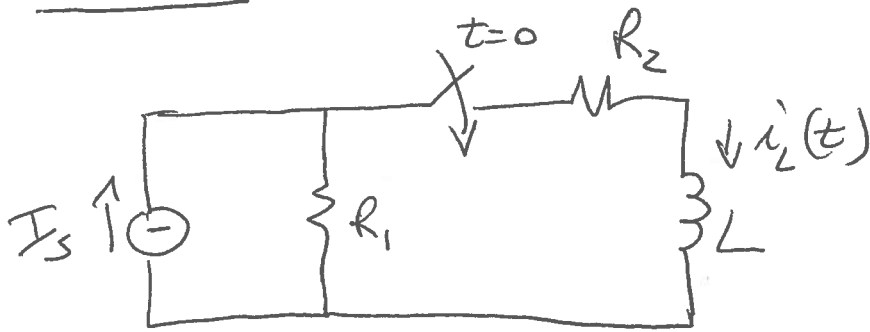


$$i_0 = \frac{R_N}{R_2 + R_N} I_N = \frac{6}{5} \text{ mA}$$

ES 22



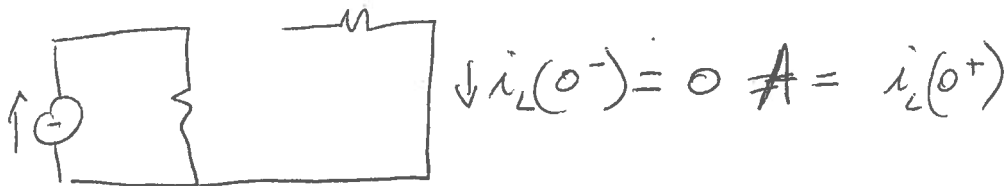
$$I_S = 6 \text{ A}$$

$$R_1 = 2 \Omega$$

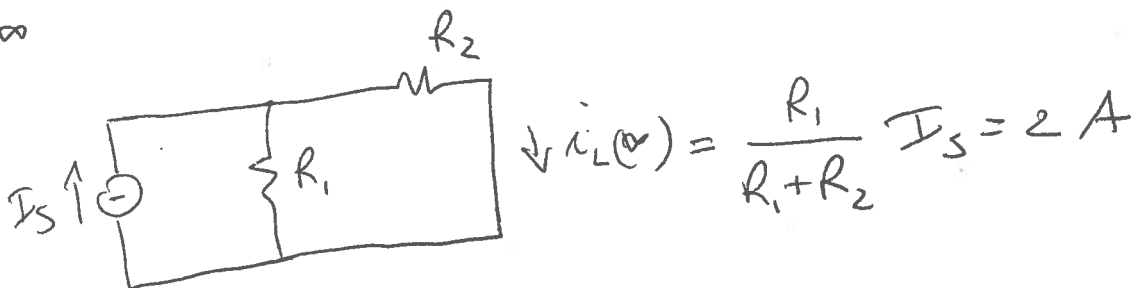
$$R_2 = 4 \Omega$$

$$L = 3 \text{ H}$$

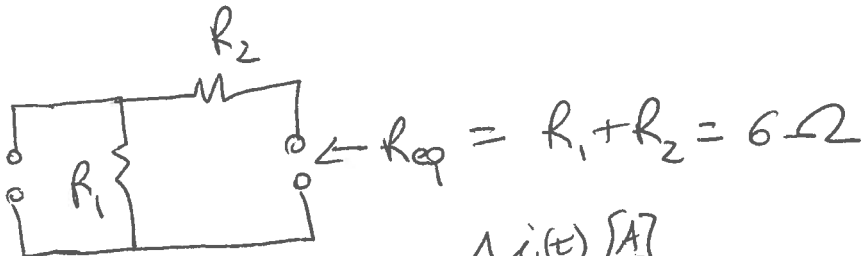
$t < 0$



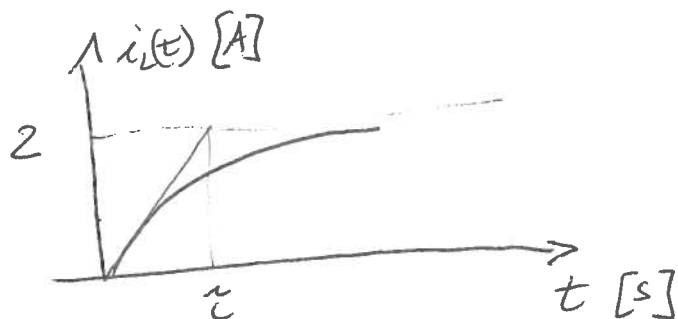
$t = \infty$



R_{eq}

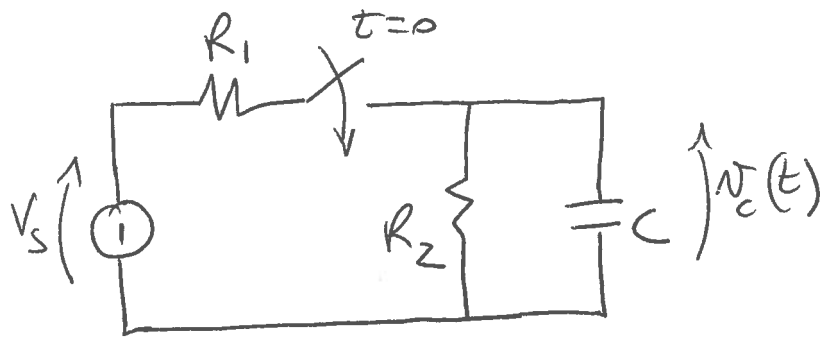


$$\tau = \frac{L}{R_{eq}} = \frac{1}{2} \text{ s}$$



$$i_L(t) = [i_L(0) - i_L(\infty)] \exp\left(-\frac{t}{\tau}\right) + i_L(\infty)$$

ES 23



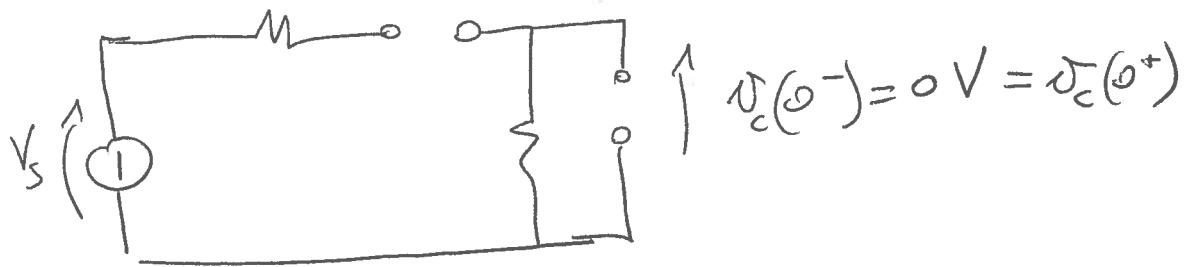
$$V_s = 12 \text{ V}$$

$$R_1 = 3 \Omega$$

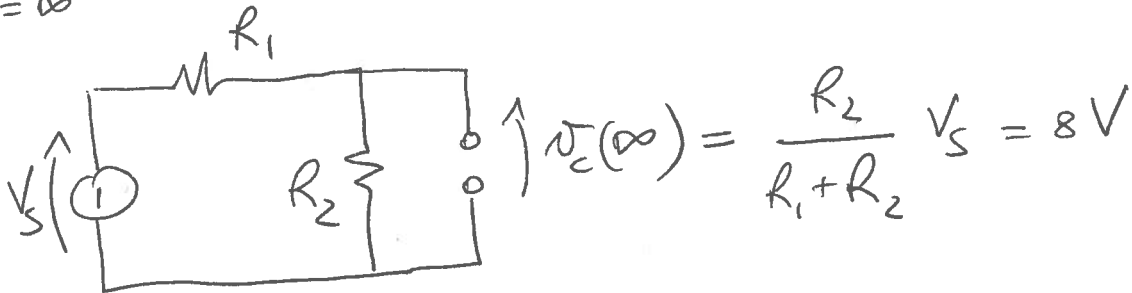
$$R_2 = 6 \Omega$$

$$C = \frac{1}{2} \text{ F}$$

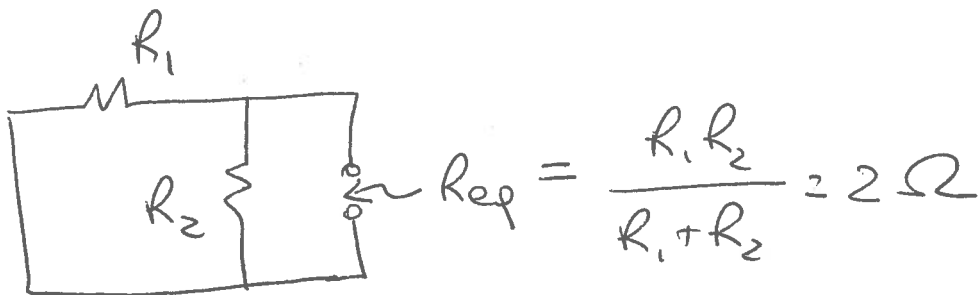
$t < 0$



$t = \infty$



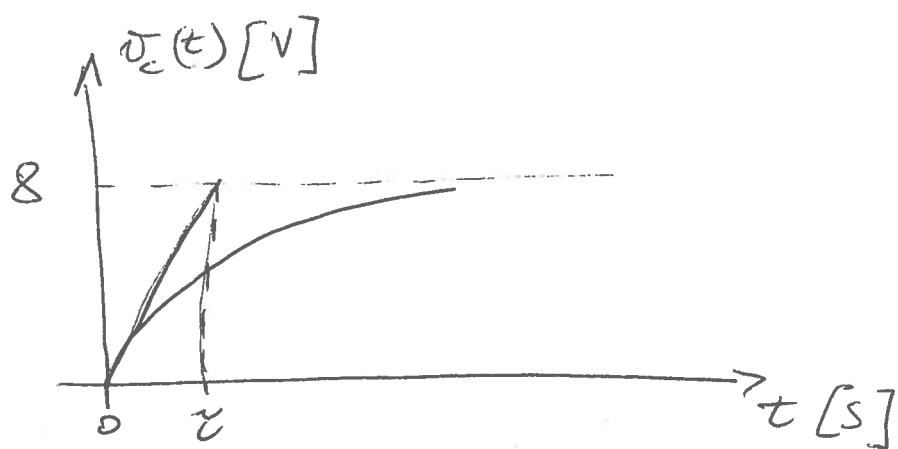
R_{eq}



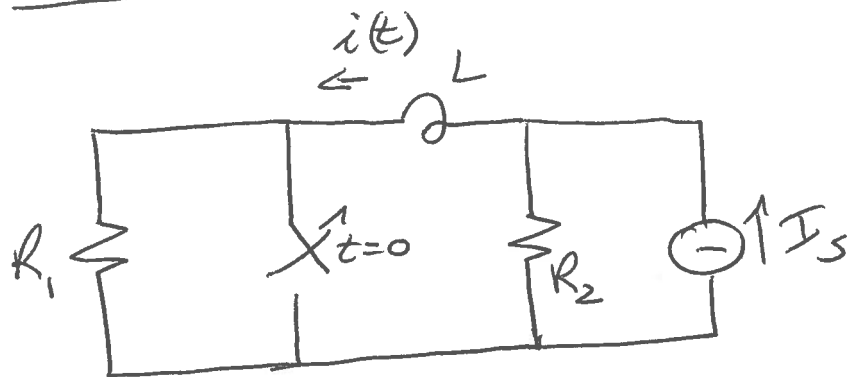
$$\tau = R_{eq} C = 1 \text{ s}$$

$$v_c(t) = [v_c(0) - v_c(\infty)] \exp\left(-\frac{t}{\tau}\right) + v_c(\infty)$$

$$= \frac{R_2}{R_1 + R_2} V_s \left(1 - \exp\left(-t \frac{R_1 + R_2}{R_1 R_2 C}\right)\right)$$

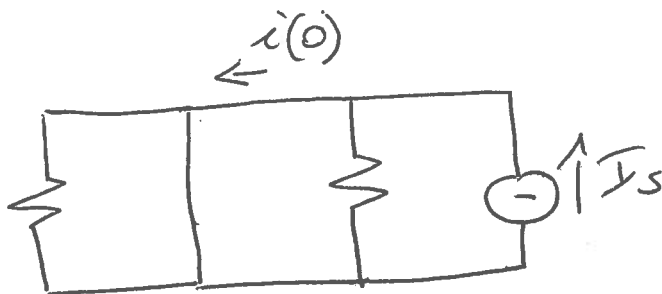


ES 24



$$\begin{aligned} I_s &= 3 \text{ A} \\ R_1 &= 5 \Omega \\ R_2 &= 10 \Omega \\ L &= 1,5 \text{ H} \end{aligned}$$

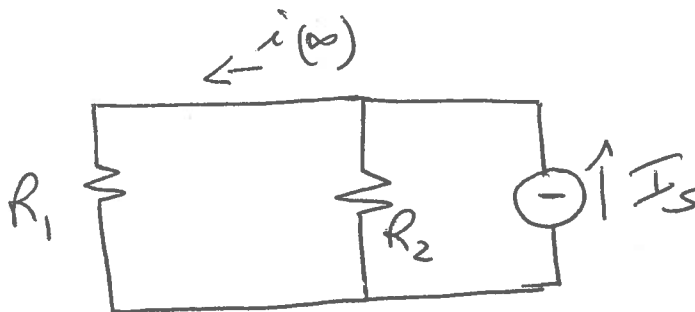
$t < 0$



$$i(0) = I_s = 3 \text{ A}$$

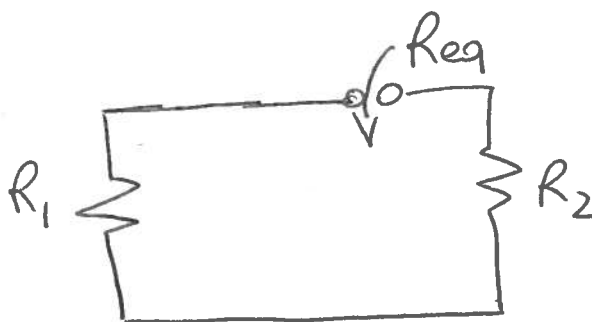
$$i(0^+) = i(0^-)$$

$t = \infty$



$$i(\infty) = I_s \frac{R_2}{R_1 + R_2} = 2 \text{ A}$$

τ

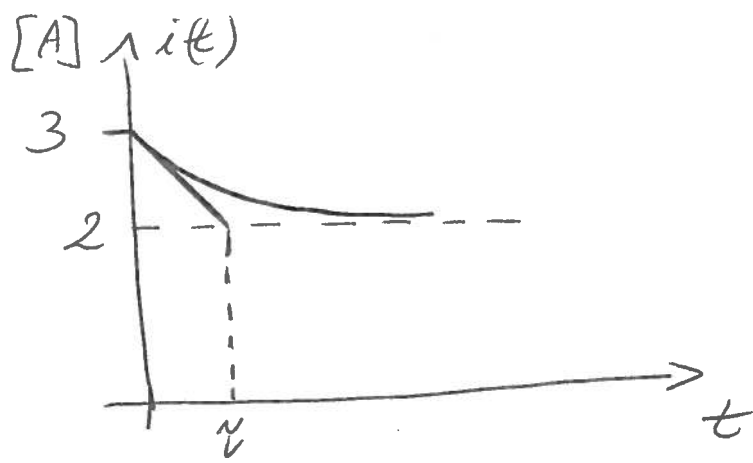


$$R_{eq} = R_1 + R_2 = 15 \Omega$$

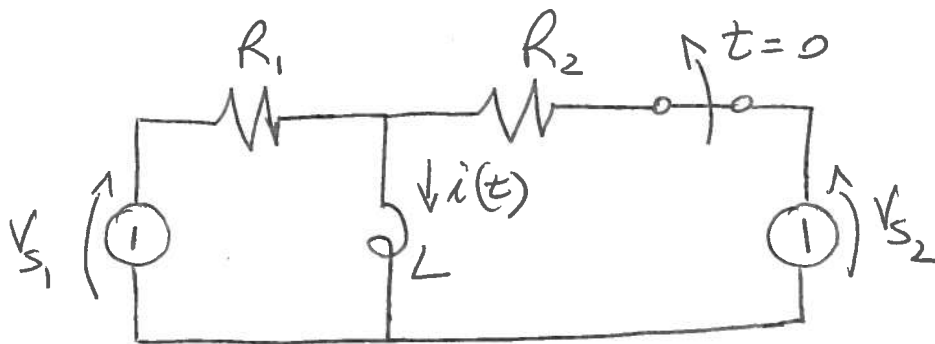
$$\tau = \frac{L}{R_{eq}} = 0,1 \text{ s}$$

$$i(t) = I_s \left[1 - \frac{R_2}{R_1 + R_2} \right] \exp\left(-\frac{(R_1 + R_2)t}{L}\right) + I_s \frac{R_2}{R_1 + R_2}$$

$$= \exp(-10t) + 2 \text{ A}$$



ES 25



$$V_{s1} = 20 \text{ V}$$

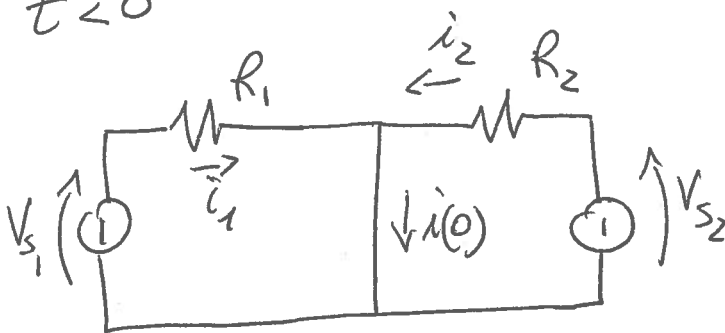
$$V_{s2} = 3 \text{ V}$$

$$R_1 = 4 \Omega$$

$$R_2 = 3 \Omega$$

$$L = 2 \text{ H}$$

$t < 0$



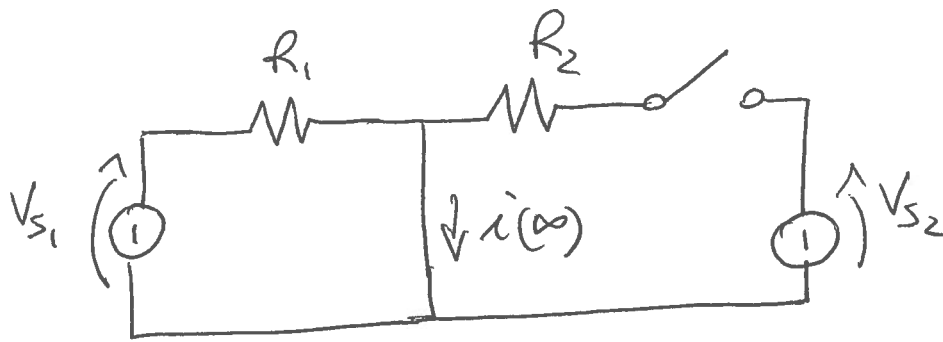
$$i(0) = i_1 + i_2$$

$$i_1 = \frac{V_{s1}}{R_1} \quad \bigg| \quad i_2 = \frac{V_{s2}}{R_2}$$

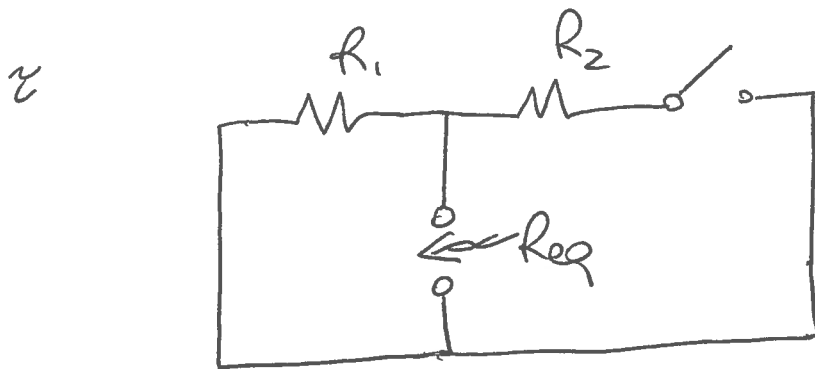
$$i(0) = \frac{V_{s1}}{R_1} + \frac{V_{s2}}{R_2} = 6 \text{ A}$$

$$i(0^+) = i(0^-)$$

$$t = \infty$$



$$i(\infty) = \frac{V_{s1}}{R_1} = 5 \text{ A}$$

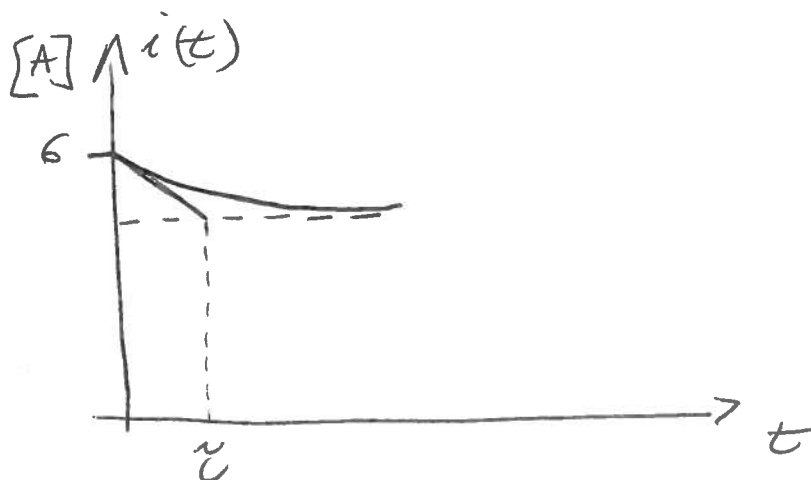


$$R_{eq} = R_1 = 4 \Omega$$

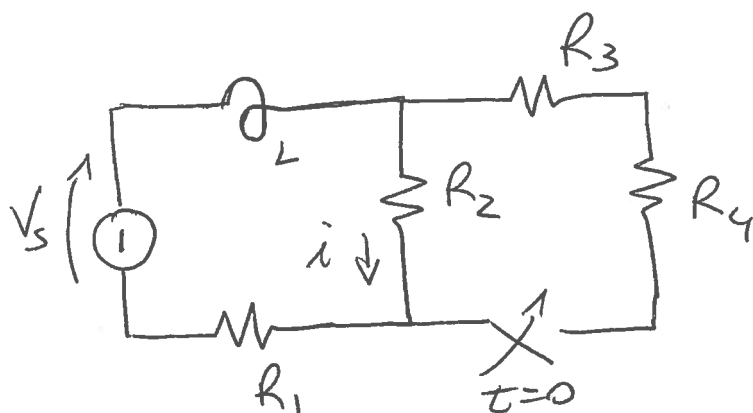
$$\tau = \frac{L}{R_{eq}} = \frac{L}{R_1} = 0,5 \text{ s}$$

$$i(t) = \frac{V_{s2}}{R_2} \exp\left(-\frac{R_1 t}{L}\right) + \frac{V_{s1}}{R_1}$$

$$= \exp(-2t) + 5 \text{ A}$$



ES 26



$$V_s = 10V$$

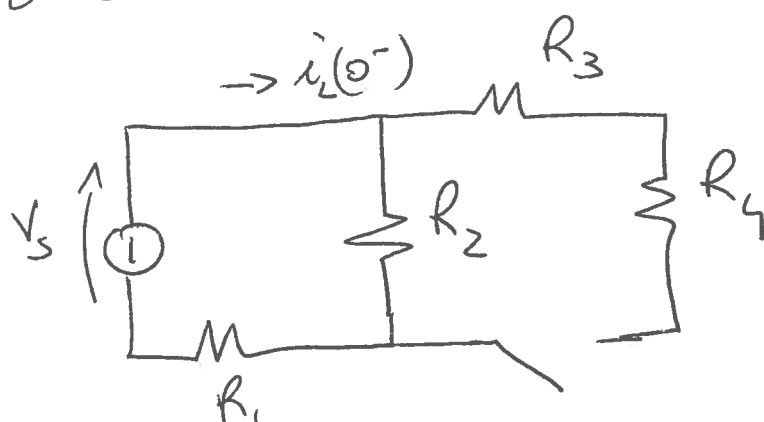
$$R_1 = R_4 = 3\Omega$$

$$R_2 = 1\Omega$$

$$R_3 = 2\Omega$$

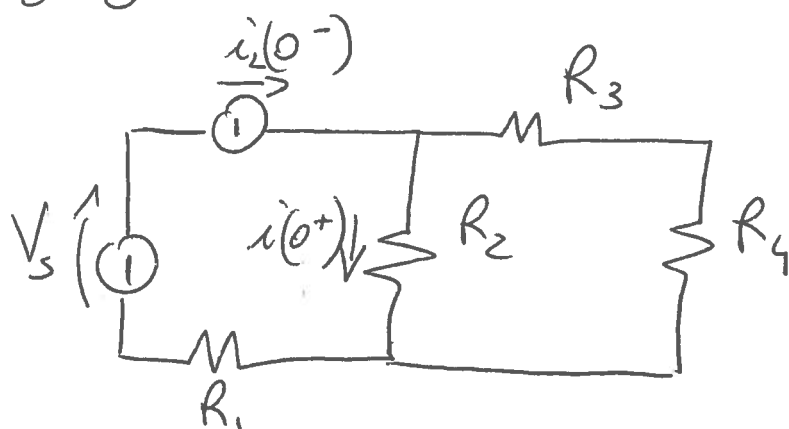
$$L = 1H$$

$t = 0^-$



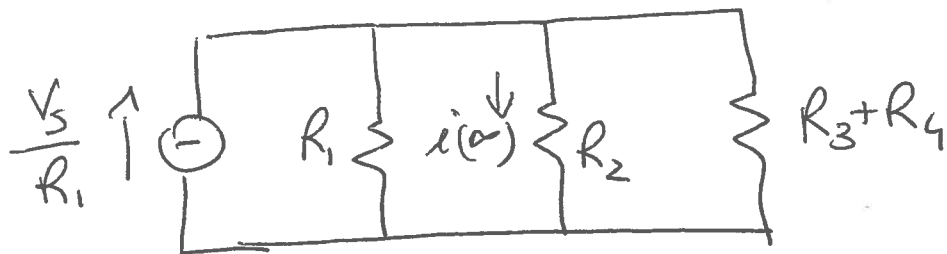
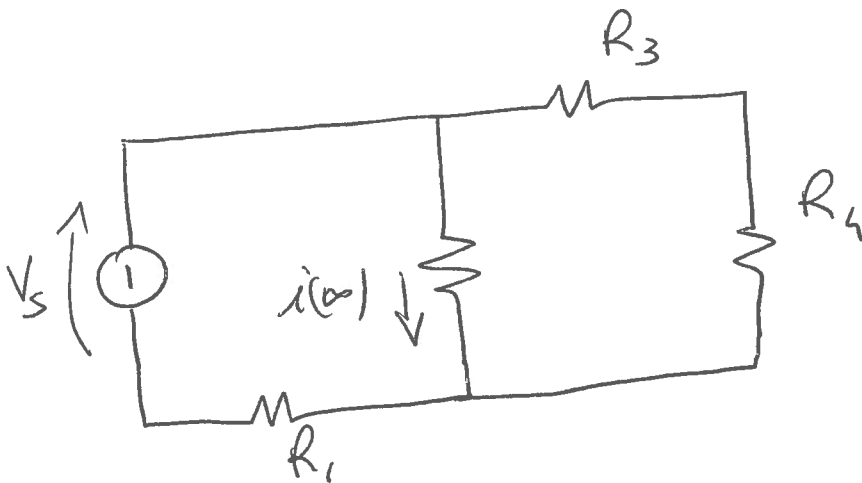
$$i_L(0^-) = i(0^-) = \frac{V_s}{R_1 + R_2} = 2,5A$$

$t = 0^+$



$$i(0^+) = i_L(0^-) \frac{R_3 + R_4}{R_2 + R_3 + R_4} = V_s \frac{R_3 + R_4}{R_1 + R_2} \frac{1}{R_2 + R_3 + R_4} = 2,08A$$

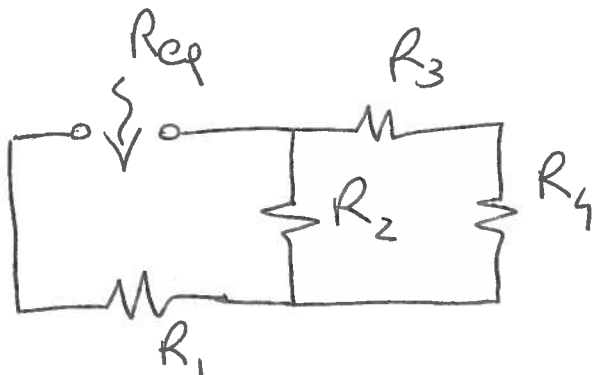
$$t = \infty$$



$$i(\infty) = \frac{V_s}{R_1} \frac{\frac{1}{R_2}}{\frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3 + R_4}} = \frac{V_s (R_3 + R_4)}{(R_1 + R_2)(R_3 + R_4) + R_1 R_2}$$

$$= 2,17 \text{ A}$$

τ



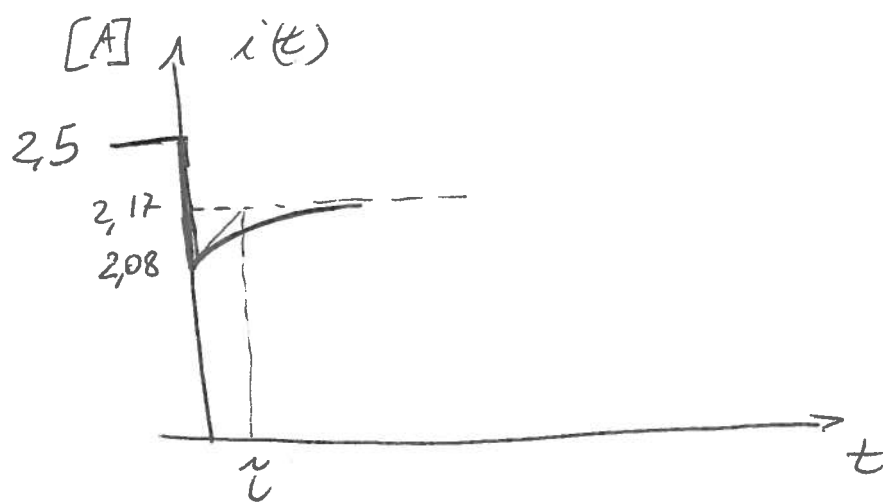
$$R_{eq} = R_1 + \frac{R_2 (R_3 + R_4)}{R_2 + R_3 + R_4}$$

$$= 3,83 \Omega$$

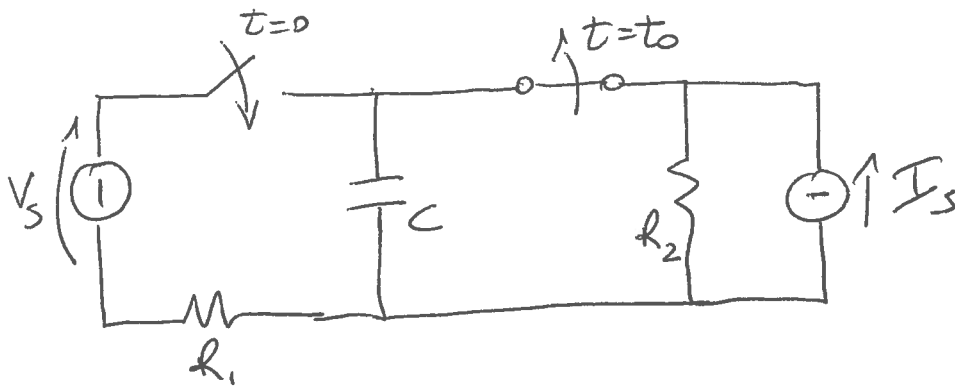
$$\tau = \frac{L}{R_{eq}} = 0,26 \text{ s}$$

$$i(t) = [i(0^+) - i(\infty)] \exp\left(-\frac{t}{\tau}\right) + i(\infty)$$

$$= -0,09 \exp\left(-\frac{t}{0,26}\right) + 2,17 \text{ A}$$



ES 27



$$\begin{aligned} V_s &= 120 \text{ V} \\ I_s &= 30 \text{ A} \\ R_1 &= 5 \Omega \\ R_2 &= 10 \Omega \\ C &= 12 \mu\text{F} \\ t_0 &= 50 \mu\text{s} \end{aligned}$$

1° transitorio

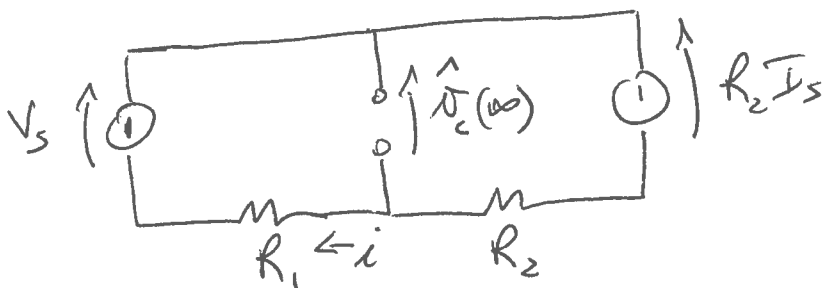
$t=0^-$



$$i_C(0^-) = 0$$

$$\begin{aligned} V_d(0^-) &= V_c(0^+) = R_2 I_s \\ &= 300 \text{ V} \end{aligned}$$

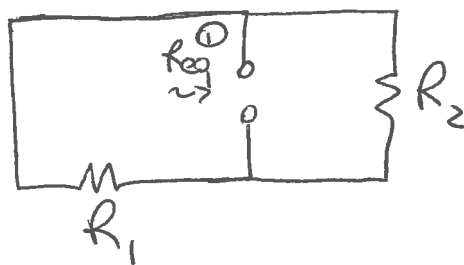
$t = \infty$ (come se il secondo transitorio non ci fosse)



$$i = \frac{V_s - R_2 I_s}{R_1 + R_2}$$

$$\begin{aligned} \hat{V}_c(\infty) &= V_s - R_1 i = V_s - R_1 \frac{V_s - R_2 I_s}{R_1 + R_2} = \frac{V_s R_2 - R_1 R_2 I_s}{R_1 + R_2} \\ &= 180 \text{ V} \end{aligned}$$

$$\tau_1 = R_{eq}^{(1)} C$$

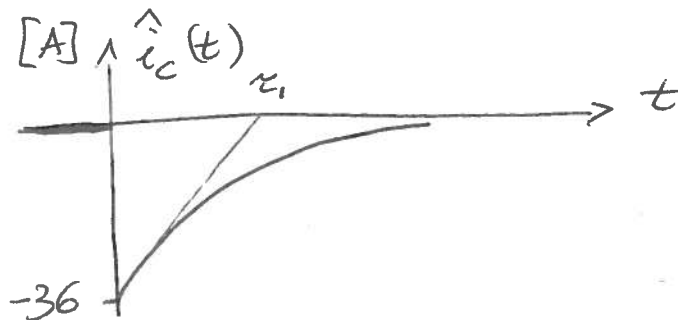


$$R_{eq}^{(1)} = \frac{R_1 R_2}{R_1 + R_2}$$

$$\tau_1 = R_{eq}^{(1)} C = \frac{R_1 R_2 C}{R_1 + R_2} = 40 \mu s$$

$$\begin{aligned} \hat{v}_c(t) &= [\hat{v}_c(0) - \hat{v}_c(\infty)] \exp\left(-\frac{t}{\tau_1}\right) + \hat{v}_c(\infty) \\ &= 120 \exp\left(-\frac{t(R_1 + R_2)}{R_1 R_2 C}\right) + 180 \text{ V} \end{aligned}$$

$$\hat{i}_c(t) = C \frac{d\hat{v}_c}{dt} = -36 \exp\left(-\frac{t}{\tau_1}\right) \text{ A}$$



2° transitorio

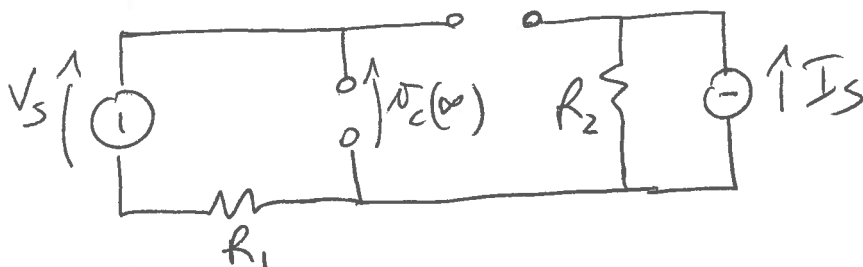
$$t_0 = 50 \mu s$$

$$v_c(t_0^-) = \hat{v}_c(t_0^-) = 120 \exp\left(-\frac{5}{4}\right) + 120 = 214,38 \text{ V}$$

$$i_c(t_0^-) = \hat{i}_c(t_0^-) = -36 \exp\left(-\frac{5}{4}\right) = -19,31 \text{ A}$$

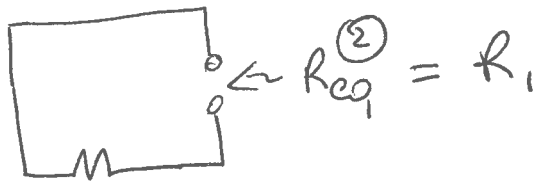
$$v_c(t_0^+) = v_c(t_0^-) = 214,38 \text{ V}$$

$$t = +\infty$$



$$v_c(\infty) = V_s = 120 \text{ V}$$

$$\tau_2$$

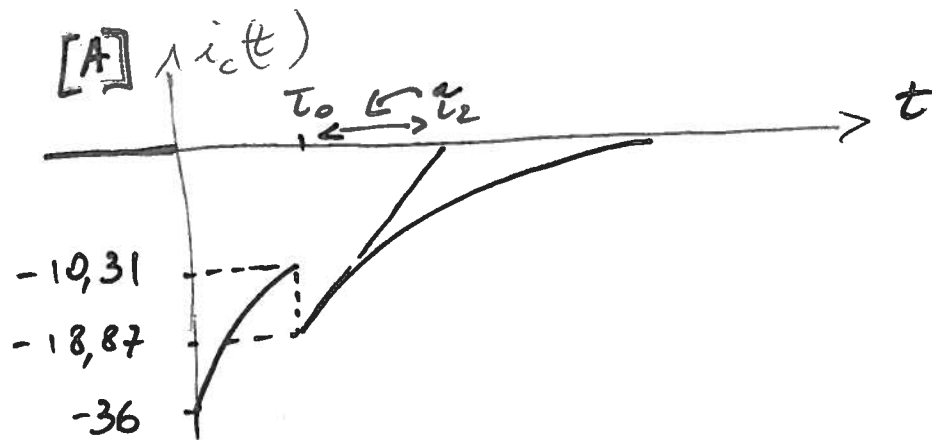


$$\tau_2 = R_1 C = 60 \mu s$$

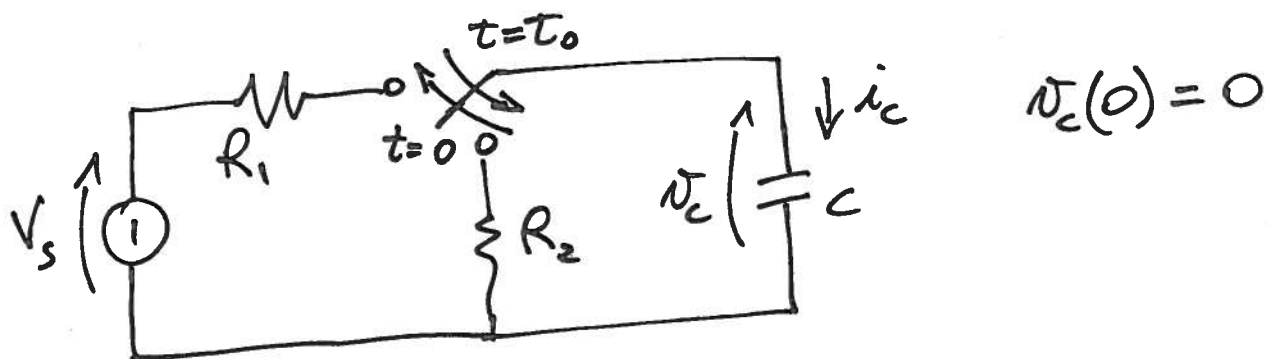
$$\begin{aligned} v_c(t) &= (214,38 - 120) \exp\left(-\frac{t-t_0}{\tau_2}\right) + 120 \text{ V} \\ &= 94,38 \exp\left(-\frac{t-t_0}{\tau_2}\right) + 120 \text{ V} \end{aligned}$$

$$i_c(t) = C \frac{dv_c}{dt} = -18,876 \exp\left(-\frac{t-t_0}{\tau_2}\right) \text{ A}$$

$$i_c(t_0^+) = -18,876 \text{ A}$$



ES 28 (FLASH FOTOGRAFICO)

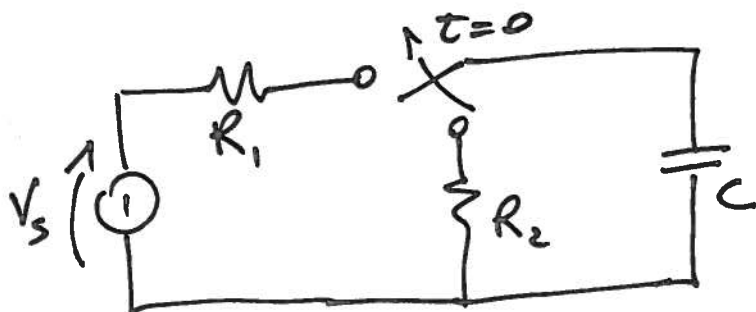


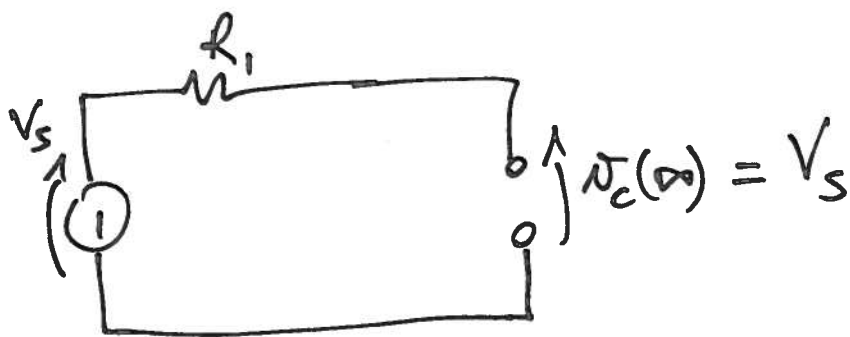
V_s - Tensione elevata

R_1 - resistore di resistenza elevata (\Rightarrow limitatore di corrente nella fase di carica)

R_2 - lampada del flash, resistenza piccola

1) fase di carica $0 < t < t_0 \ll 5 \tau_1$





$\tau_1 = R_1 C$, elevate

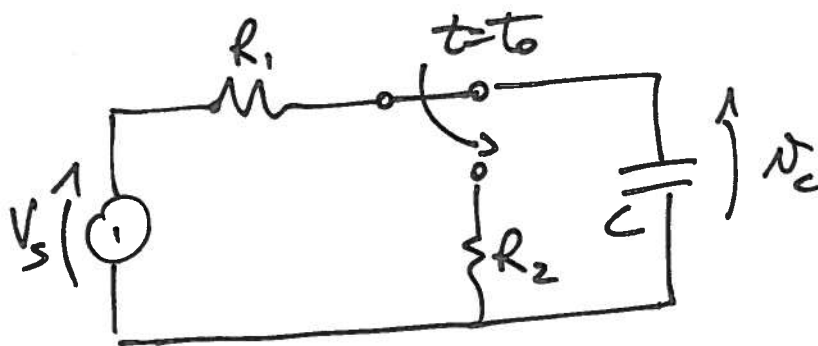
$$v_c(t) = [v_c(0) - v_c(\infty)] \exp\left(-\frac{t}{\tau_1}\right) + v_c(\infty)$$

$$= V_s \left[1 - \exp\left(-\frac{t}{\tau_1}\right)\right]$$

$$i_c(t) = C \frac{dv_c}{dt} = \frac{V_s C}{R_1 C} \exp\left(-\frac{t}{\tau_1}\right)$$

$$= \frac{V_s}{R_1} \exp\left(-\frac{t}{\tau_1}\right)$$

2) fase di scarica



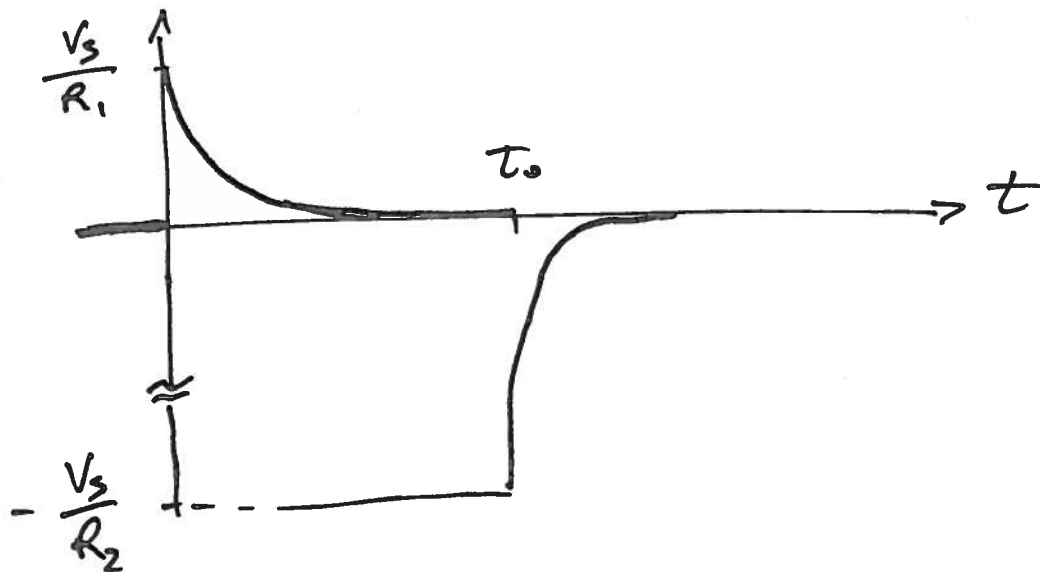
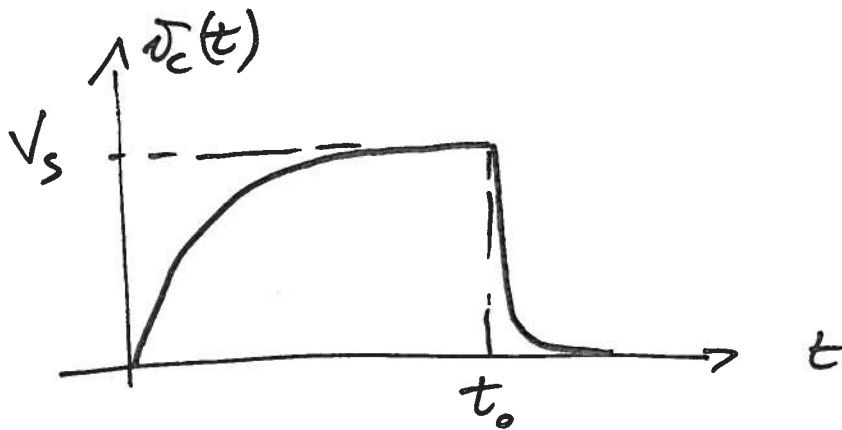
$$t = t_0 \quad v_c(t_0) = V_s \quad (t_0 \gg 5\tau_1)$$

$$v_c(\infty) = 0$$

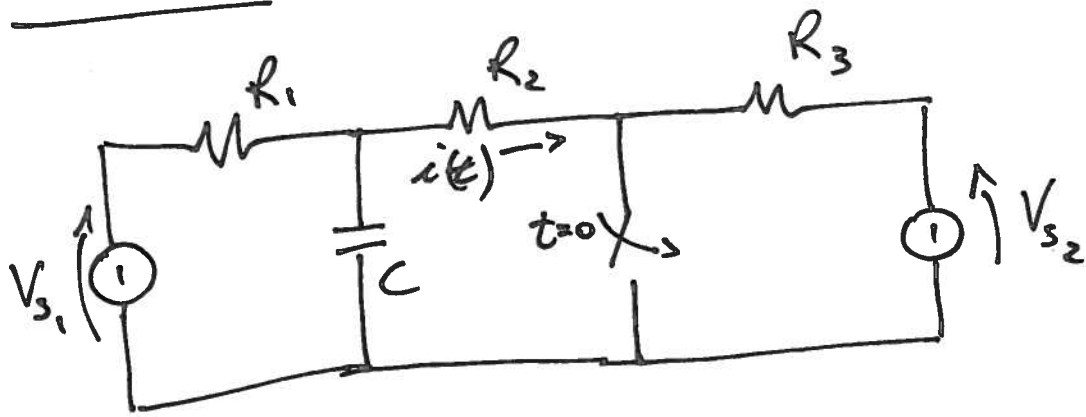
$\tau_2 = R_2 C$, piccola

$$\begin{aligned}
 v_c(t) &= [v_c(t_0) - v_c(\infty)] \exp\left(-\frac{t-t_0}{\tau_2}\right) + v_c(\infty) \\
 &= V_s \exp\left(-\frac{t-t_0}{\tau_2}\right)
 \end{aligned}$$

$$\begin{aligned}
 i_c(t) &= C \frac{dv_c}{dt} = -\frac{V_s C}{R_2 C} \exp\left(-\frac{t-t_0}{\tau_2}\right) \\
 &= -\frac{V_s}{R_2} \exp\left(-\frac{t-t_0}{\tau_2}\right)
 \end{aligned}$$

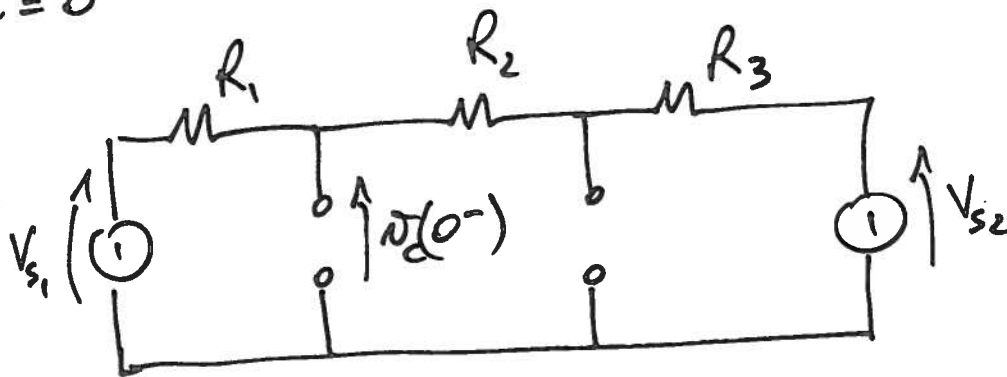


ES 29



$$\begin{aligned} V_{s1} &= 36 \text{ V} \\ V_{s2} &= 12 \text{ V} \\ R_1 &= 2 \text{ k}\Omega \\ R_2 &= 6 \text{ k}\Omega \\ R_3 &= 4 \text{ k}\Omega \\ C &= 100 \mu\text{F} \end{aligned}$$

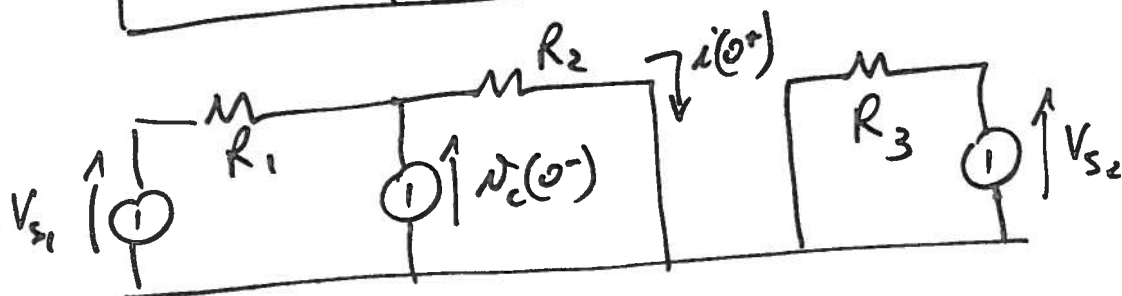
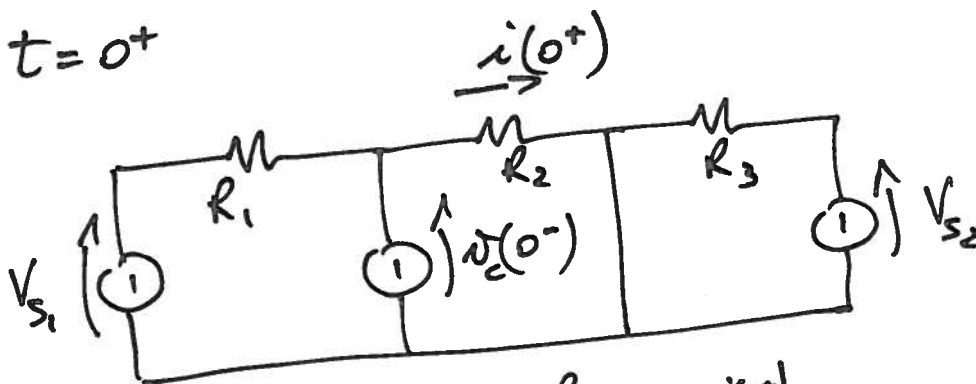
$t = 0^-$



$$i(0^-) = \frac{V_{s1} - V_{s2}}{R_1 + R_2 + R_3} = 2 \text{ mA}$$

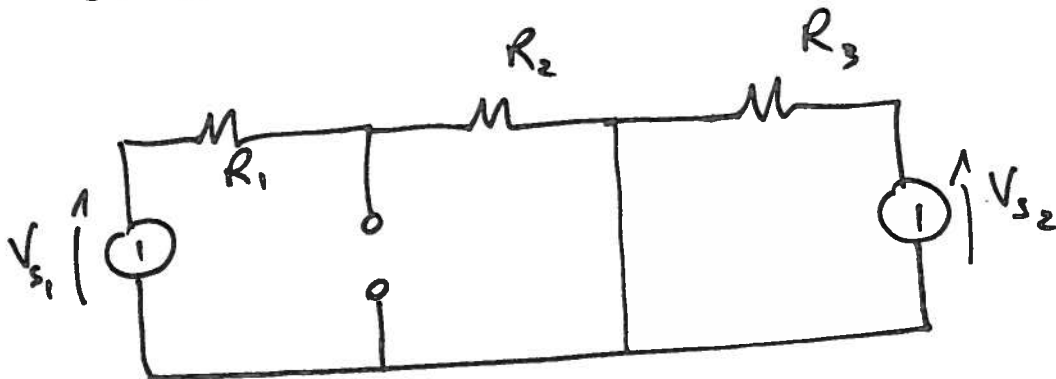
$$v_c(0^-) = V_{s1} - R_1 i(0^-) = 32 \text{ V}$$

$t = 0^+$



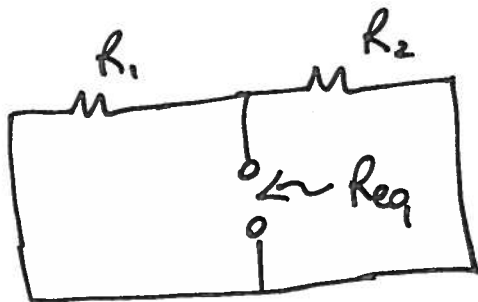
$$i(0^+) = \frac{v_c(0^-)}{R_2} = \frac{16}{3} \text{ mA}$$

$$t = \infty$$



$$i(\infty) = \frac{V_{s1}}{R_1 + R_2} = \frac{9}{2} \text{ mA}$$

τ



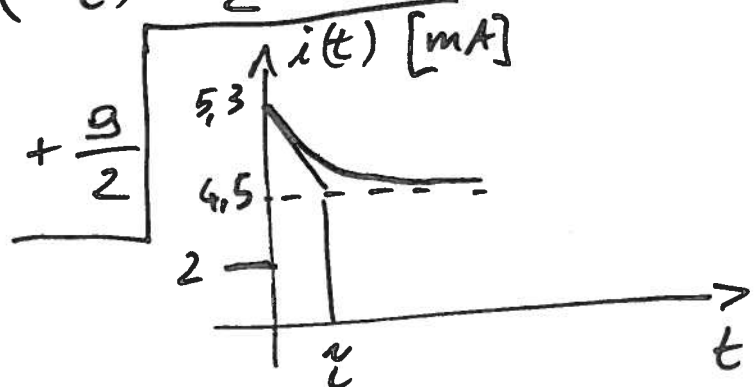
$$R_{eq} = \frac{R_1 R_2}{R_1 + R_2} = \frac{3}{2} \text{ k}\Omega$$

$$\tau = R_{eq} C = 150 \text{ ms}$$

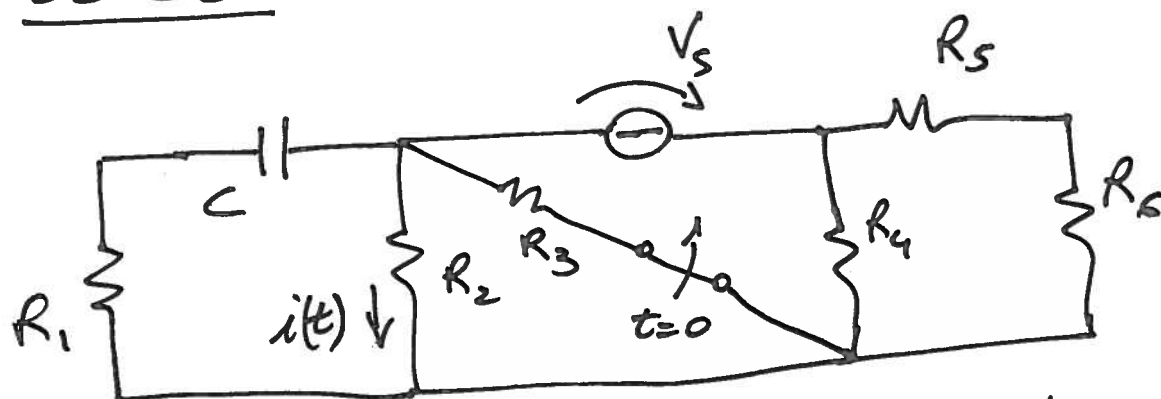
$$i(t) = [i(0^+) - i(\infty)] \exp\left(-\frac{t}{\tau}\right) + i(\infty)$$

$$= \left(\frac{16}{3} - \frac{9}{2}\right) \exp\left(-\frac{t}{\tau}\right) + \frac{9}{2} \text{ mA}$$

$$= \frac{5}{6} \exp\left(-\frac{t}{\tau}\right) + \frac{9}{2}$$



ES 30



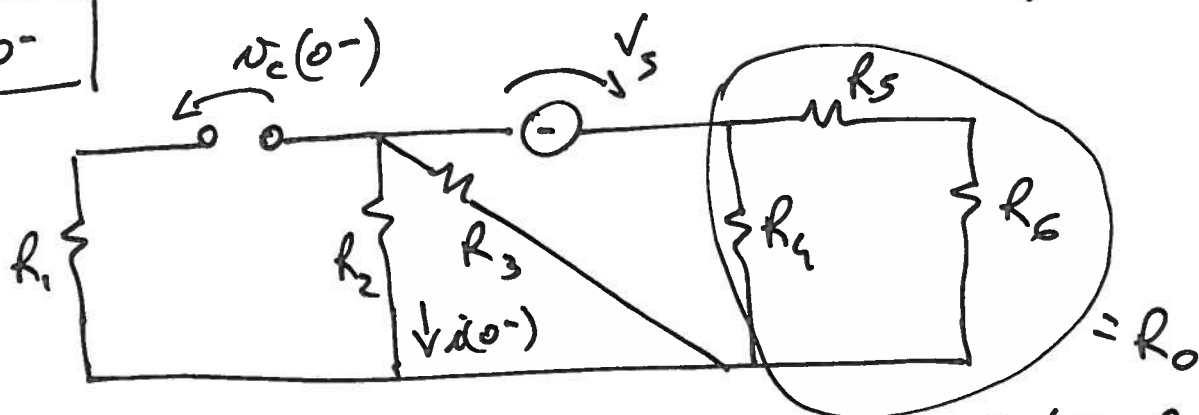
$$V_s = 10\text{V}$$

$$R_1 = R_5 = R_6 = 5\Omega$$

$$R_2 = R_3 = R_4 = 10\Omega$$

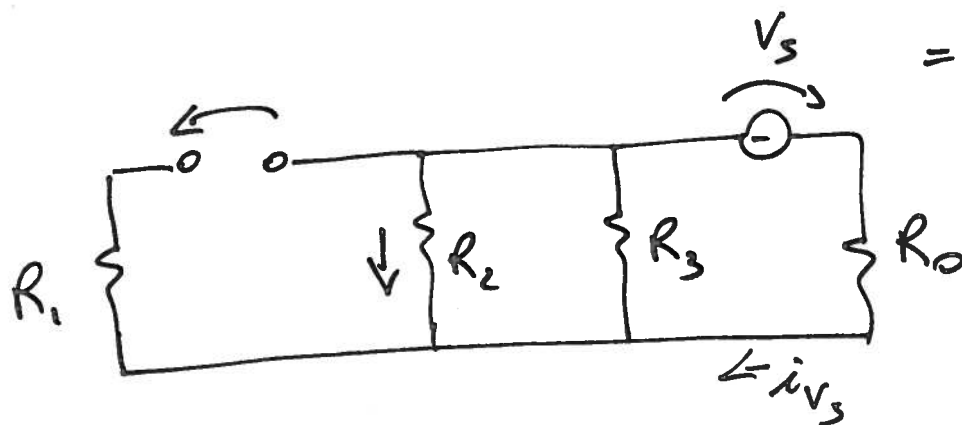
$$C = 10\mu\text{F}$$

$t = 0^-$



$$R_0 = \frac{R_4(R_5 + R_6)}{R_4 + R_5 + R_6}$$

$$= 5\Omega$$

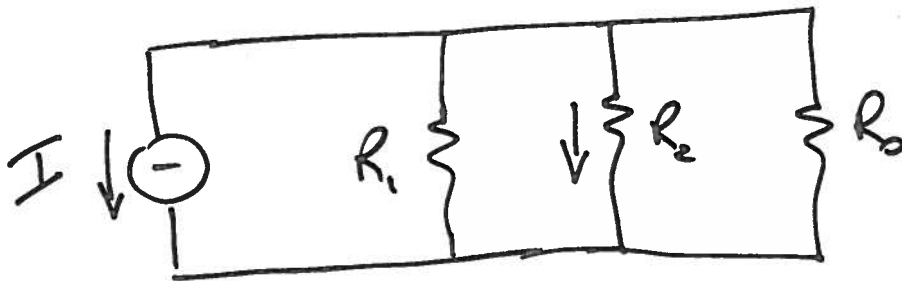
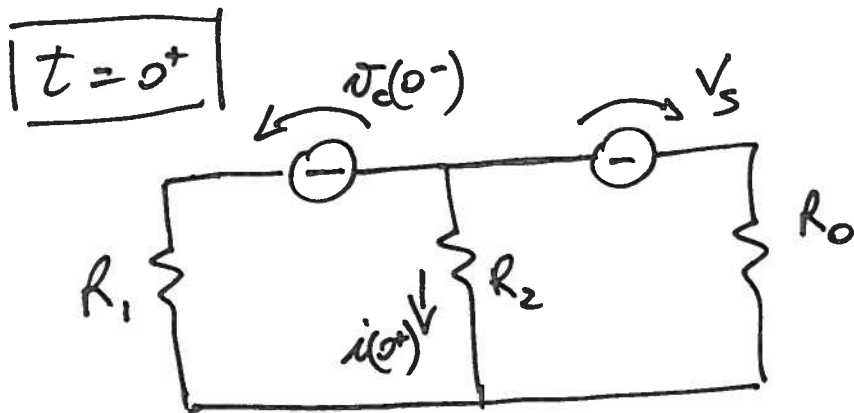


$$i_{V_s} = \frac{V_s}{R_0 + \frac{R_2 R_3}{R_2 + R_3}} \Rightarrow i(0^-) = -\frac{R_3}{R_2 + R_3} i_{V_s}$$

$$i(0^-) = - \frac{R_3 V_s}{R_2 R_3 + R_0 (R_2 + R_3)} = -0,5 \text{ A}$$

$$v_c(0^-) = -R_2 i(0^-) = \frac{R_2 R_3 V_s}{R_2 R_3 + R_0 (R_2 + R_3)} = 5 \text{ V}$$

$$v_c(0^+) = v_c(0^-)$$



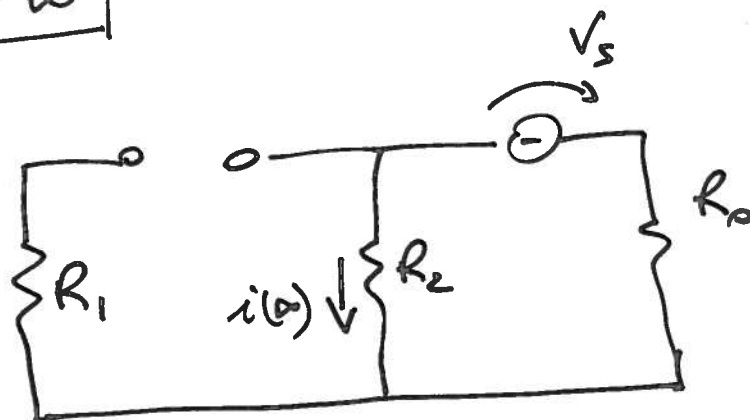
$$I = \frac{V_s}{R_0} + \frac{v_c(0^-)}{R_1}$$

$$i(0^+) = - \frac{1}{R_2} I \frac{1}{\frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_0}}$$

$$= - \left(\frac{V_s}{R_0} + \frac{v_c(0^-)}{R_1} \right) \frac{R_1 R_0}{R_1 R_2 + R_1 R_0 + R_2 R_0}$$

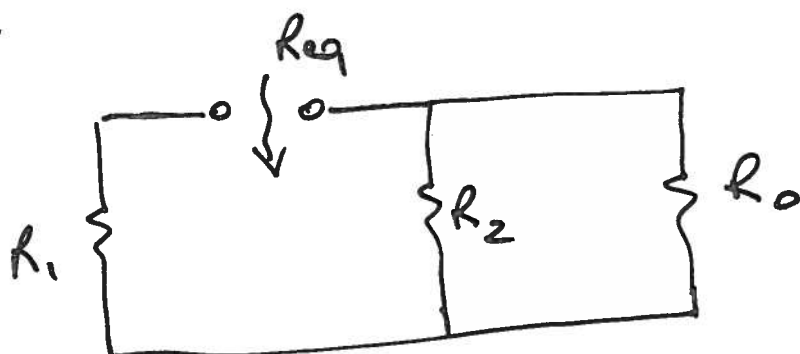
$$= -0,6 \text{ A}$$

$$\boxed{t \rightarrow \infty}$$



$$i(\infty) = - \frac{V_s}{R_2 + R_0} = -0,67 \text{ A}$$

τ



$$R_{eq} = R_1 + \frac{R_2 R_0}{R_0 + R_2} = 8,33 \Omega$$

$$\tau = R_{eq} C = 83,3 \mu s$$

$$i(t) = [i(0^+) - i(\infty)] \exp\left(-\frac{t}{\tau}\right) + i(\infty)$$

$$= -0,07 \exp\left(-\frac{t}{\tau}\right) - 0,67 \text{ A}$$

