EE 2351 – Circuits II
Test # 1

KEY 1

Jul. 17, 2017

Instructions:

a. **Please keep your cell phone stored in your bag or pocket. No cellphone access during the exam. If you are found using your cellphone, you will be asked to leave the room and will receive a grade of 0 in the test.**

b. **You cannot talk to your classmates during the exam. If you talk to your classmates during the exam, you will be asked to leave the room and will receive a grade of 0 in the test.**

c. **This is a closed book, closed notes, no computer exam. All the formulas are provided for the test in the last page of this exam. DO NOT TEAR ANY PAGES.**

d. **Put the proper units and prefixes with your answers and use the appropriate sign conventions.**

e. **Show all work, including intermediate steps. Failure to do so will be penalized. Explicitly state in your answer when the calculator is used to get the roots of a polynomial or to solve a system of equations.**

f. **Write clearly the answer(s) to each question and highlight them or box them. Do all your work on the pages provided. No scrap paper is permitted. You may also use the back of the paper if you run out of space.**

g. **No bathroom breaks during the exam.**

By signing this exam, you agree that the work presented here represents only your effort.

Name: KEY

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1.– Answer correctly the next questions (2.5 points each)

1. In the presence of a constant current, after a long time, an inductor becomes

   short ckt / wire

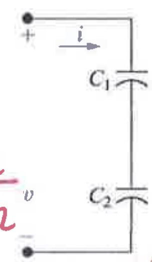
2. The voltage in a capacitor cannot change instantaneously across its terminals.

3. In the presence of a constant voltage, after a long time, a capacitor becomes

   open ckt

4. The current in a ~~capacitor~~ inductor cannot change instantaneously across its terminals.

5. In a circuit with a series of inductors like the one shown above, the equivalent inductance L_{eq} is $L1+L2+L3$



6. In a circuit with a series of capacitors like the one shown right, the equivalent inductance C_{eq} is $\left[\frac{1}{C_1}+\frac{1}{C_2}\right]^{-1}$ or $\frac{C_1C_2}{C_1+C_2}$

7. Give a brief explanation on what is a Natural Response in RL/RC Circuit: No source / discharge / initial current / open switch

8. Give a brief explanation on what is a Step Response in RL/RC Circuit: Source / charge-discharge / final current / close switch

9. The variable tau (τ) in an RL/RC circuit is called time constant

10. The general equation derived from RL/RC circuits to determine their behavior is called 1st Order Differential Equation

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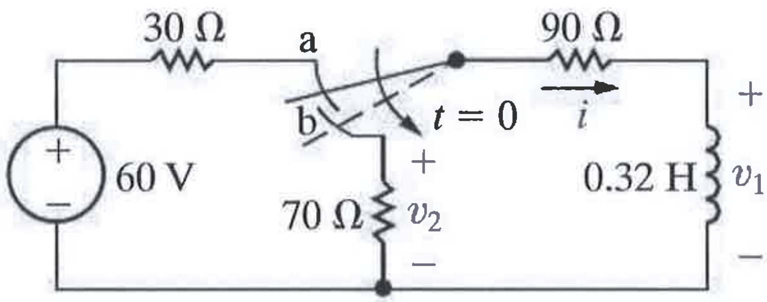
2. – Natural Response of RL/RC Circuits (25 points)

In the circuit shown below, the switch makes contact with position 'b' just before breaking contact with position 'a', so there is no interruption of current through the inductor. The switch has been in position 'a' for a long time before moving to position 'b' at $t = 0$. Find

a) The initial current in the inductor (5 Pts.)
b) τ for $t > 0$ (5 Pts.)
c) Current $i(t)$ for $t \geq 0$ (5 Pts.)
d) Inductor voltage $v_1(t)$ for $t \geq 0$ (5 Pts.)
e) Voltage across the 70 Ω resistor $v_2(t)$ for $t \geq 0$ (5 Pts.)



a) $i(0)$

Equivalent ckt

$i(0^-) = i(0) = i(0^+) = \frac{60}{120} = \boxed{0.5A}$

b) τ

Equivalent ckt

$\tau = \frac{L}{R} = \frac{0.32}{160} = \boxed{0.002\,s \quad 2ms} = \tau$

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c) $i = I_0 e^{-t/\tau}$

$I_0 = 0.5\,A$ $\quad \boxed{i(t) = 0.5\, e^{-500t}\,A,\ t \geq 0}$

$\tau = 0.02$

d) $v_1(t) = L\dfrac{di(t)}{dt} = 0.32\dfrac{(0.5e^{-500t})}{dt} = (0.32)(0.5)(-500)\,e^{-500t}$

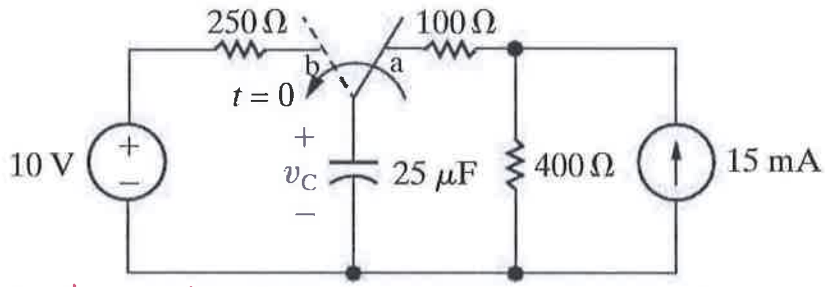
$\boxed{v_1(t) = -80\, e^{-500t}\,V,\ t \geq 0^+}$

e) $v_2(t) = i(t)R = -70\,[i(t)] = \boxed{-35\, e^{-500t}\,V,\ t \geq 0^+}$

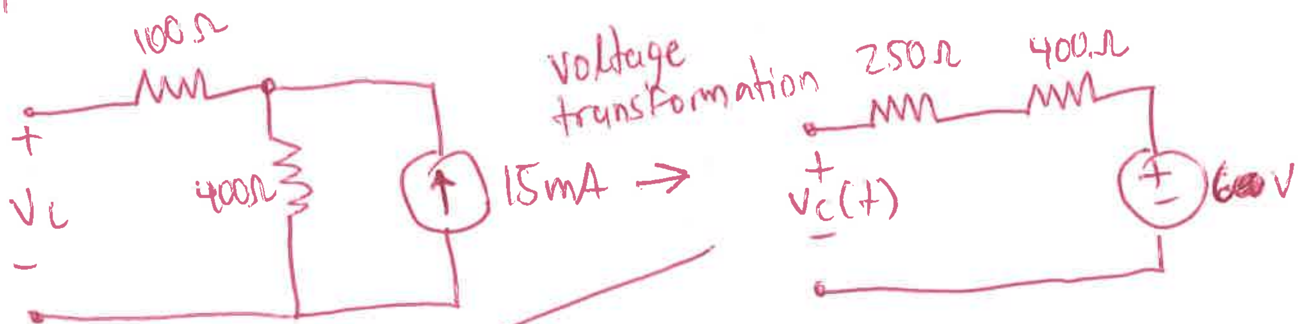
3. – Step Response of RL/RC Circuits (25 points)

The switch in the circuit shown below has been in position ‘a’ for a long time before moving to position ‘b’ at $t = 0$. Find

a) The initial value of the capacitor voltage (6.25 Pts.)
b) The final value of the capacitor voltage (6.25 Pts.)
c) τ for $t \geq 0$ (6.25 Pts.)
d) Expression for the capacitor voltage for $t \geq 0$ (6.25 Pts.)

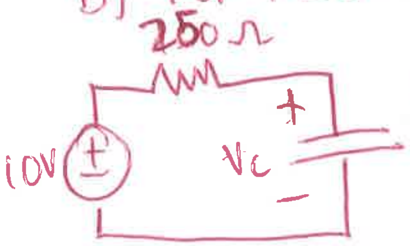


a) Equivalent ckt for $t < 0$



initial value $\boxed{V_{Ci} = 6.00V}$

b) For $t \geq 0$ equivalent ckt



as $t \to \infty$ → $\boxed{V_{CF} = 10V}$

c) $\tau = RC = (250)(0.25 \times 10^{-8})$

OR $(250)(25 \times 10^{-6}) = \boxed{6.25 \times 10^{-3} \text{ ms}}$

d) $v_c(t) = v_{cf} + [v_{ci} - v_{cf}]e^{-t/\tau}$

$= 10 + (6.00 - 10)e^{-t/6.25\times10^{-3}}$

$\boxed{v_c(t) = 10 - 4e^{-160t}\ V,\ t \geq 0}$

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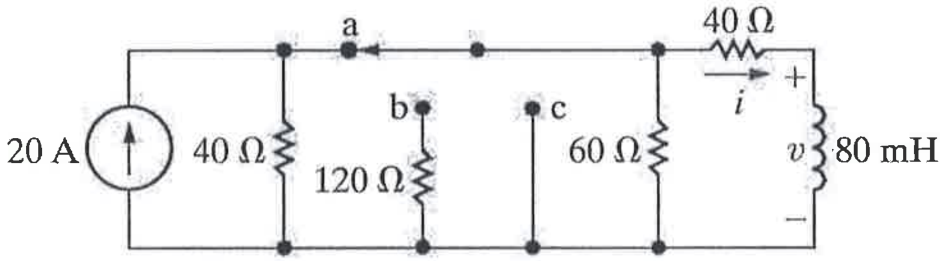
4. – Sequential Switching (25 points)

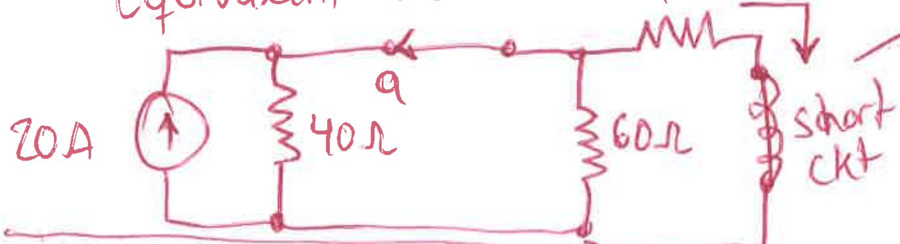
The switch in the circuit shown below has been in position 'a' for a long time. At $t = 0$, the switch is moved to position 'b', where it remains for $1\ ms$. The switch is then moved to position 'c', where it stays indefinitely. Find

a) The initial current through the inductor (5 Pts.)
b) $i(t), 0 \leq t \leq 1\ ms$ (5 pts.)
c) $i(t), t \geq 1\ ms$ (5 pts.)
d) $v(t), 0 \leq t \leq 1\ ms$ (5 pts.)
e) $v(t), t \geq 1\ ms$ (5 pts.)



a) For $t < 0$

Equivalent ckt



current divider across 40Ω resistor

$$20\left(\frac{60\|40}{60\|40+40}\right)$$

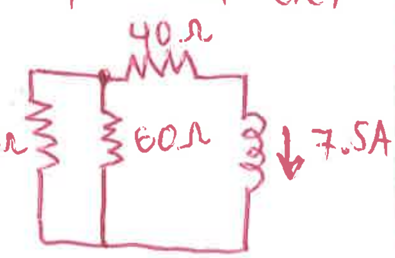
$$20\left(\frac{(60\cdot 40)/100}{\frac{60\cdot 40}{100}+40}\right)$$

$$20\left(\frac{24}{24+40}\right) = \boxed{7.5A = i(0^-)}$$

remember that across inductor $i(0^-) = i(0^+)$

b) $0 \leq t \leq 1\ ms$ $i(t)$ equivalent ckt

Natural response



$$\tau = \frac{R_{eq}}{L} = \frac{80}{80\times 10^{-3}}$$

$$R_{eq} = 40 + 120\|60 = 40 + \frac{120\cdot 60}{180} = 80\Omega$$

$$\tau = \frac{80}{80\times 10^{-3}} = 1000$$

$$\frac{1}{\tau} = 1000$$

$$\boxed{i(t) = 7.5e^{-1000t}, 0 \leq t \leq 1ms}$$

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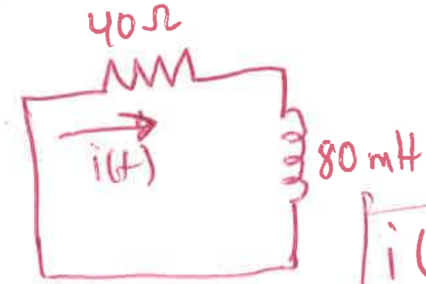
c) at 1 ms,

$$i(1\,ms) = 7.5\,e^{-(1000)(1\times10^{-3})} = 2.7591\ A$$

equivalent ckt



$$\tau = \frac{L}{R} = \frac{80\times10^{-3}}{40} = 0.002\,s$$

$$\frac{1}{\tau} = 500$$

$$\boxed{i(t) = 2.759\,e^{-500(t-0.001)}\ A, \quad t \geq 1\,ms}$$

d) $v_L(t) = L\dfrac{di(t)}{dt}$ at $0 \leq t \leq 1\,ms$

$$= (80\times10^{-3})(7.5)(-1000)\,e^{-1000t}$$

$$\boxed{v_L(t) = -600\,e^{-1000t}\ V, \quad 0 \leq t \leq 1\,ms}$$

e) $v_L(t) = L\dfrac{di(t)}{dt}$ at $t \geq 1\,ms$

$$= (80\times10^{-3})(2.759)(-500)\,e^{-500(t-0.001)}$$

$$\boxed{V_L(t) = -110.36\,e^{-500(t-0.001)}\ V, \quad t \geq 1\,ms}$$

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Formulas for Test 1

$$v_L(t) = L\frac{di}{dt}$$

$$i_C(t) = C\frac{dv}{dt}$$

$$i_L(t) = \frac{1}{L}\int_{t_0}^{t} v\,d\tau + i(t_0)$$

$$p_L(t) = iL\frac{di}{dt}$$

$$w_L(t) = \frac{1}{2}L[i_L(t)]^2$$

$$v_C(t) = \frac{1}{C}\int_{t_0}^{t} i\,d\tau + v(t_0)$$

$$p_C(t) = vC\frac{dv}{dt}$$

$$w_c(t) = \frac{1}{2}C[v_C(t)]^2$$

$$\tau = \frac{L}{R}\ ,\quad \tau = RC$$

$$i(t) = I_o e^{-\frac{t}{\tau}}$$

$$v(t) = I_o R e^{-\frac{t}{\tau}}$$

$$p(t) = I_o^2 R e^{-\frac{2t}{\tau}}$$

$$w(t) = \frac{1}{2}LI_o^2\left(1 - e^{\frac{2t}{\tau}}\right)$$

$$v(t) = V_o e^{-\frac{t}{\tau}}$$

$$i(t) = \frac{V_o}{R}e^{-\frac{t}{\tau}}$$

$$p(t) = \frac{V_o^2}{R}e^{-\frac{2t}{\tau}}$$

$$w(t) = \frac{1}{2}CV_o^2\left(1 - e^{\frac{2t}{\tau}}\right)$$

$$i(t) = \frac{Vs}{R} + \left(I_o - \frac{V_s}{R}\right)e^{-\frac{t}{\tau}}$$

$$v_L(t) = (V_s - I_o R)e^{-\frac{t}{\tau}}$$

$$i_c(t) = \left(I_s - \frac{V_o}{R}\right)e^{-\frac{t}{\tau}}$$

$$v(t) = I_s R + (V_o - I_s R)e^{-\frac{t}{\tau}}$$

$$x(t) = x_f + \left[x(t_o) - x_f\right]e^{-\frac{(t-t0)}{\tau}}$$