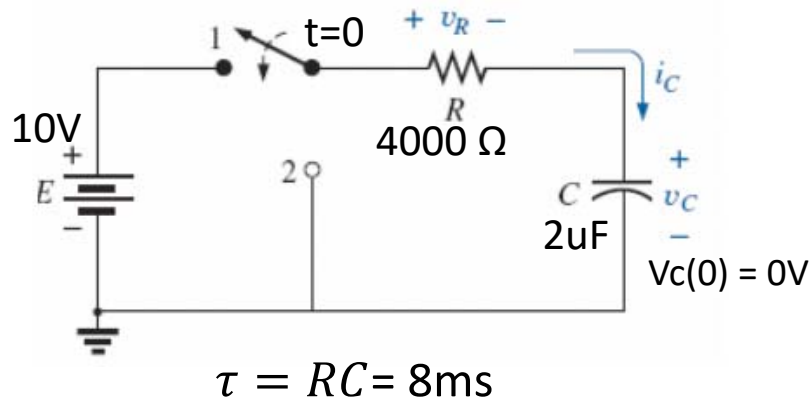
Given:

- There is no initial voltage on the capacitor, $V_C(0) = 0V$
- $E = 10V$, $R = 4000 \text{ Ohms}$, $C = 2\mu F$
- The switch is moved to position 1 at $t=0$

Find:

- $i_C(t)$ and sketch
- $V_C(t)$ and sketch
- $V_R(t)$ and sketch
- $V_C(t)$ at $10ms$
- $i_C(t)$ at $10ms$

Multisim - Demo



Analyses and Simulation

Active Analysis:

- Interactive Simulation
- DC Operating Point
- AC Sweep
- Transient**
- DC Sweep
- Single Frequency AC
- Parameter Sweep
- Noise
- Monte Carlo
- Fourier
- Temperature Sweep
- Distortion
- Sensitivity
- Worst Case

Transient

Analysis parameters | Output | Analysis options | Summary

Initial conditions: User-defined

Start time (TSTART): 0 s

End time (TSTOP): 0.04 s

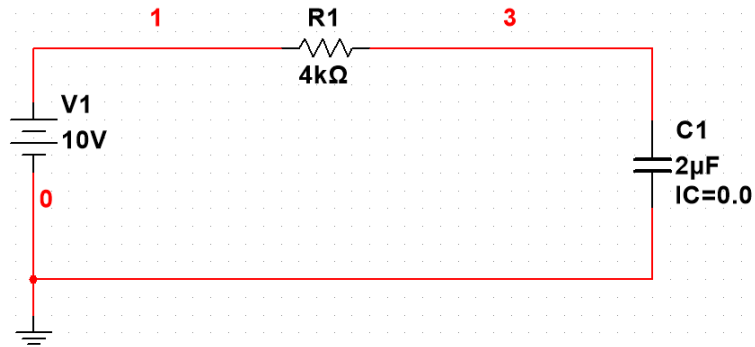
☐ Maximum time step (TMAX): Determine automatically s

Setting a small TMAX value will improve accuracy, however the simulation time will increase.

☐ Initial time step (TSTEP): Determine automatically s

Set to 5τ to view the entire transient period

Multisim - Demo



Analyses and Simulation

Active Analysis:

Interactive Simulation

DC Operating Point

AC Sweep

Transient

DC Sweep

Single Frequency AC

Parameter Sweep

Noise

Monte Carlo

Fourier

Temperature Sweep

Distortion

Sensitivity

Worst Case

Noise Figure

Pole Zero

Transfer Function

Trace Width

Batched

User-Defined

Transient

Analysis parameters

Output

Analysis options

Summary

Variables in circuit:

All variables

I(R1)

I(V1)

P(C1)

P(R1)

P(V1)

V(1)

V(3)

>

Add

>

<

Remove

<

Edit expression...

Add expression...

Filter unselected variables...

More options

Add device/model parameter...

☒ Show all device parameters in the audit trail

Delete selected variable

Select variables to plot

Selected variables for analysis:

All variables

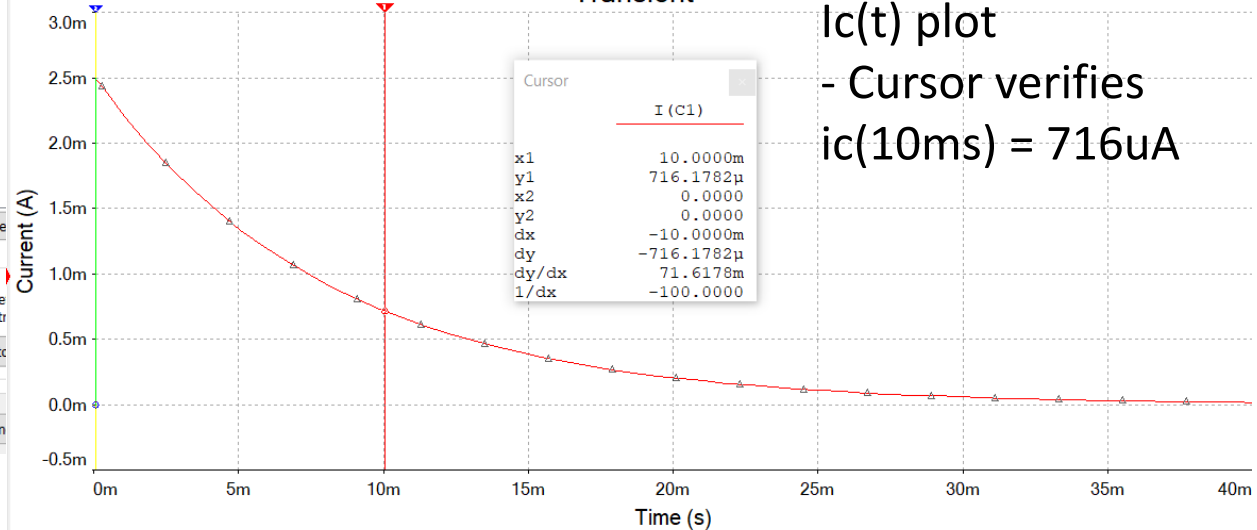
I(C1)

Grapher View

File Edit View Graph Trace Cursor Legend Tools Help

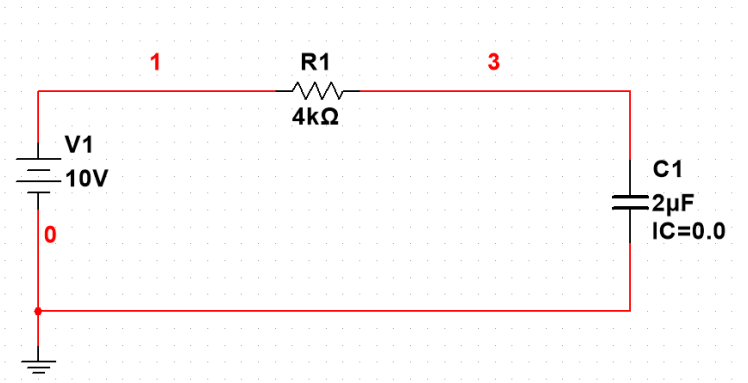
Transient

CapCharge
Transient



Ic(t) plot
- Cursor verifies
ic(10ms) = 716uA

Multisim - Demo



Analyses and Simulation

Active Analysis:

- Interactive Simulation
- DC Operating Point
- AC Sweep
- Transient**
- DC Sweep
- Single Frequency AC
- Parameter Sweep
- Noise
- Monte Carlo
- Fourier

Transient

Analysis parameters

Variables in circuit:

All variables

I(C1)
I(R1)
I(V1)
P(C1)
P(R1)
P(V1)
V(1)

Add

Remove

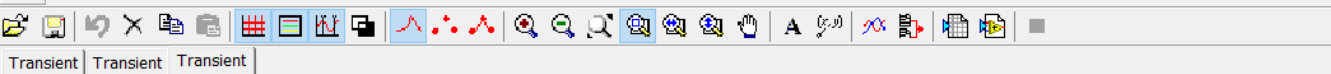
Selected variables for analysis:

All variables

V(3)

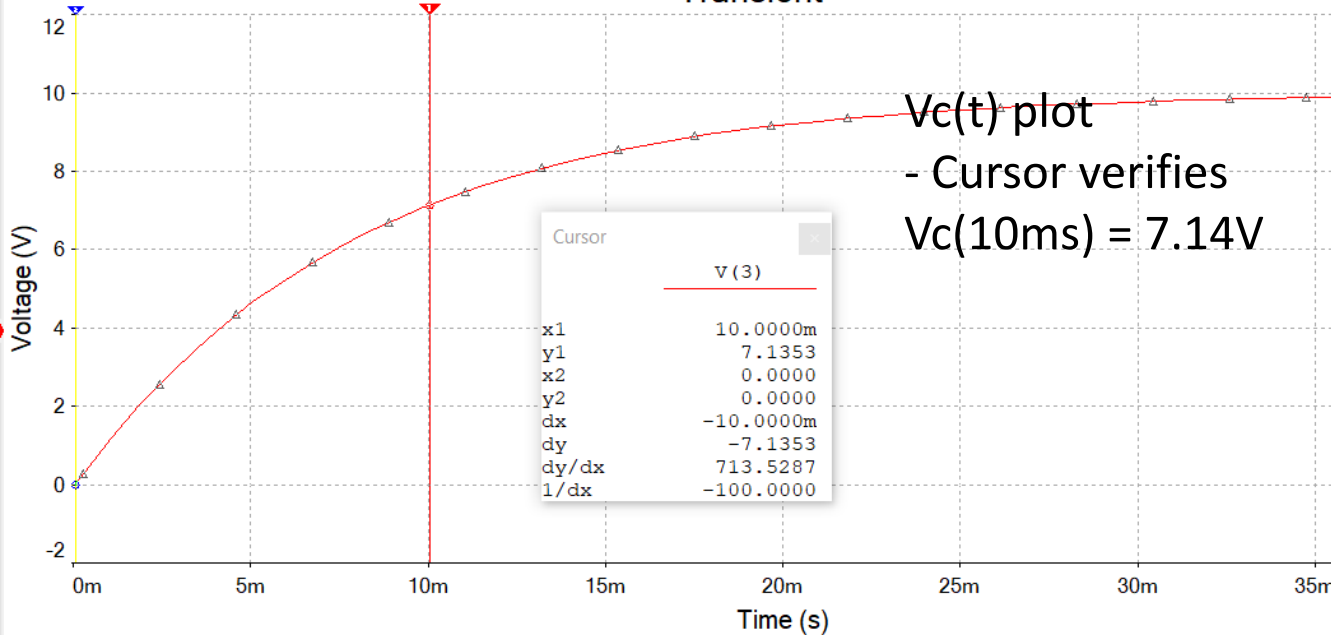
Grapher View

File Edit View Graph Trace Cursor Legend Tools Help



Transient Transient Transient

CapCharge Transient



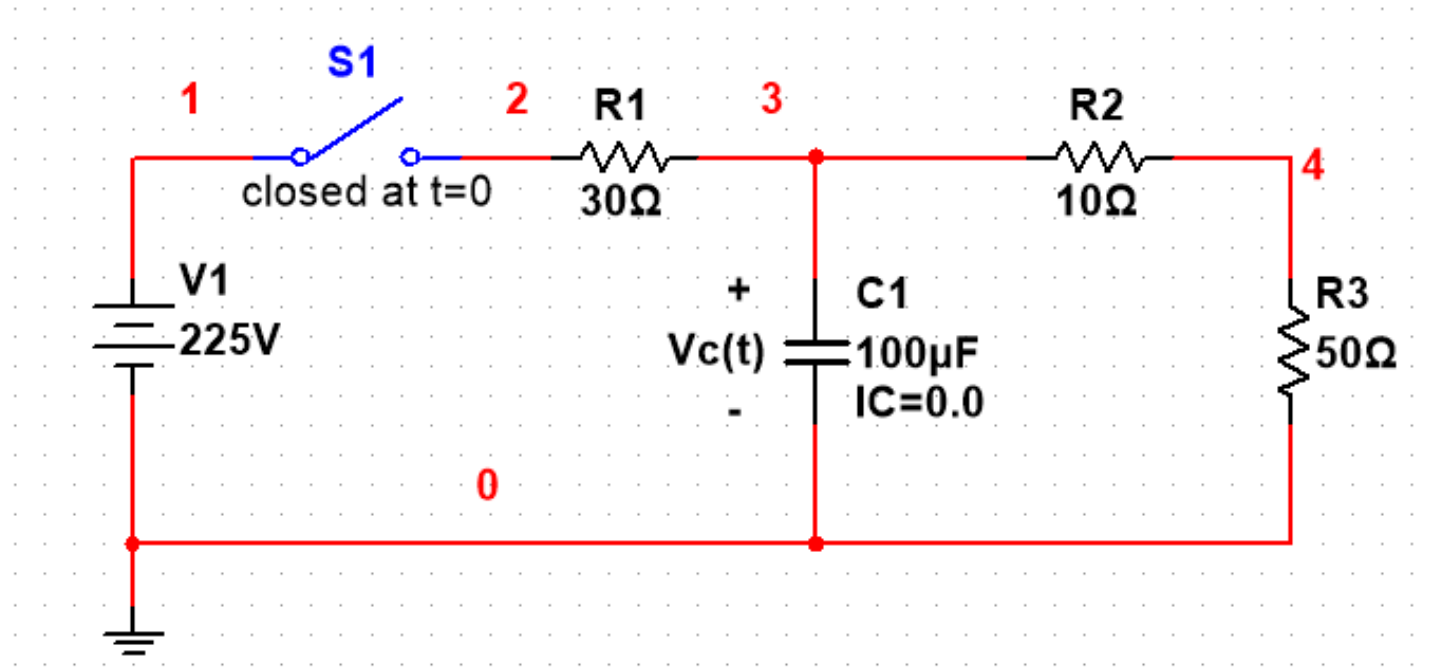
Vc(t) plot

- Cursor verifies

Vc(10ms) = 7.14V

V(3)

Example – Multiple Resistors

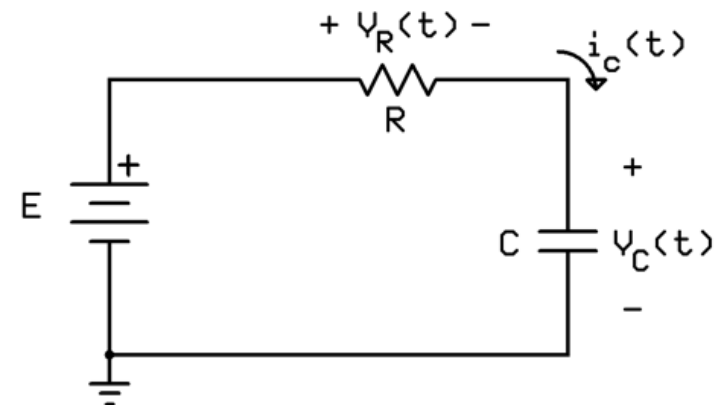


Find:

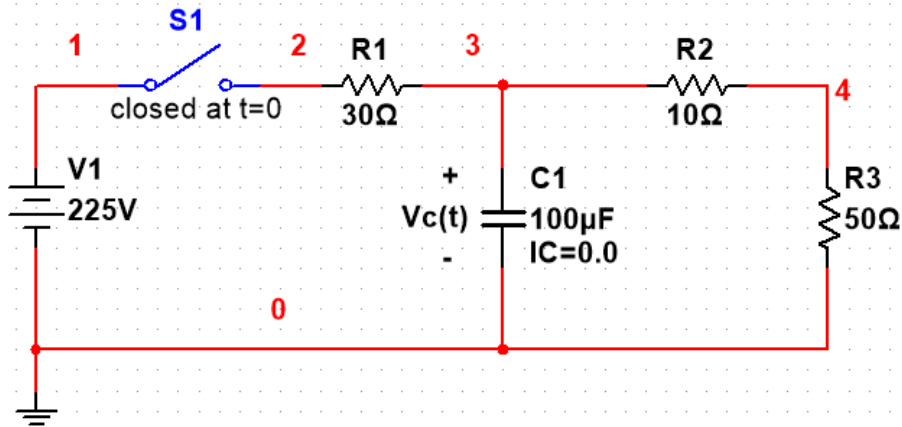
- $V_C(t)$ and sketch for $t > 0$ seconds
- Estimate t for $V_C(t) = 100V$

Approach??

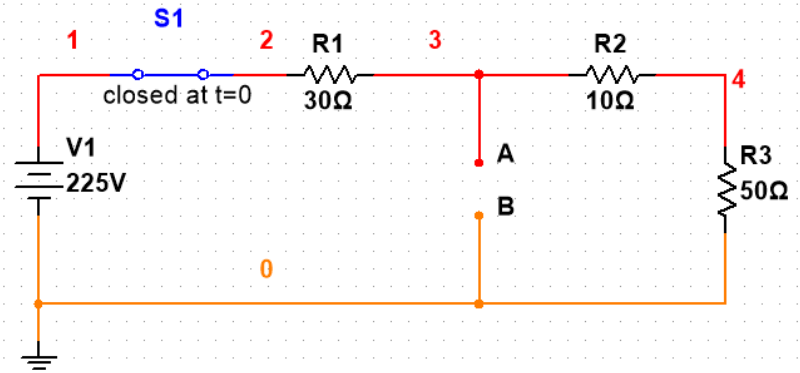
Hint – Can we handle THIS circuit?



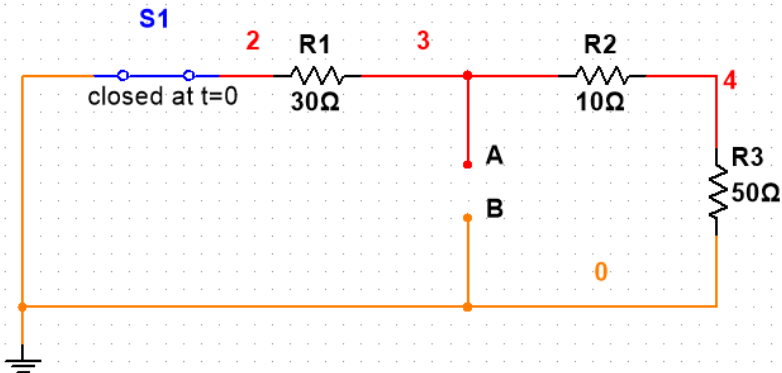
Example – Multiple Resistors



V_{TH}



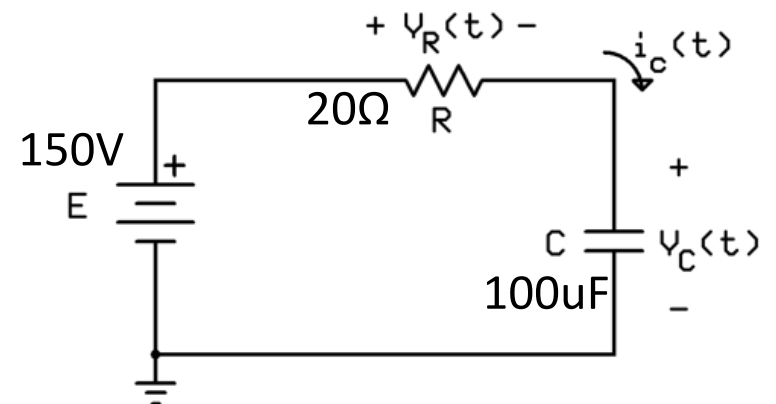
R_{TH}



V_{TH}

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

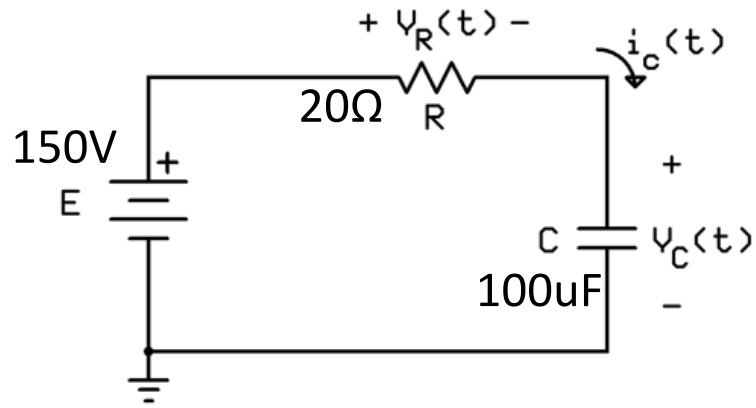
Analyze the Thevenin Equivalent Circuit:



R_{TH}

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

Example – Multiple Resistors

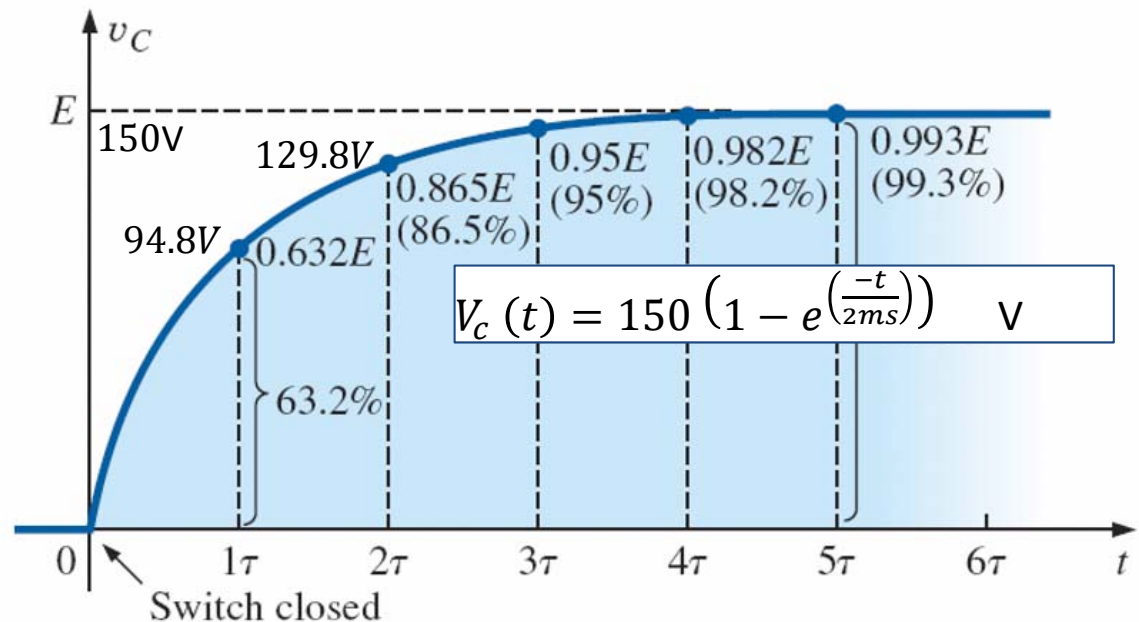


$$V_C(t) = E \left(1 - e^{\frac{-t}{\tau}} \right)$$

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

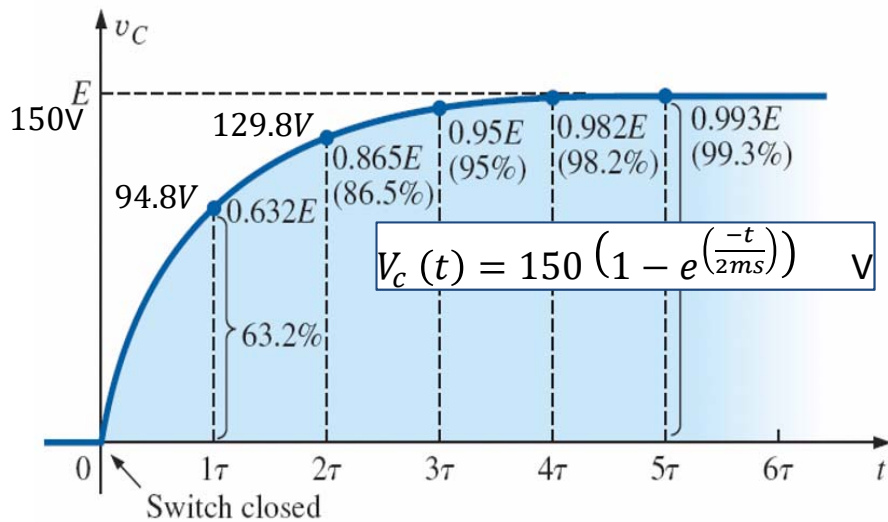
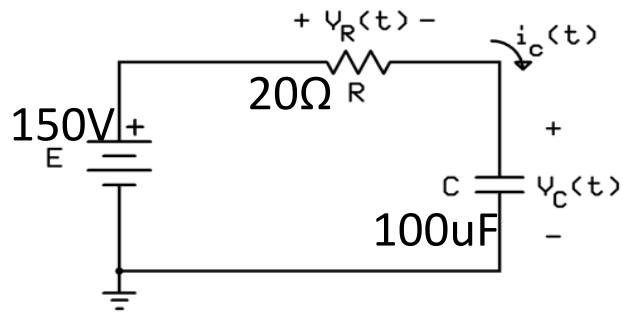
Estimate t for $V_C(t) = 100\text{V}$

From the plot: Just over 1 time constant
or $\sim 2.1\text{ms}$



Example – Multiple Resistors

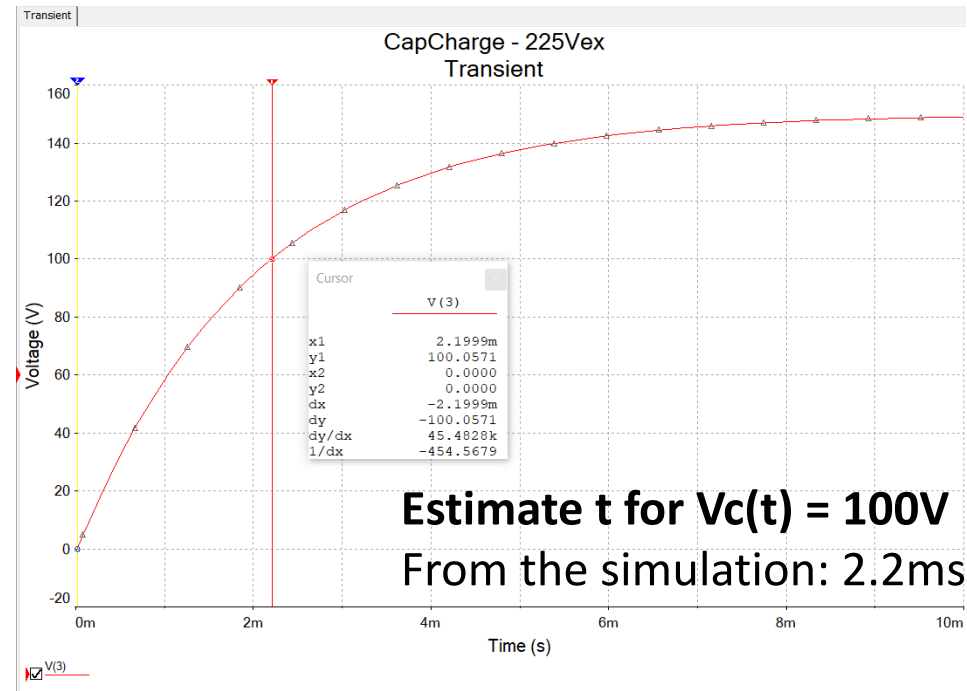
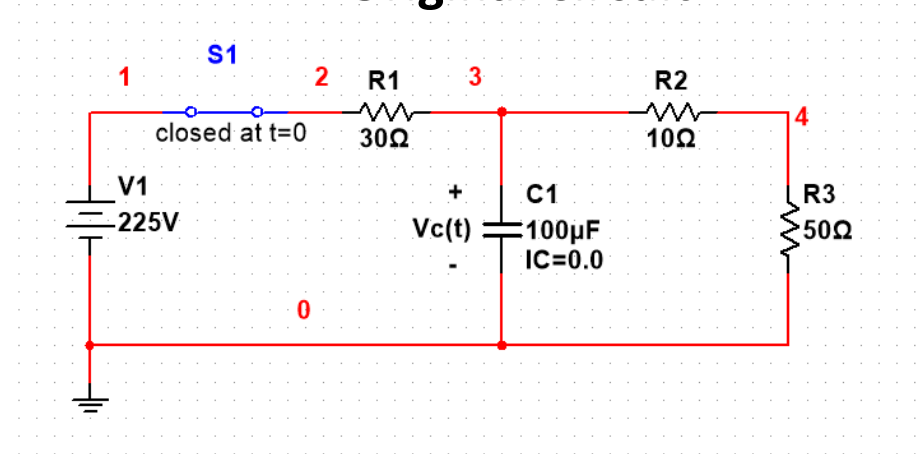
Thevenin Eq



Estimate t for $V_C(t) = 100\text{V}$

From the plot: Just over 1 time constant
or $\sim 2.1\text{ms}$

Original Circuit



Estimate t for $V_C(t) = 100\text{V}$

From the simulation: 2.2ms