P 6.3 Note – the initial current should be 1 A.

$0 \leq t \leq 2\,\text{s}$

$$i_L = \frac{1}{2.5 \times 10^{-4}} \int_0^t 3 \times 10^{-3} e^{-4x}\, dx + 0 = 1.2 \frac{e^{-4x}}{-4} \Big|_0^t + 0$$

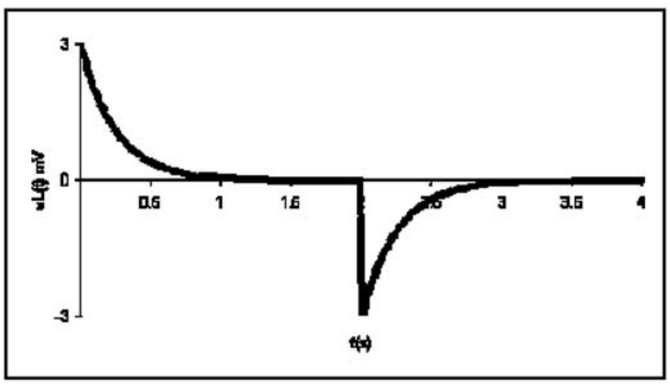
$$= 0.3 - 0.3e^{-4t}\,\text{A}, \qquad 0 \leq t \leq 2\,\text{s}$$

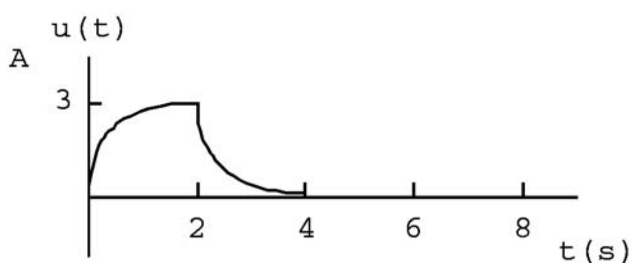
$i_L(2) = 0.3\text{A}$

$2\,\text{s} < t < \infty$

$$i_L = -1.2 \left(\frac{e^{-4(x-2)}}{-4} \Big|_2^t + 0.3 \right)$$

$$= 0.3e^{-4(t-2)}\,\text{A}, \qquad 2\,\text{s} \leq t < \infty$$





P 6.4 **[a]** $v = L\frac{di}{dt}$

$$\frac{di}{dt} = 18[t(-10e^{-10t}) + e^{-10t}] = 18e^{-10t}(1 - 10t)$$

$$v = (50 \times 10^{-6})(18)e^{-10t}(1 - 10t)$$

$$= 0.9e^{-10t}(1 - 10t)\,\text{mV}, \quad t > 0$$

[b] $p = vi$

$$v(200\,\text{ms}) = 0.9e^{-2}(1 - 2) = -121.8\,\mu\text{V}$$

$$i(200\,\text{ms}) = 18(0.2)e^{-2} = 487.2\,\text{mA}$$

$$p(200\,\text{ms}) = (-121.8 \times 10^{-6})(487.2 \times 10^{-3}) = -59.34\,\mu\text{W}$$

[c] delivering

[d] $w = \frac{1}{2}Li^2 = \frac{1}{2}(50 \times 10^{-6})(487.2 \times 10^{-3})^2 = 5.93\,\mu\text{J}$

[e] The energy is a maximum where the current is a maximum:

$$\frac{di_L}{dt} = 18[t(-10)e^{-10t} + e^{-10t}) = 18e^{-10t}(1 - 10t)$$

$$\frac{di_L}{dt} = 0 \quad \text{when} \quad t = 0.1\,\text{s}$$

$$i_{\text{max}} = 18(0.1)e^{-1} = 662.2\,\text{mA}$$

$$w_{\text{max}} = \frac{1}{2}(50 \times 10^{-6})(662.2 \times 10^{-3})^2 = 10.96\,\mu\text{J}$$

P 6.21 $30\|20 = 12\,\text{H}$

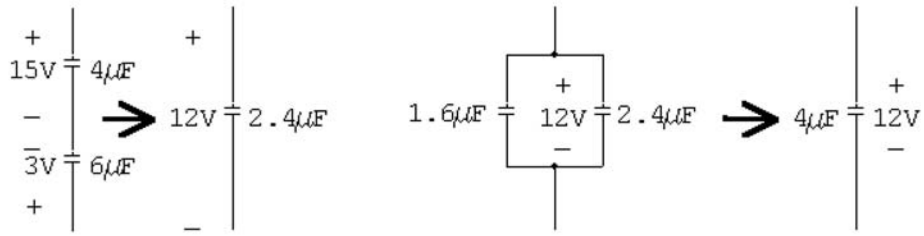
$$80\|(8 + 12) = 16\,\text{H}$$

$$60\|(14 + 16) = 20\,\text{H}$$

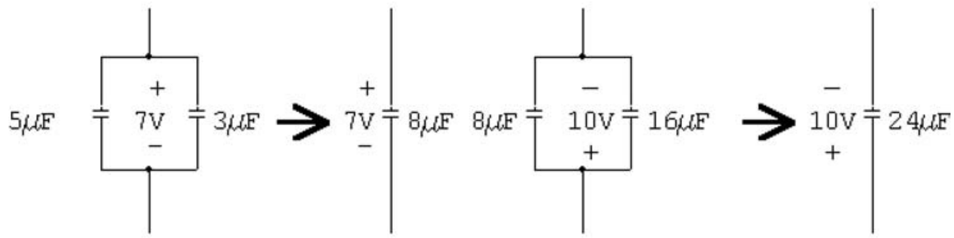
$$15\|(20 + 10) = 20\,\text{H}$$

$$L_{\text{ab}} = 5 + 10 = 15\,\text{H}$$

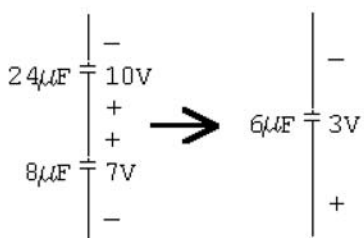
P 6.25 $\frac{1}{4} + \frac{1}{6} = \frac{5}{12} \quad \therefore \quad C_{eq} = 2.4\,\mu\text{F}$



$$\frac{1}{4} + \frac{1}{12} = \frac{4}{12} \quad \therefore \quad C_{eq} = 3\,\mu\text{F}$$



$$\frac{1}{24} + \frac{1}{8} = \frac{4}{24} \quad \therefore \quad C_{eq} = 6\,\mu\text{F}$$



P 7.4 **[a]** $\frac{v}{i} = R = \frac{400e^{-5t}}{10e^{-5t}} = 40\,\Omega$

[b] $\tau = \frac{1}{5} = 200\,\text{ms}$

[c] $\tau = \frac{L}{R} = 200 \times 10^{-3}$

$$L = (200 \times 10^{-3})(40) = 8\,\text{H}$$

[d] $w(0) = \frac{1}{2}L[i(0)]^2 = \frac{1}{2}(8)(10)^2 = 400\,\text{J}$

[e] $w_{\text{diss}} = \int_0^t 4000e^{-10x}\,dx = 400 - 400e^{-10t}$

$$0.8w(0) = (0.8)(400) = 320\,\text{J}$$

$$400 - 400e^{-10t} = 320 \qquad \therefore \quad e^{10t} = 5$$

Solving, $t = 160.9$ ms.

P 7.5 **[a]** $i_L(0) = \frac{12}{6} = 2\,\text{A}$

$$i_o(0^+) = \frac{12}{2} - 2 = 6 - 2 = 4\,\text{A}$$

$$i_o(\infty) = \frac{12}{2} = 6\,\text{A}$$

[b] $i_L = 2e^{-t/\tau}; \qquad \tau = \frac{L}{R} = \frac{1}{4}\,\text{s}$

$$i_L = 2e^{-4t}\,\text{A}$$

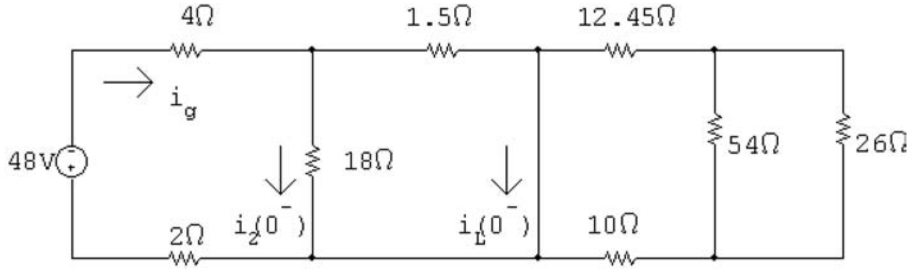
$$i_o = 6 - i_L = 6 - 2e^{-4t}\,\text{A}, \qquad t \geq 0^+$$

[c] $6 - 2e^{-4t} = 5$

$$1 = 2e^{-4t}$$

$$e^{6t} = 2 \qquad \therefore \quad t = 173.3\,\text{ms}$$

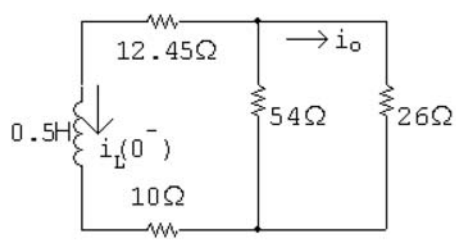
P 7.9 For $t < 0^+$



$$i_g = \frac{-48}{6 + (18\|1.5)} = -6.5\,\text{A}$$

$$i_L(0^-) = \frac{18}{18 + 1.5}(-6.5) = -6\,\text{A} = i_L(0^+)$$

For $t > 0$



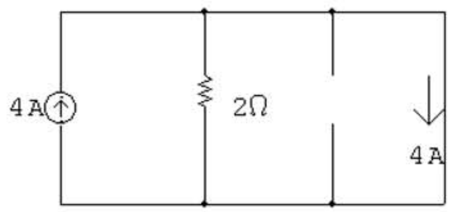
$$i_L(t) = i_L(0^+)e^{-t/\tau}\,\text{A}, \qquad t \geq 0$$

$$\tau = \frac{L}{R} = \frac{0.5}{10 + 12.45 + (54\|26)} = 0.0125\,\text{s}; \qquad \frac{1}{\tau} = 80$$

$$i_L(t) = -6e^{-80t}\,\text{A}, \qquad t \geq 0$$

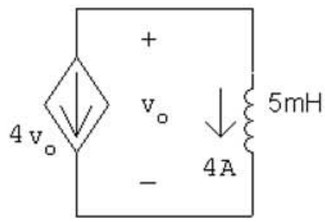
$$i_o(t) = \frac{54}{80}(-i_L(t)) = \frac{54}{80}(6e^{-80t}) = 4.05e^{-80t}\,\text{V}, \qquad t \geq 0^+$$

P 7.13 $t < 0$

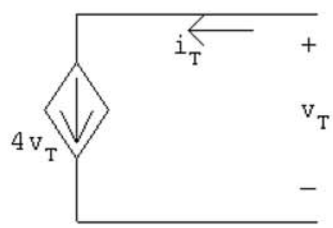


$$i_L(0^-) = i_L(0^+) = 4\,\mathrm{A}$$

$t > 0$

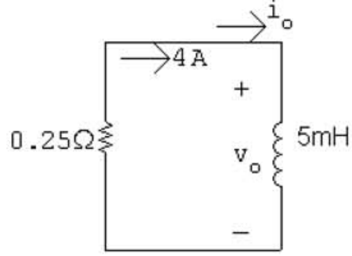


Find Thévenin resistance seen by inductor



$$i_T = 4v_T; \qquad \frac{v_T}{i_T} = R_{\mathrm{Th}} = \frac{1}{4} = 0.25\,\Omega$$

$$\tau = \frac{L}{R} = \frac{5 \times 10^{-3}}{0.25} = 20\,\mathrm{ms}; \qquad 1/\tau = 50$$

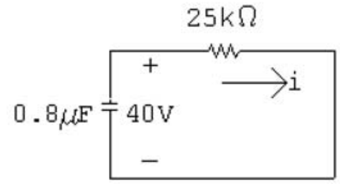


$$i_o = 4e^{-50t}\,\mathrm{A}, \qquad t \geq 0$$

$$v_o = L\frac{di_o}{dt} = (5 \times 10^{-3})(-200e^{-50t}) = -e^{-50t}\,\mathrm{V}, \quad t \geq 0^+$$

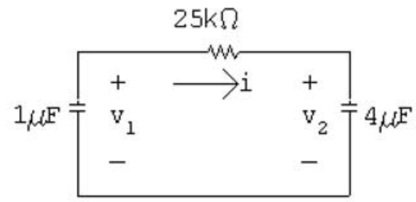
P 7.21 **[a]** $v_1(0^-) = v_1(0^+) = 40\,\text{V}$ $\qquad v_2(0^+) = 0$

$C_{\text{eq}} = (1)(4)/5 = 0.8\,\mu\text{F}$



$$\tau = (25 \times 10^3)(0.8 \times 10^{-6}) = 20\text{ms}; \qquad \frac{1}{\tau} = 50$$

$$i = \frac{40}{25{,}000} e^{-50t} = 1.6e^{-50t}\,\text{mA}, \qquad t \geq 0^+$$



$$v_1 = \frac{-1}{10^{-6}} \int_0^t 1.6 \times 10^{-3} e^{-50x}\,dx + 40 = 32e^{-50t} + 8\,\text{V}, \qquad t \geq 0$$

$$v_2 = \frac{1}{4 \times 10^{-6}} \int_0^t 1.6 \times 10^{-3} e^{-50x}\,dx + 0 = -8e^{-50t} + 8\,\text{V}, \qquad t \geq 0$$

[b] $w(0) = \frac{1}{2}(10^{-6})(40)^2 = 800\,\mu\text{J}$

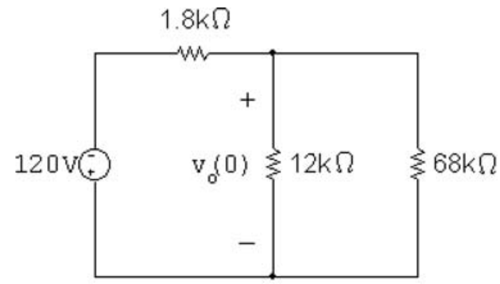
[c] $w_{\text{trapped}} = \frac{1}{2}(10^{-6})(8)^2 + \frac{1}{2}(4 \times 10^{-6})(8)^2 = 160\,\mu\text{J}.$

The energy dissipated by the 25 kΩ resistor is equal to the energy dissipated by the two capacitors; it is easier to calculate the energy dissipated by the capacitors (final voltage on the equivalent capacitor is zero):

$$w_{\text{diss}} = \frac{1}{2}(0.8 \times 10^{-6})(40)^2 = 640\,\mu\text{J}.$$

Check: $\quad w_{\text{trapped}} + w_{\text{diss}} = 160 + 640 = 800\,\mu\text{J}; \qquad w(0) = 800\,\mu\text{J}.$

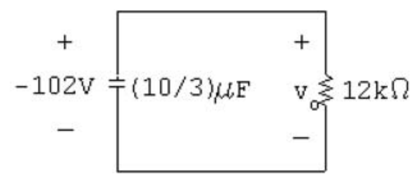
P 7.25 **[a]** $t < 0$:



$$R_e = 12\text{ k}||68\text{ k} = 10.2\text{ k}\Omega$$

$$v_o(0) = \frac{10{,}200}{10{,}200 + 1800}(-120) = -102\text{ V}$$

$t > 0$:



$$\tau = [(10/3) \times 10^{-6})(12{,}000) = 40\text{ ms}; \qquad \frac{1}{\tau} = 25$$

$$v_o = -102e^{-25t}\text{ V}, \quad t \geq 0$$

$$p = \frac{v_o^2}{12{,}000} = 867 \times 10^{-3}e^{-50t}\text{ W}$$

$$w_{\text{diss}} = \int_0^{12\times10^{-3}} 867 \times 10^{-3}e^{-50t}\,dt$$
$$= 17.34 \times 10^{-3}(1 - e^{-50(12\times10^{-3})}) = 7.82\text{ mJ}$$

[b] $w(0) = \left(\frac{1}{2}\right)\left(\frac{10}{3}\right)(102)^2 \times 10^{-6} = 17.34\text{ mJ}$

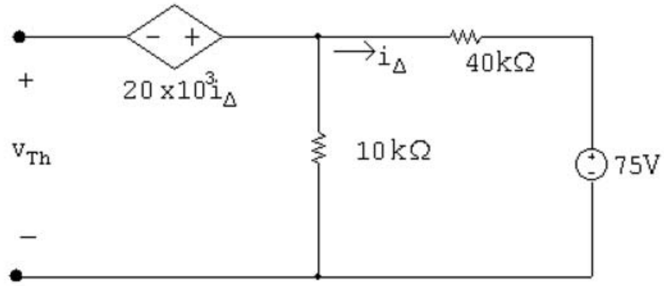
$$0.75w(0) = 13\text{ mJ}$$

$$\int_0^{t_o} 867 \times 10^{-3}e^{-50x}\,dx = 13 \times 10^{-3}$$

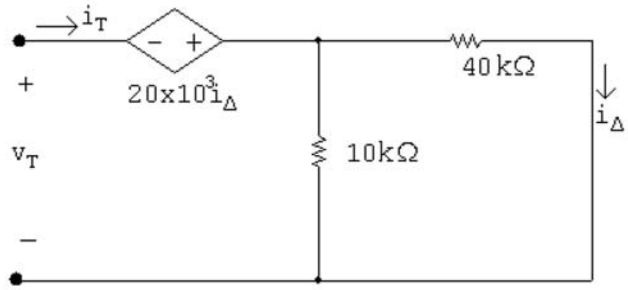
$$\therefore \quad 1 - e^{-50t_o} = 0.75; \qquad e^{50t_o} = 4; \quad \text{so} \quad t_o = 27.73\,ms$$

P 7.55 For $t < 0$, $v_o(0) = (-3\,\mathrm{m})(15\,\mathrm{k}) = -45\,\mathrm{V}$

$t > 0$:



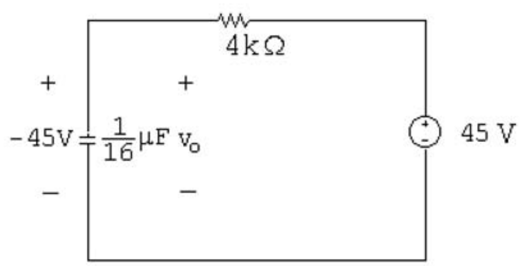
$$V_{\mathrm{Th}} = -20 \times 10^3 i_\Delta + \frac{10}{50}(75) = -20 \times 10^3 \left(\frac{-75}{50 \times 10^3}\right) + 15 = 45\,\mathrm{V}$$



$$v_T = -20 \times 10^3 i_\Delta + 8 \times 10^3 i_T = -20 \times 10^3 (0.2) i_T + 8 \times 10^3 i_T = 4 \times 10^3 i_T$$

$$R_{\mathrm{Th}} = \frac{v_T}{i_T} = 4\,\mathrm{k}\Omega$$

$t > 0$

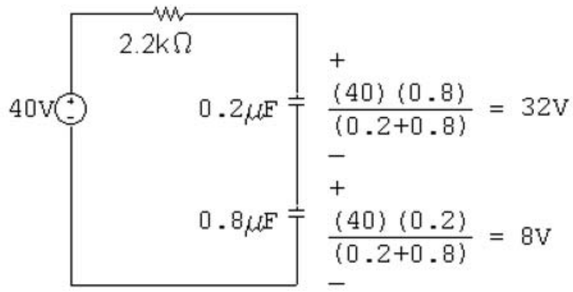


$$v_o = 45 + (-45 - 45)e^{-t/\tau}$$

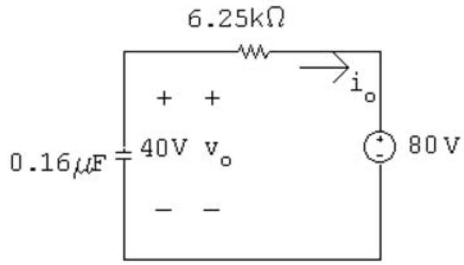
$$\tau = RC = (4000)\left(\frac{1}{16} \times 10^{-6}\right) = 250\,\mu\mathrm{s}; \qquad \frac{1}{\tau} = 4000$$

$$v_o = 45 - 90e^{-4000t}\,\mathrm{V}, \quad t \geq 0$$

P 7.60 **[a]** $t < 0$



$t > 0$



$$v_o(0^-) = v_o(0^+) = 40\,\text{V}$$

$$v_o(\infty) = 80\,\text{V}$$

$$\tau = (0.16 \times 10^{-6})(6.25 \times 10^3) = 1\,\text{ms}; \qquad 1/\tau = 1000$$

$$v_o = 80 - 40e^{-1000t}\,\text{V}, \qquad t \geq 0$$

[b] $i_o = -C\dfrac{dv_o}{dt} = -0.16 \times 10^{-6}[40{,}000e^{-1000t}]$

$$= -6.4e^{-1000t}\,\text{mA}; \qquad t \geq 0^+$$

[c] $v_1 = \dfrac{-1}{0.2 \times 10^{-6}} \displaystyle\int_0^t -6.4 \times 10^{-3} e^{-1000x}\,dx + 32$

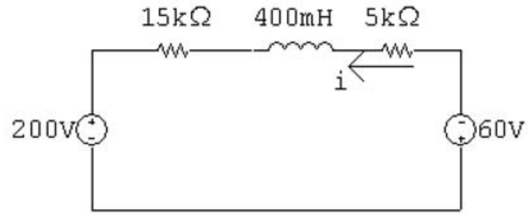
$$= 64 - 32e^{-1000t}\,\text{V}, \qquad t \geq 0$$

[d] $v_2 = \dfrac{-1}{0.8 \times 10^{-6}} \displaystyle\int_0^t -6.4 \times 10^{-3} e^{-1000x}\,dx + 8$

$$= 16 - 8e^{-1000t}\,\text{V}, \qquad t \geq 0$$

[e] $w_{\text{trapped}} = \dfrac{1}{2}(0.2 \times 10^{-6})(64)^2 + \dfrac{1}{2}(0.8 \times 10^{-6})(16)^2 = 512\,\mu\text{J}.$

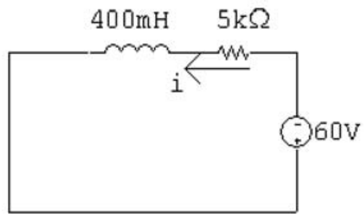
P 7.63 **[a]** For $t < 0$, calculate the Thévenin equivalent for the circuit to the left and right of the 400-mH inductor. We get



$$i(0^-) = \frac{-60 - 200}{15\,\text{k} + 5\,\text{k}} = -13\,\text{mA}$$

$$i(0^-) = i(0^+) = -13\,\text{mA}$$

[b] For $t > 0$, the circuit reduces to



Therefore $\quad i(\infty) = -60/5{,}000 = -12\,\text{mA}$

[c] $\tau = \dfrac{L}{R} = \dfrac{400 \times 10^{-3}}{5000} = 80\,\mu\text{s}$

[d] $i(t) = i(\infty) + [i(0^+) - i(\infty)]e^{-t/\tau}$

$$= -12 + [-13 + 12]e^{-12{,}500t} = -12 - e^{-12{,}500t}\,\text{mA}, \qquad t \geq 0$$