McGill University

Faculty of Engineering

April 2014

Final Examination

Version #1

ELECTRIC CIRCUITS 1

ECSE-200B

25 April 2014, 2pm

Examiner: Professor O. Liboiron-Ladouceur   Assoc Examiner: Professor F. Labeau

Student Name:		**McGill ID:**									

Signature: ____

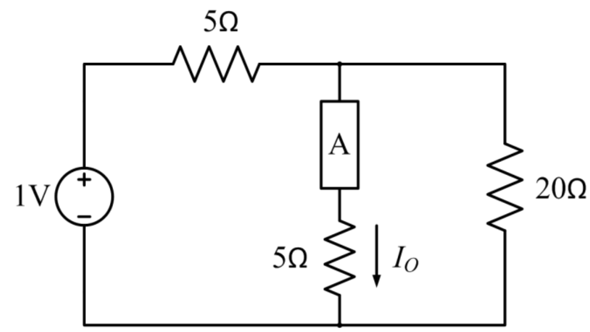
INSTRUCTIONS:

- Print your name, fill in your student ID number and sign on the line.
- This is a **CLOSED BOOK** examination. **NO CRIB SHEET** allowed.
- FACULTY **STANDARD CALCULATOR** permitted **ONLY**.
- This is, in part, a **MULTIPLE** CHOICE examination. As such, the following warning applies:

  The Examination Security Monitor Program detects pairs of students with unusually similar answer patterns on multiple-choice exams. Data generated by this program can be used as admissible evidence, either to initiate or corroborate an investigation or a charge of cheating under Section 16 of the Code of Student Conduct and Disciplinary Procedures.
- **Mark your answer to the multiple choice questions on the computer sheet using PENCIL ONLY.**
- Each question is worth 1 mark. No answer or incorrect answer to a multiple choice question receives 0 mark.
- Answer the problems in the exam booklet provided. Show your work and clearly indicate your answer.
- Read through all of the questions and ensure that you have a complete examination (see page number at the bottom). The examination consists of a total of 9 pages including this cover page.
- The examination consists of 2 parts. Part 1 consists of 10 multiple choice questions (10 marks). Part 2 consists of 4 problems (20 marks). This examination consists of a total of 30 marks.
- This examination paper **MUST BE RETURNED**

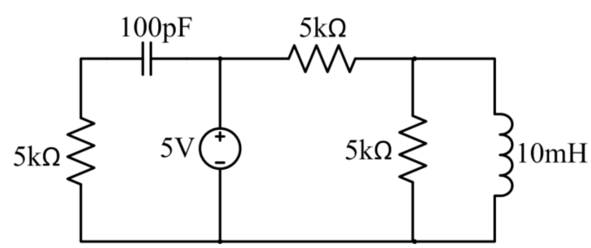
PART 1 –Indicate your answer to each question on the computer sheets provided. There is only one possible answer.

1.1. In the circuit shown below, a practical ammeter (rectangle labeled A) with a total internal resistance of 0.5Ω is used to measure the current I_0. What is the difference between the current measured and the actual current if the ammeter was ideal (i.e., the internal resistance is zero)?



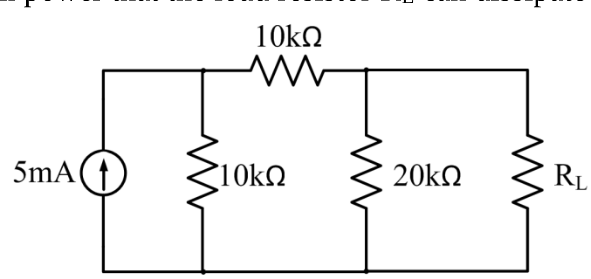
a) 0.2mA
b) 0.9mA
c) 3.8mA
d) 4.7mA

1.2. Assume that the circuit below reached DC steady-state. What is the power delivered by the 5V voltage source in the circuit?



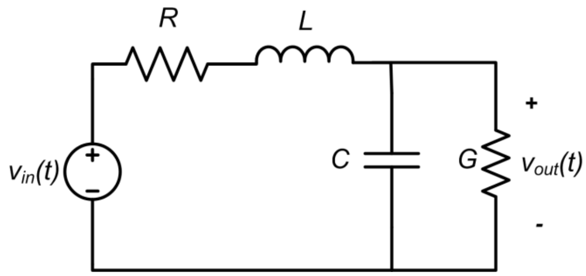
a) 2.5mW
b) 5mW
c) 7.5mW
d) 10mW

1.3. What is the maximum power that the load resistor R_L can dissipate?



a) 7.825mW
b) 15.625mW
c) 46.9mW
d) Cannot answer without knowing the resistance value of R_L

1.4. What is the differential equation of the circuit shown?



a) $v_{in}(t) = \left(1 + \frac{R}{G}\right) v_{out}(t) + \left(\frac{L}{G} + RC\right) \frac{dv_{out}(t)}{dt} + LC \frac{d^2 v_{out}(t)}{dt}$

b) $v_{in}(t) = (1 + GR) v_{out}(t) + (LG + RC) \frac{dv_{out}(t)}{dt} + LC \frac{d^2 v_{out}(t)}{dt}$

c) $v_{in}(t) = v_{out}(t) + LG \frac{dv_{out}(t)}{dt} + LC \frac{d^2 v_{out}(t)}{dt}$

d) None of the above equations is correct

1.5. How is energy stored in an inductor?

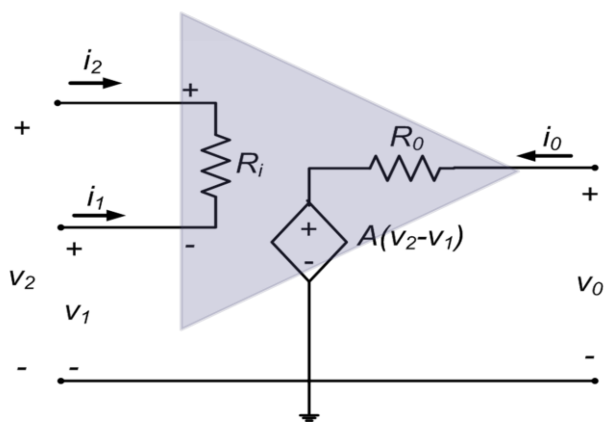
a) Energy is stored in the form of electric charges between two metallic plates.

b) Energy is stored in the form of electric charges in a coiled conductor.

c) Energy is stored within a continuous change of the voltage across an inductor.

d) Energy is stored within the magnetic flux within a coiled conductor.

1.6. What assumptions are made about the input resistance R_i, the output resistance R_o, and the open-loop gain A of the practical Op-Amp circuit model shown below so that it behaves as the ideal Op-Amp model?



a) R_i is infinite, R_o is 0, and A is large

b) R_i is 0, R_o is infinite, and A is large

c) R_i is infinite, R_o is 0, and A is small

d) R_i is 0, R_o is infinite, and A is small

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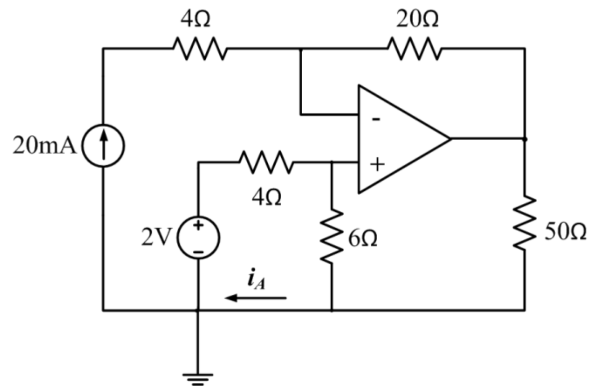
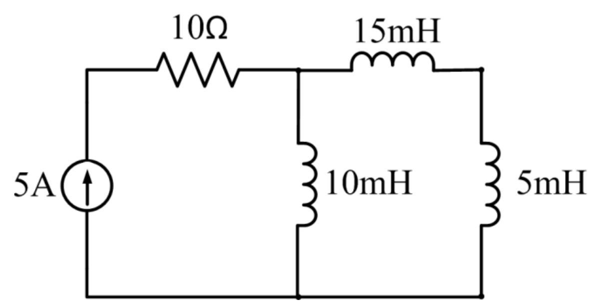
1.7. Assume an ideal Op-Amp in the circuit shown below. What is the current $\boldsymbol{i_A}$?



a) 0mA
b) 216mA
c) 365mA
d) None of the above

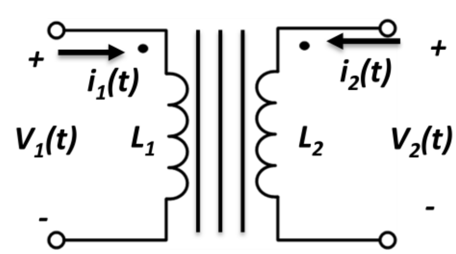
1.8. Assume that the circuit below is in DC steady state. What is the total energy stored in the inductors of the circuit?



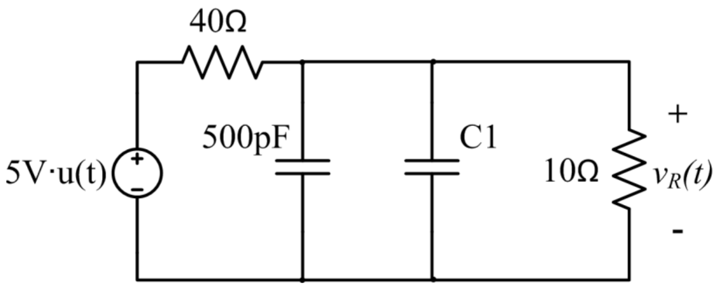
a) 83.33mJ
b) 171.88mJ
c) 187.5mJ
d) 375mJ

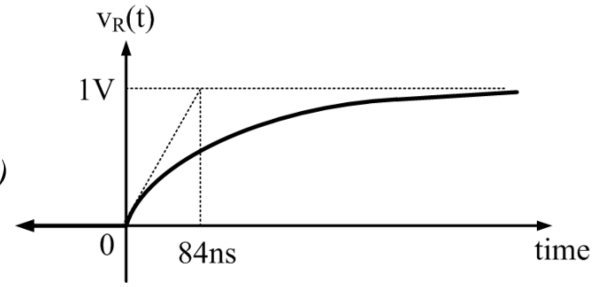
1.9. For the ideal transformer shown, what is the mutual inductance M if L_1 is 50nH and L_2 is 10nH?

a) 22.36nH
b) 24.49nH
c) 60nH
d) 500nH



1.10. What is the capacitance of the capacitor C1 in the circuit shown below? The diagram of the voltage $v_R(t)$ across the 10kΩ resistor is shown.

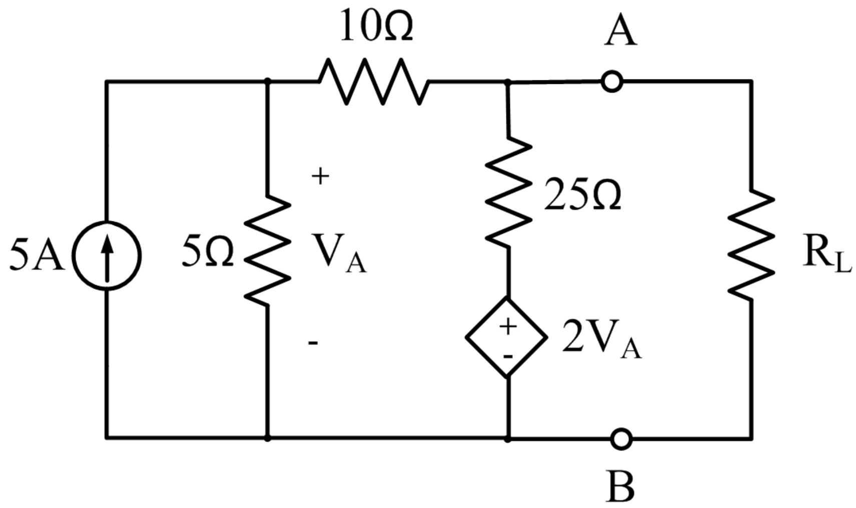




a) 10nF
b) 7.9nF
c) 1.18nF
d) 11nF

PART 2 – This part consists of 4 questions. Write your answer in the exam booklet. Show your work and clearly indicate your answer.

2.1. Consider the circuit shown below and answer the following questions. [5pts]



(a) Find the Thévenin equivalent circuit with respect to terminals A and B.
(b) If the voltage across the load resistance (V_{AB}) is constrained to 22.5V, what is the power transferred to the load resistance R_L?

a) To find the thevenin equivalent circuit, the open-circuit voltage (voc) is needed and the equivalent resistance. To find the equivalent resistance, the short-circuit current (isc) is needed.

Voc is found by keeping the terminals A and B open. A KCL equation is found at the top node of the 5ohm resistance:

$$-5A + \frac{V_A}{5} + \frac{V_A - V_{OC}}{10} = 0$$

A 2nd equations is required. We note that the current through the 10ohm resistance will flow also in the 25 ohm resistance. A KCL equation at terminal A is found:

$$\frac{V_A - V_{OC}}{10} = \frac{V_{OC} - 2V_A}{25} \rightarrow V_{OC} = \frac{9}{7} V_A$$

Using the two equations:

$$V_A = \frac{350}{12} V = \frac{175}{6} V \rightarrow V_{OC} = \frac{9}{7} \frac{175}{6} = 37.5V$$

Then, the short circuit current is found by shorting terminals A and B. A KCL at the same node as above is obtained:

$$-5A + \frac{V_A}{5} + \frac{V_A}{10} = 0 \rightarrow V_A = \frac{50}{3} V \rightarrow i_{SC} = \frac{V_A}{10} = \frac{5}{3} A$$

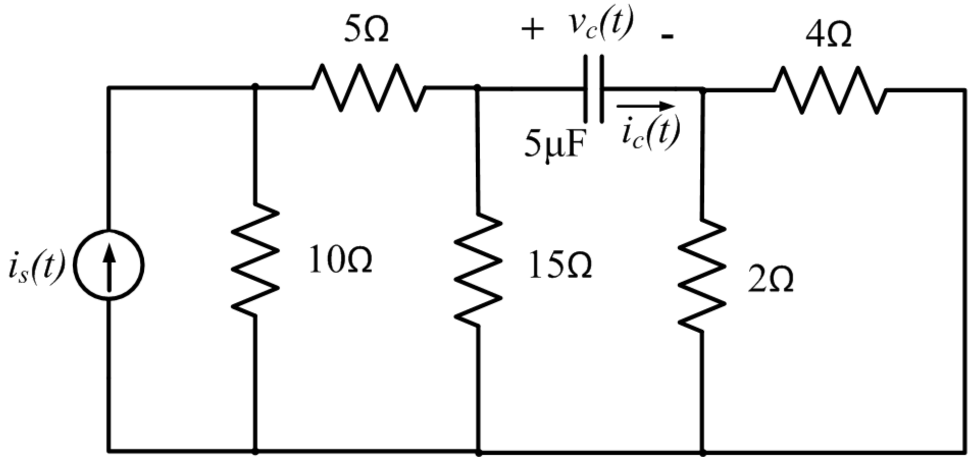
The equivalent resistance is also obtained: $R_T = \frac{V_{OC}}{i_{SC}} = 37.5 \cdot \frac{3}{5} = 22.5\Omega$

The drawing of the circuit (no access to visio at this point) would be a voltage source of 37.5V in series with 22.5 ohms. The relationship between the voltage and the current at the terminals have been obtained in part a) $i_{AB} = i_{SC} - \frac{v_{AB}}{R_T} = \frac{5}{3} A - \frac{22.5V}{22.5\Omega} = \frac{2}{3} A$

So the power transferred is: $P_{AB} = i_{AB} \cdot v_{AB} = \frac{2}{3} \cdot 22.5V = 15W$

2.2. Consider the circuit shown below and the given equation for the current source $i_s(t)$. The circuit is in DC steady state for $t < 0$. Answer the following questions. [5pts]

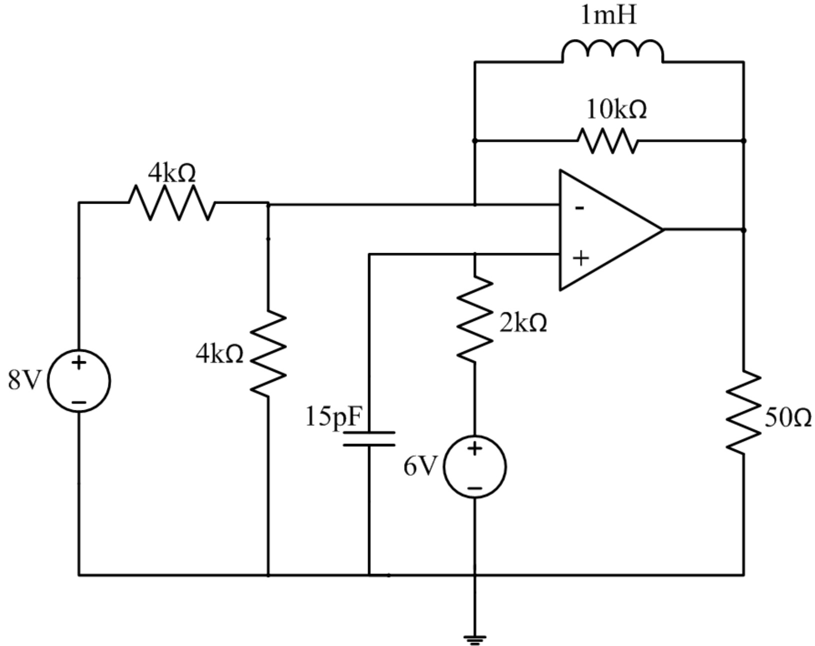
$$\boldsymbol{i_s(t) = 2A \cdot u(t) - 2A \cdot u(t - 40\mu s)}$$



(a) Find the capacitor voltage $v_c(t)$ and its current $i_c(t)$.

(b) Find the energy stored in the capacitor at t = 20μs.

2.3. Consider the circuit shown below. Assume that the Op-Amp is ideal and that the circuit is in DC steady-state. Answer the following questions. [5pts]

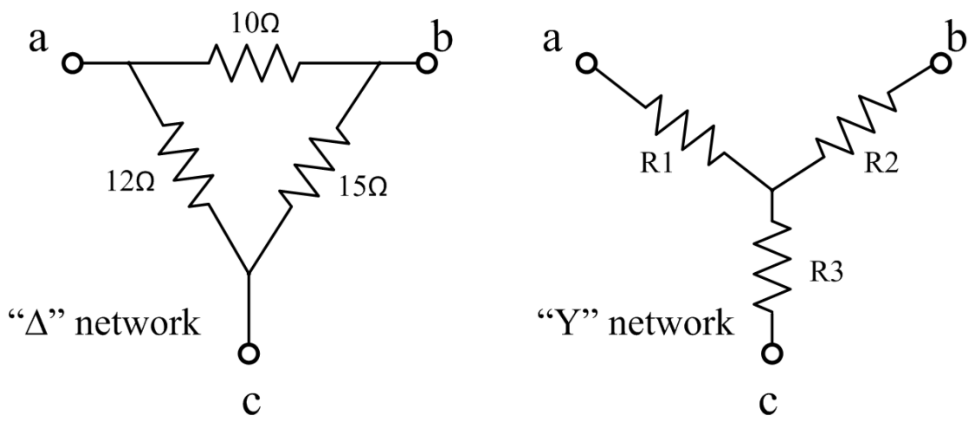


(a) Find the power absorbed by the 50Ω load resistor.
(b) Find the energy stored in the 1mH inductor

a) In DC steady-state, the capacitor is open and the inductor is shorted. This means that the output node of the opamp will be at the same voltage as the inverting node of the op-amp. The non-inverting node voltage is set by the 6V power supply. Thus, the output voltage is 6V and the power absorbed by the load resistance is: $P = \frac{v^2}{50} = \frac{36}{50} = 0.72W$

b) The energy in the inductor is proportional to the current going through. Thus, we find the current using source transformation on the 8V supply with the resistance in series which can be transformed to a 4V supply in series with a 2kohm resistor. The current is then: $i = \frac{4V-6V}{2k\Omega} = -1mA$. The energy stored in the inductor is thus: $U = \frac{1}{2}Li^2 = 0.5 \cdot 1mH \cdot (1mA)^2 = 0.2pJ$

2.4. Consider the Δ network (left) and the Y network (right) shown below. Answer the following questions. [5pts]



(a) Find the equivalent resistance for all terminal pairs (ab,bc,ca) of the Δ network.
(b) Find R1, R2, and R3 such that the Y network has the same equivalent resistance for all terminal pairs (ab,bc,ca).