Florida Gulf Coast University
U. A. Whitaker College of Engineering

BME 3506C Circuits for Bioengineers

Fall 2025

Exam #2

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You have 75 minutes to complete this exam. The questions should not take long to answer if you know the material. I recommend that you first read all the problems so that you can think about it as you work on other problems. Do the easer ones first so that you get the majority of the exam complete early.

You are not to use any other electronic device besides your calculator.
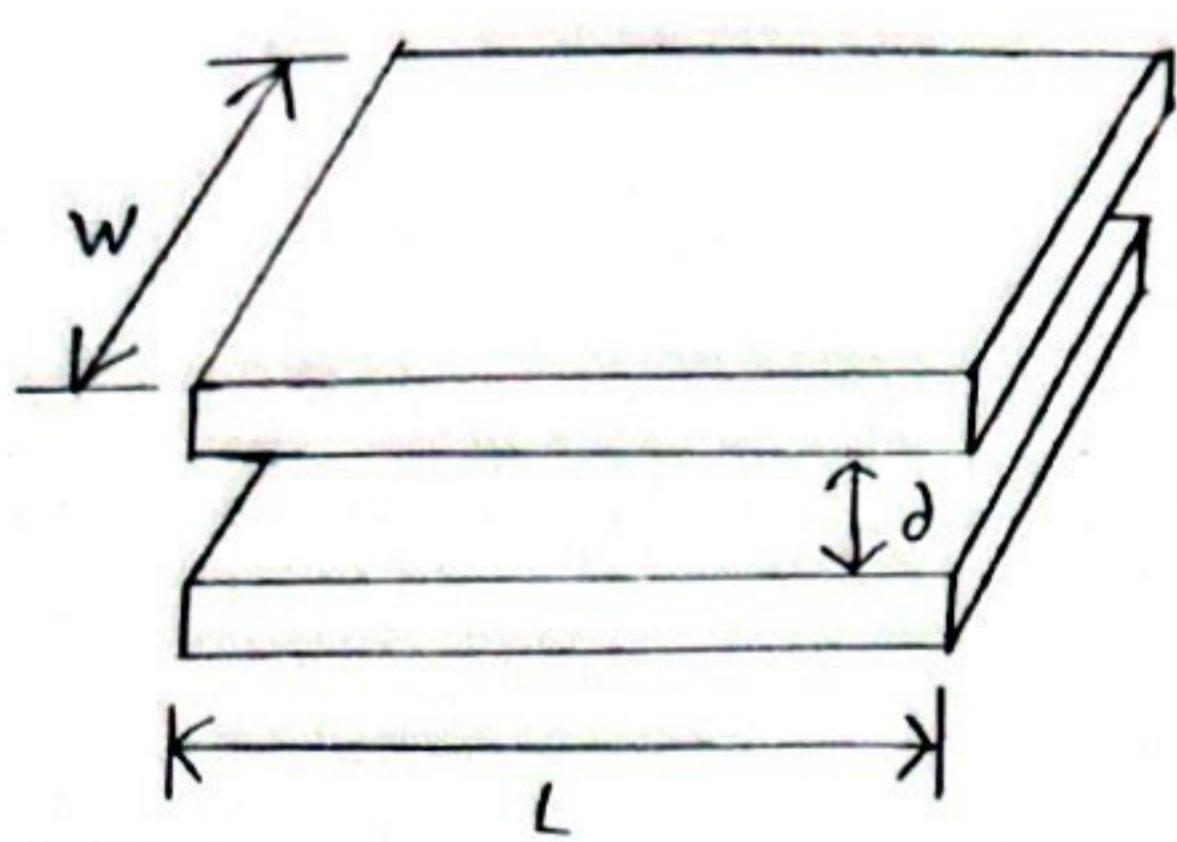
There are some equations on the last page that you may find helpful.

Circle your answers.

Turn off your phone, laptop, I-pad, I-pod, and any other electronic device.

1. Consider the capacitance of a capacitor if we have two plates separated by a thin piece of mica. The mica has a thickness of .1mm and a relative dielectric constant of $\epsilon_r = 7$. Recall, you must use $\epsilon = \epsilon_r \epsilon_o$ where $\epsilon_o = 8.85 \times 10^{-12}$. If we want to width of the plates to be 3cm, what will the length of the plate need to be to get a capacitance of $30\mu F$?

$$\epsilon_r = 7 \qquad d = 0.1mm = 1e^{-4}m$$

$$\epsilon_o = 8.85e^{-12} \qquad C = 30\mu F = 30e^{-6}F$$

$$E = \epsilon_r \epsilon_o \qquad L = ?$$
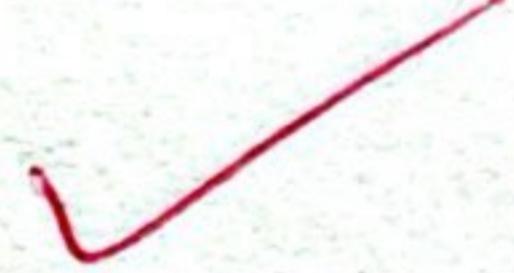
$$C = \epsilon_r \epsilon_o \frac{A}{d} \qquad A = L \times W$$

$$C = 7 \cdot 8.85e^{-12} \cdot \frac{L \cdot 0.03}{1e^{-4}}$$

$$30e^{-6} = 7 \times 8.85e^{-12} \cdot \frac{L \times 0.03}{1e^{-4}} = \frac{1.8585e^{-12}(L)}{1e^{-4}}$$

$$L = \frac{30e^{-6}}{1.8585e^{-8}} \qquad L = \frac{30}{1.8585e^{-2}}$$

$$L = 16.149 \times 100 = \boxed{1614.9 m} \quad \checkmark \boxed{16.15}$$

$\checkmark$

2. In a $30\mu F$ capacitor,
   a. What voltage is needed to store 75W of energy in the capacitor?

$$E = \frac{1}{2}CV^2 \qquad 75 = \frac{1}{2} \cdot 30e^{-6} \cdot V^2 \quad \text{why } e^6 \neq 10^6$$

-1

$$\frac{75}{15e^{-6}} = V^2 \qquad \frac{75}{75} \cdot \textcircled{e}^6 = V^2 \quad 5 \cdot e6 = V^2$$

$$V = \sqrt{5e6} = \boxed{2236.06 = 2.236e^3} ?$$

   b. What charge will be stored in the capacitor when it has 75W of energy using the voltage computed in part a.
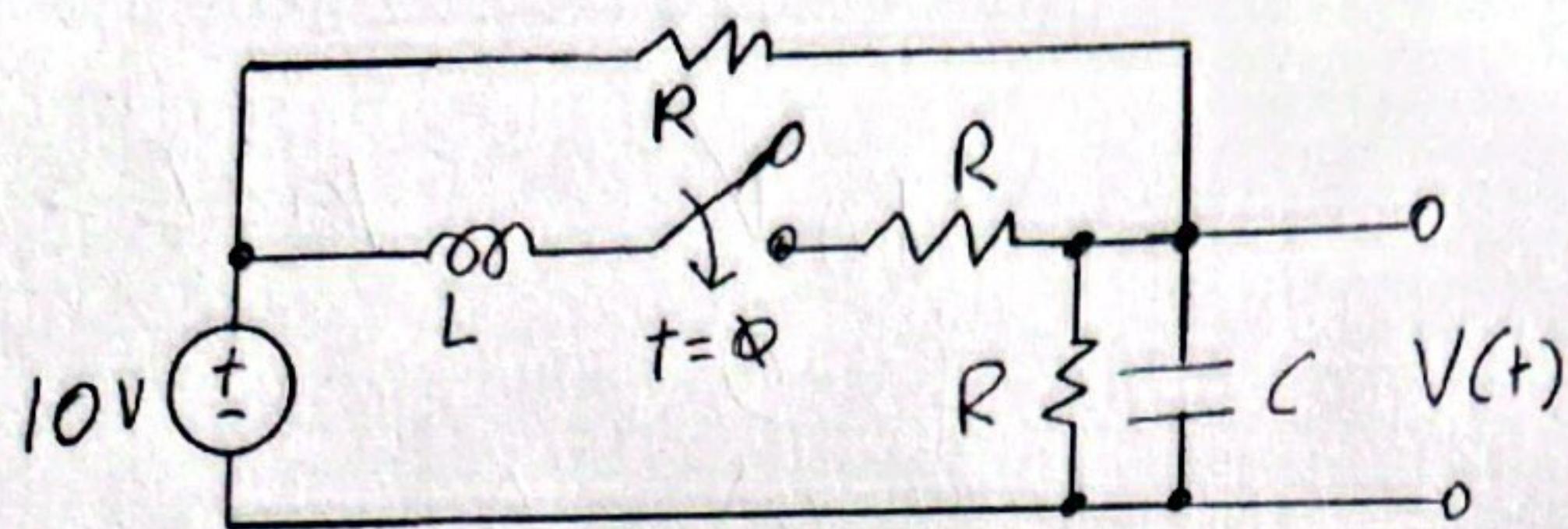
$$Q = CV$$

$$Q = 30e^{-6} \cdot 2.236e^3$$

$$\boxed{= 0.06708 C} \quad \checkmark$$

1. Assume the following circuit is in steady state before the switch closes. At $t = 0$ the switch closes.

a. Compute the voltage V(t) at $t = 0$, when the switch closes. Note, since things do not change instantly, it's the same as when the switch is still open, $t < 0$. Hint, it's a voltage divider.

$$V(0) = \frac{R}{R+R} \cdot 10V = \frac{1}{2} \cdot 10V = \boxed{5V}$$

$$Req_s = R + R$$

$$V(0) = V_{in} \cdot \frac{R}{Req} = 10 \cdot \frac{R}{2R} = \boxed{5V}$$
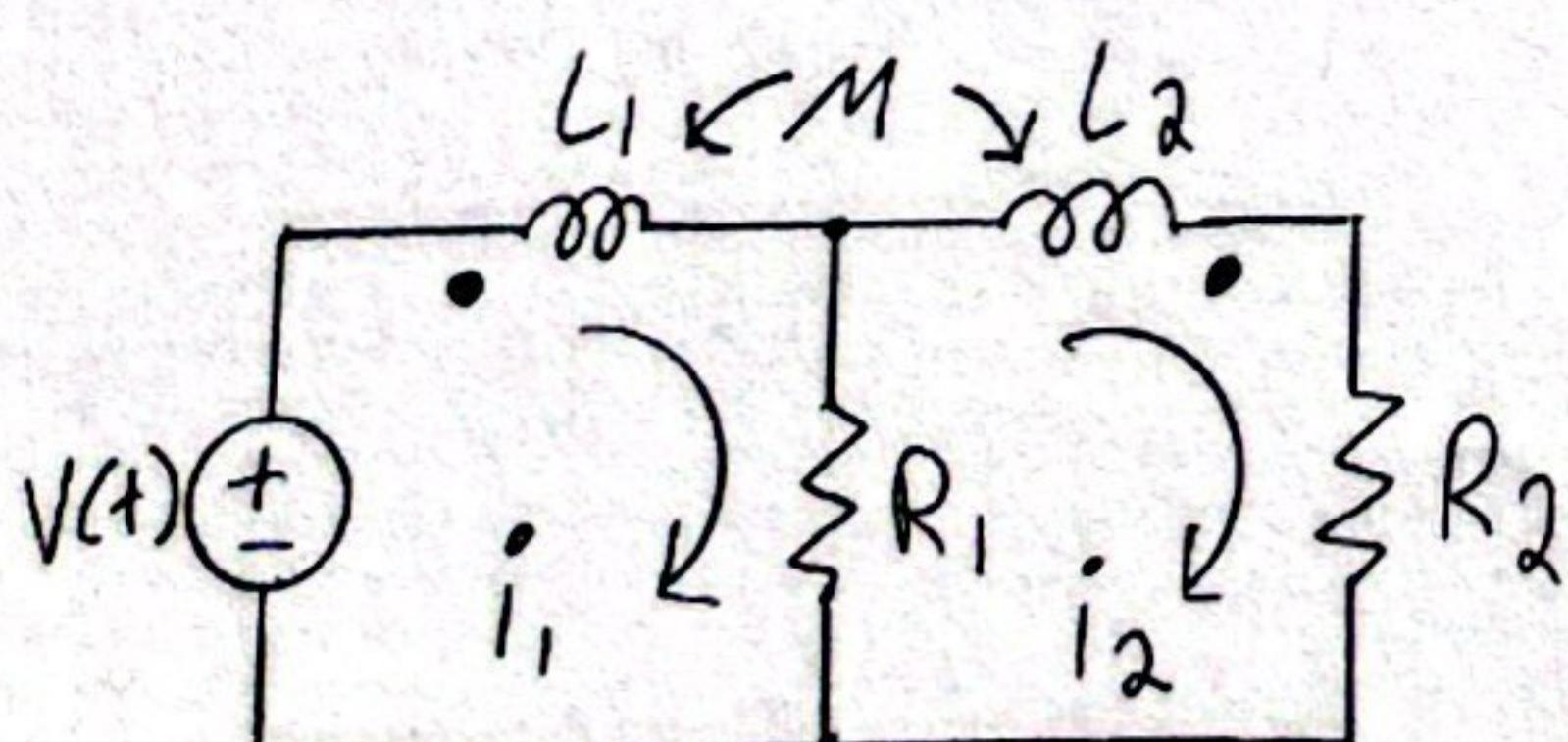
b. Compute the voltage V(t) at $t = \infty$. Hint, also a voltage divider but different than in part a above.

$$V(\infty) = \frac{R}{R+R+R} \cdot 10V = \frac{2R}{3R} \cdot 10V = \boxed{\frac{2}{3}}$$

$$R_{total} = R + R + R = 3R$$

$$V(\infty) = V_{in} \cdot \frac{R+R}{R_{total}} = 10 \cdot \frac{2R}{3R} = \boxed{6.67V}$$

2. Compute the two mesh current equations and do not simplify or try to solve. The term M is the mutual inductance.

$$V_A = R_1 i_1 + L_1 \frac{di_1}{dt} + M \frac{di_2}{dt}$$

$$0 = R_2 i_2 + L_2 \frac{di_2}{dt} + M \frac{di_1}{dt}$$
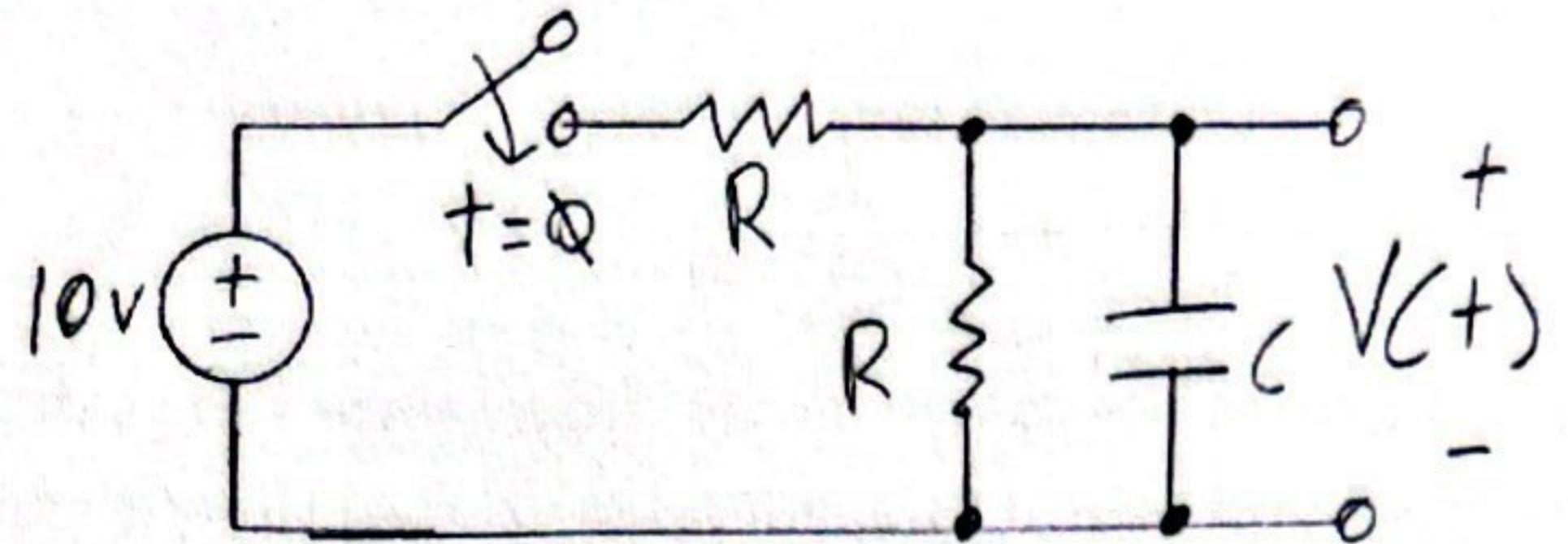
$$0 = L_2 \frac{di_2}{dt} + R_2 i_2 + M \frac{di_1}{dt}$$

$$V_A = L_1 \frac{di_1}{dt} + R_1 i_1 + M \frac{di_2}{dt}$$

$$0 = $$

$$-1$$

3. Given the following circuit, determine $V(t)$ for $t \geq 0$. Assume the capacitor has no charge for $t < 0$. At $t = 0$ the switch closes. The solution is of the form $V(t) = K_1 + K_2 e^{-t/\tau}$. You are to determine the constants K_1, K_2, and τ.

$10V$

$\tau \cdot c L = \frac{1}{4} = \frac{1}{2} r c$

$t = 0$

$V_c(0) = 0$

KCL, $\dfrac{10 - V}{R} = \dfrac{V}{R} + C\dfrac{dv}{dt}, \quad \dfrac{10 - 2V}{R} = C\dfrac{dv}{dt}$

$\therefore \dfrac{dv}{dt} + \dfrac{2}{RC}V = \dfrac{10}{RC}$

so, $\dfrac{dv}{dt} + aV = b \qquad a = \dfrac{2}{RC}, \quad b = \dfrac{10}{RC}$

Then, $\boxed{V(t) = K_1 + K_2 e^{-at} \qquad \tau = \dfrac{1}{a} = \dfrac{RC}{2}}$

as $t \to \infty$

so, $0 = \dfrac{2}{RC} V(\infty) = \dfrac{10}{RC} = V(\infty) = \dfrac{10}{2} = \boxed{5V}$

so, $K_1 = 5V$

at $t = 0$

$V(0) = K_1 + K_2 = 0 = K_2 = -K_1 = -5V$

$\boxed{\begin{array}{l} V(t) = 5 - 5e^{-2t/RC} \\ K_1 = 5 \\ K_2 = -5 \\ \tau = \dfrac{RC}{2} \end{array}}$

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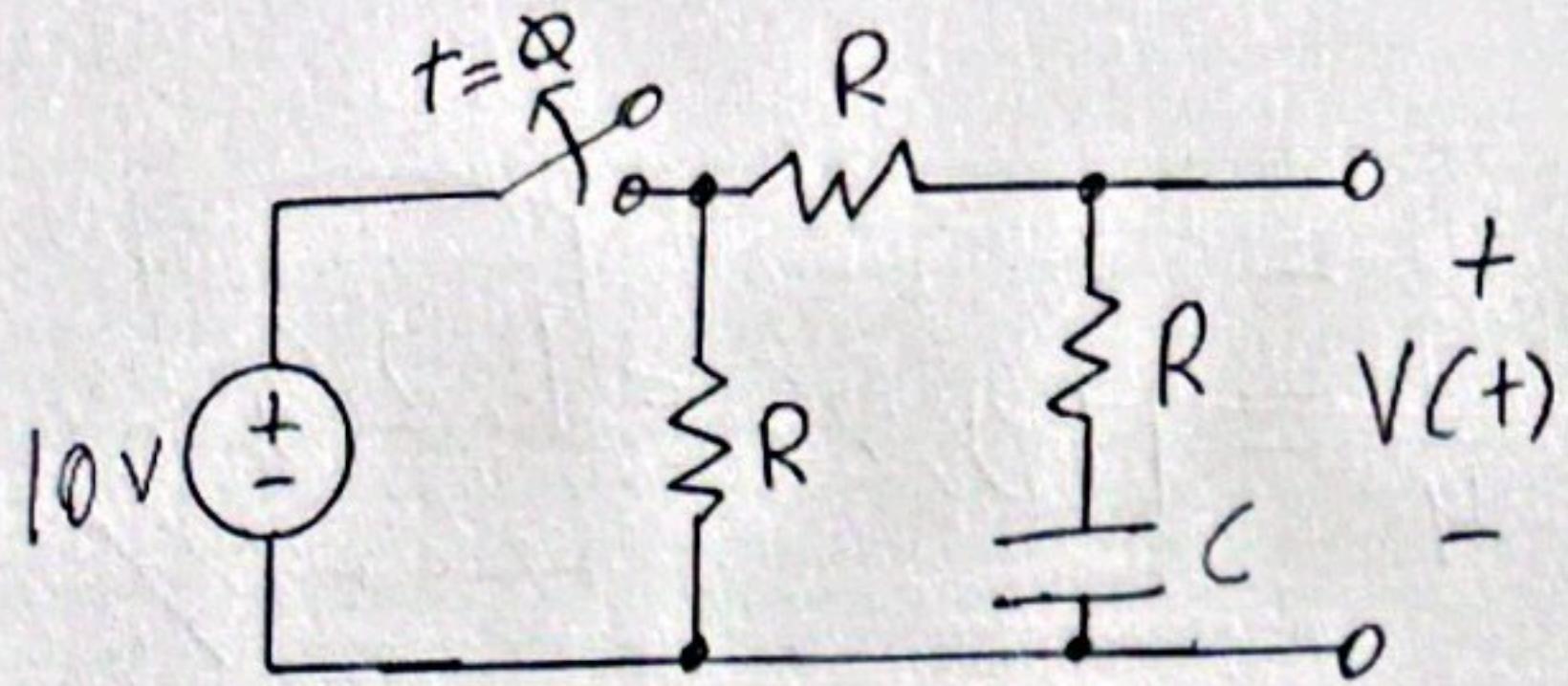
4. Given the following circuit, determine $V(t)$ for $t \geq 0$. Assume the circuit is in steady state for $t < 0$. At $t = 0$ the switch opens. The solution is of the form $V(t) = Ke^{-t/\tau}$. You are to determine the constants. Hint, once the switch opens, the voltage source does not play a role in $V(t)$.

1) $V(0) = 10V \cdot \dfrac{R}{R+R} = 10 \cdot \frac{1}{2} = 5V$

2) $V(0) = 5V$ 10
       $V(\infty) = 0$
       $\tau = RC = 3RC$

3) $V(t) = V(0^+)e^{-t/\tau}$

$\boxed{= 5e^{-t/(3RC)}V} \quad t \geq 0$
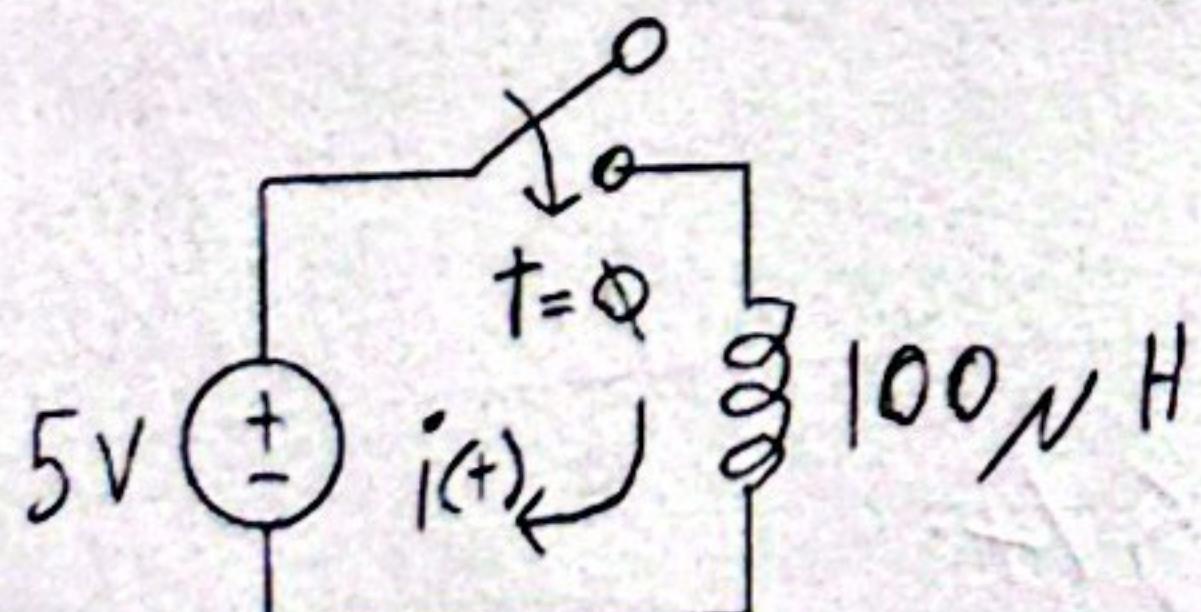
$\boxed{K = 5V, \quad \tau = RC}$

-3

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5. Given the following circuit, assume $i(t) = 0$ for $t < 0$. At $t = 0$ the switch closes. How long will it take for the current to reach 1 amp? There are formulas in the last page.

$V_L(t) = L\dfrac{di}{dt} = 5V \Rightarrow \dfrac{di}{dt} = \dfrac{5}{L}$

$i(0) = 0$
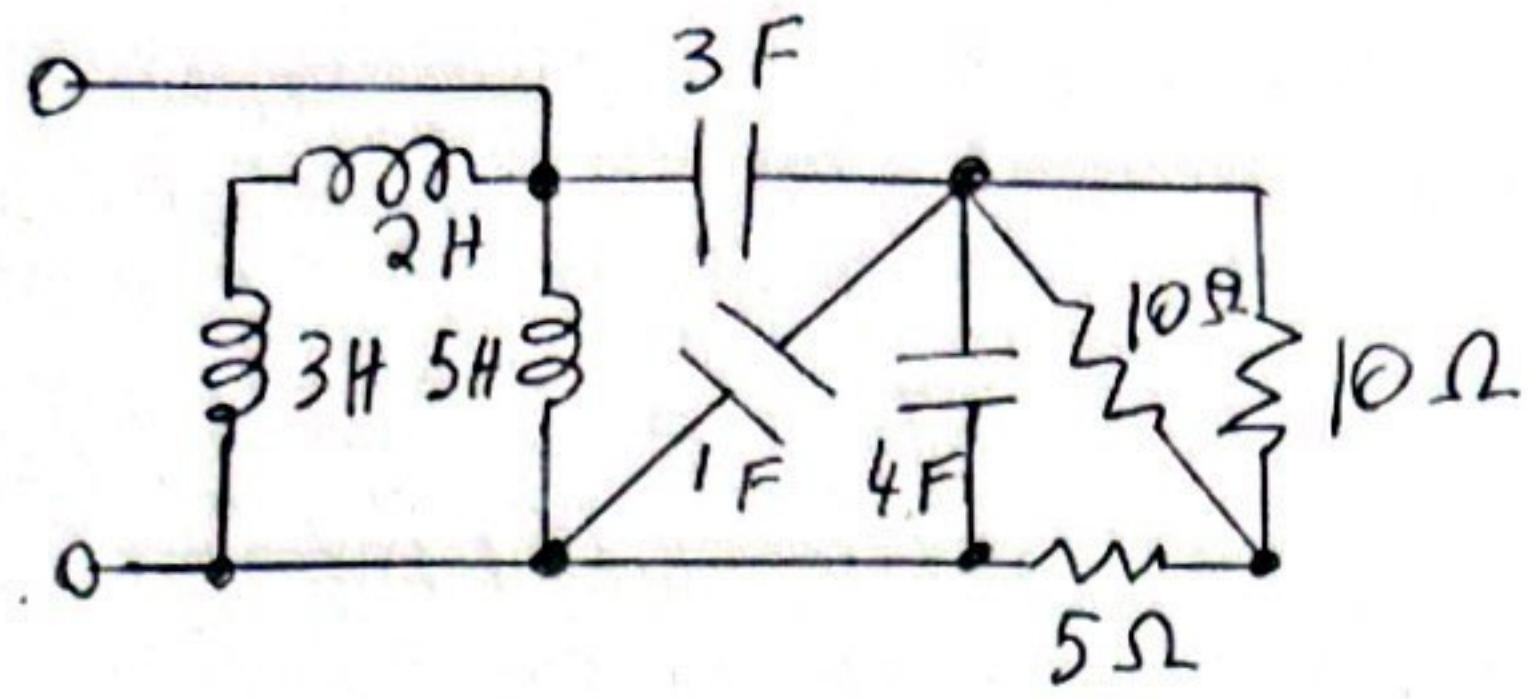
$i(t) = \displaystyle\int_0^t \dfrac{5}{L}dt' = \dfrac{5}{L}t$

$i(t_1) = 1$
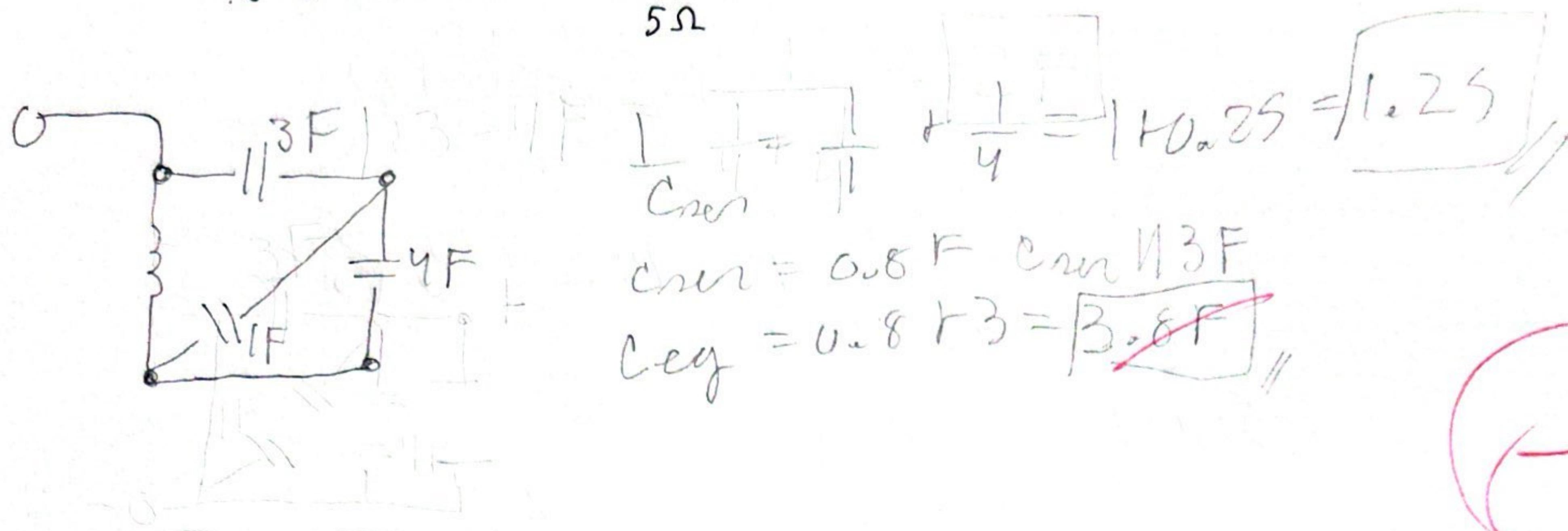
$1 = \dfrac{5}{L}t_1 \Rightarrow t_1 = \dfrac{L}{5} \quad t_1 = \dfrac{100e^{-6}}{5} = \sqrt{20e^{-6}} = 20\mu$
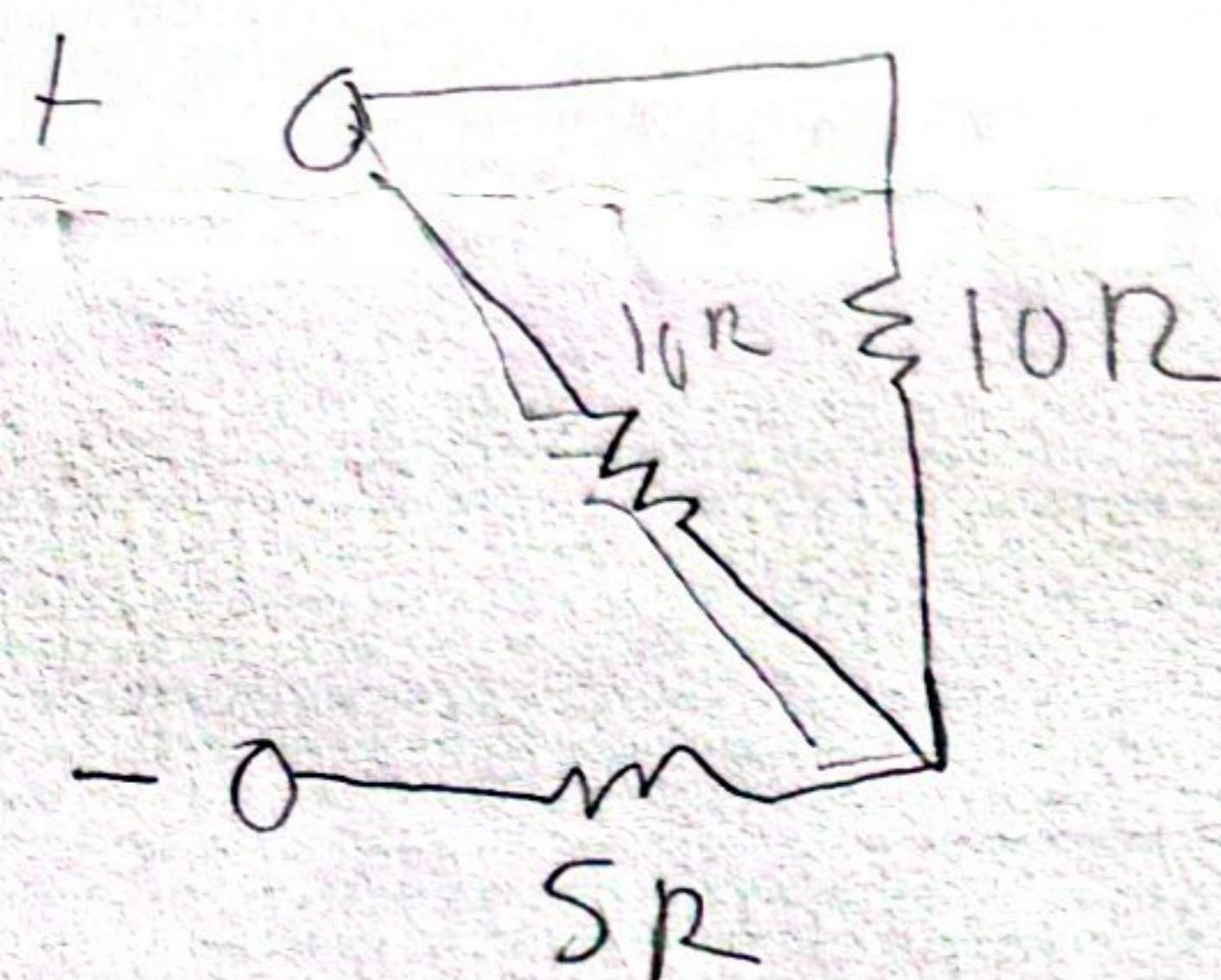
6. Reduce the circuit so that it has minimal components.

3 F

2H

3H 5H

10Ω

10Ω

1F 4F

5Ω

3F

4F

1F

$$\frac{1}{C_{new}} = \frac{1}{1} + \frac{1}{4} = 1 + 0.25 = \boxed{1.25}$$

$C_{new} = 0.8\,F \quad C_{new} \parallel 3F$

$C_{eq} = 0.8 + 3 = \boxed{3.8\,F}$

(-6)

$$\frac{1}{R_{eq}} = 10 + 10 = 20\,\Omega$$

10Ω 10Ω
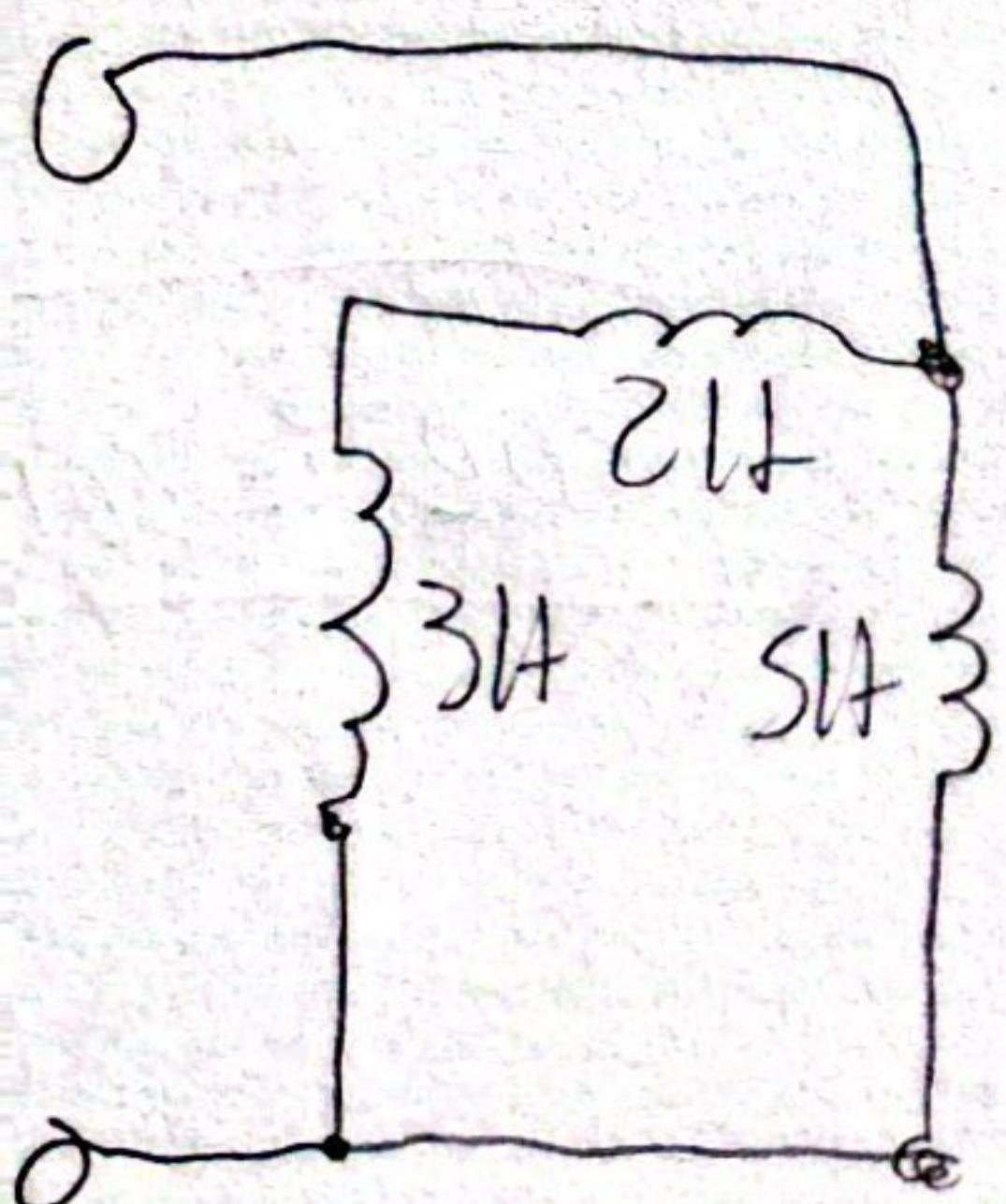
$$\frac{1}{R_{eq}} = \frac{1}{20} + \frac{1}{5} = 0.05 + 0.2 = 0.25$$

5R

$$R_{eq} = 4$$

10 Ω

$L_1 = 2H \quad L_2 = 3H, \quad L_3 = 5H$

$$\frac{1}{L_{eq}} = \frac{1}{2} + \frac{1}{3} + \frac{1}{5} \quad \frac{15}{30} + \frac{10}{30} + \frac{6}{30} = \frac{31}{30}$$

2H

3H 5H

$$L_{eq} = \frac{30}{31} H$$

2.5 H

final circuit ?