UNIVERSITY OF TORONTO
FACULTY OF APPLIED SCIENCE AND ENGINEERING

Q1	/25
Q2	/25
Q3	/25
Q4	/25
Total	/100

FINAL EXAMINATION

APRIL 2003
EXAM TYPE: A
First Year Programs: CHE, CIV, IND, LME, MEC, MMS

ECE110H1S: ELECTRICAL FUNDAMENTALS

EXAMINERS: N.P. Kherani, B. Wang

NAME: ______________________________
Last First

STUDENT NO.: ______________________________

INSTRUCTIONS:

- This is a Type A examination; no aids are allowed.
- Only non-programmable calculators are allowed.
- Answer all parts of all four questions.
- All four questions are of equal weight.
- The weight of each of the individual parts of each question is stated in the margins.
- All work is to be done on these pages.
- Place your final answers in the provided boxes unless instructed otherwise.
- When answering the questions include all the steps of your work on these pages. For additional space, you may use the back of the preceding page.
- Do not unstaple this exam.

CONSTANTS:

$e = 1.6 \times 10^{-19}\text{C}$ $\varepsilon_o = 8.85 \times 10^{-12}\text{F/m}$ $\mu_o = 4\pi \times 10^{-7}\text{H/m}$

Question 1: Electricity and Magnetism

PART A: General

Answer the following questions.

[1] (i) The electric field lines always point away from ______________________ charges and terminate at ______________________ charges.

[1] (ii) What is the universal reference for electric potential?

____

[1] (iii) List two ways by which the capacitance of a capacitor can be increased.

____

____

[1] (iv) What fundamental principle underlies Kirchoff's Current Law ?

____

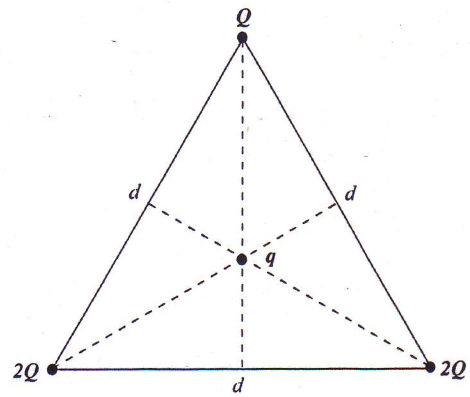
[1] (v) Faraday's Law is expressed mathematically as:

____

Question 1: Electricity and Magnetism

PART B: Electrostatics

Three point charges are positioned as shown on the corners of an equilateral triangle of side d. The three point charges are of positive polarity. A test charge q is located at the center of the triangle. q has a magnitude of $+e$.



[5] Determine the electric force (magnitude and direction) on the test charge q due to the three point charges on the corners of the triangle.

F =

Question 1: Electricity and Magnetism

PART C: Capacitor

A parallel plate capacitor, under vacuum, has $+50\ \mu C$ of charge on one plate and $-50\mu C$ of charge on the other. The plates are separated by 1 cm, and the area of each plate is $1\ cm^2$.

[2] (i) Find the magnitude of the electric field between the plates of the capacitor.

$|\mathbf{E}| =$

[1] (ii) How much work would you have to do in order to move an electron from the positively charged plate to the negatively charged plate of the capacitor in vacuum?

$W =$

[2] (iii) The capacitor is now filled with ceramic ($\kappa = 130$), what is the capacitance of the capacitor?

$C =$

Question 1: Electricity and Magnetism

PART D: Magnetism

A tightly wound coil containing 200 turns and of radius 5 cm has a current of 2 A. Assume that the closely wound 200 turns lie in a single plane and that the radius of each loop, for all intents and purposes, is 5 cm.

[1] (i) What is the magnitude of the magnetic field at the center of the coil?

|**B**| =

[2] (ii) An electron traverses through the magnetic field in part (i) such that the electron has a speed of 3000 km/s when it is at the center of the coil. The direction of electron propagation at this instant is perpendicular to the magnetic field. What is the magnitude of the magnetic force exerted on the electron at this instant?

|**F**| =

[1] (iii) Find the magnitude of the electric field which will completely balance the magnetic force in part (ii)?

|**E**| =

[1] (iv) How would you create the electric field found in part (iii) ?

Question 1: Electricity and Magnetism

PART E: Magnetic Induction

A magnetic field, uniform in space but varying linearly with time, is represented by the relation $|\mathbf{B}(t)| = \alpha\, t$, where α [T s^{-1}] is the rate of change of the magnetic field with respect to time, t is time in seconds, and $|\mathbf{B}(t)|$ is the magnetic field in tesla. A circular loop of radius 5 cm is immersed in this magnetic field. The loop has a small gap in it, the ends of which are connected to a resistor.

[1] (i) Draw a diagram showing how you would arrange the circular loop with respect to the magnetic field in order to induce the maximum possible *emf* across the resistor.

[2] (ii) What is the rate of change of the magnetic field that generates an emf of 10 V ?

$\alpha =$

[1] (iii) If the induced current in the circuit is 3A, what is the resistance of the resistor? Assume that the loop resistance is negligible.

$R =$

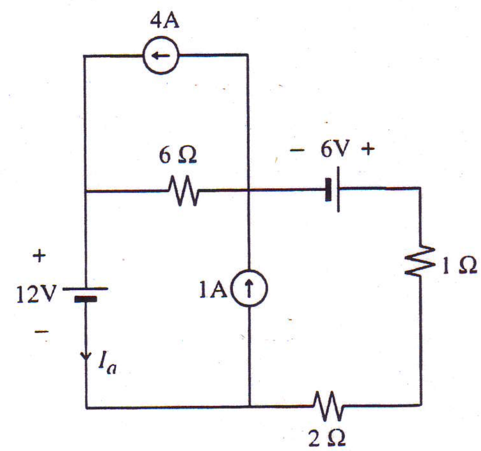
[1] (iv) How much power is delivered to the resistor ?

$P =$

Question 2: DC Circuits

PART A: Nodal Analysis

Consider the circuit shown below.



[4] (i) Find the current I_a using nodal analysis

$I_a =$

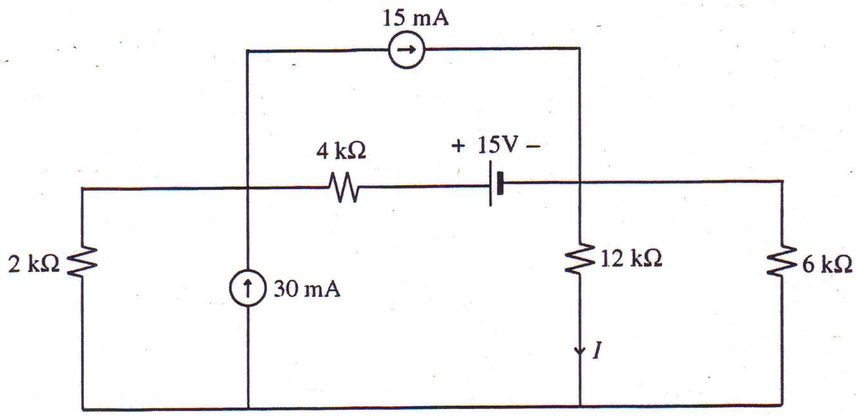
[2] (ii) Calculate the power associated with the 12 V source. Also, state whether the power is being absorbed or supplied by the 12 V source.

$P_{12V} =$ Absorbing ☐ Supplying ☐

Question 2: DC Circuits

PART B: Superposition

Consider the following circuit.



[9] Determine the current I using superposition.

I_1 due to 30 mA source =

I_2 due to 15 mA source =

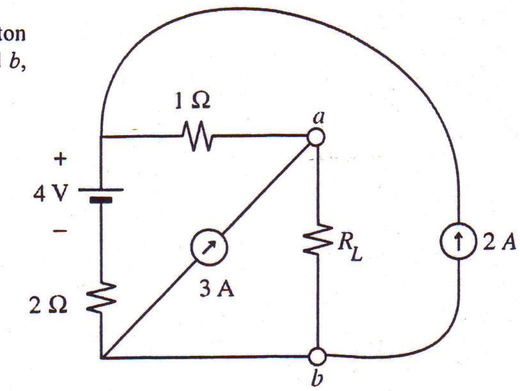
I_3 due to 15 V source =

$I =$

Question 2: DC Circuits

PART C: Source Transformation

[6] (i) Use source transformation to find the Norton equivalent circuit between terminals a and b, having removed the load, R_L.



Draw the Norton Equivalent Circuit:

[1] (ii) How much power will be delivered to a 1 Ω load connected between a and b?

P_1 =

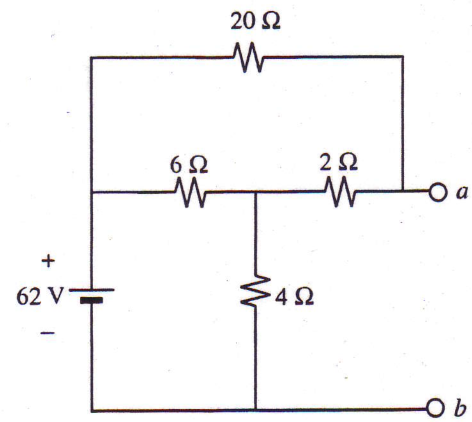
[1] (iii) What is your choice of R_L in order to draw maximum power from the system?

R_L =

Question 2: DC Circuits

PART D: Thévenin Equivalence

[2] Obtain the Thévenin equivalent *resistance* between terminals *a* and *b* for the circuit shown.

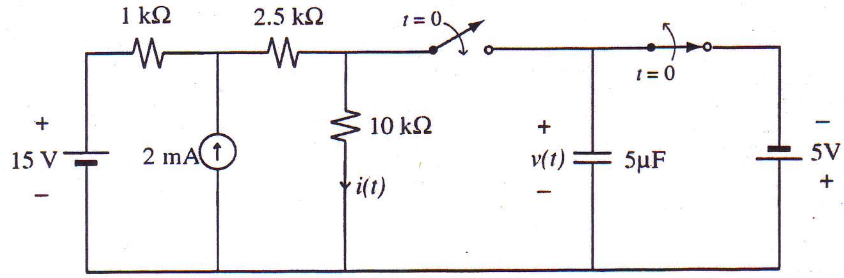


$R_{Th} =$

Question 3: Transient Analysis

PART A

The two switches are switched simultaneously at time $t=0$ in the circuit shown below. Assume that the switches were in the positions shown for a long time prior to time zero.



[2] (i) Find $v(0^-)$ and $i(0^-)$.

$v(0^-)$ =

$i(0^-)$ =

[2] (ii) Find $v(0^+)$ and $i(0^+)$.

$v(0^+)$ =

$i(0^+)$ =

[2] (iii) Find τ when $t>0$.

τ =

Question 3: Transient Analysis

PART A (...continued)

[2] (iv) Find $v(\infty)$ and $i(\infty)$.

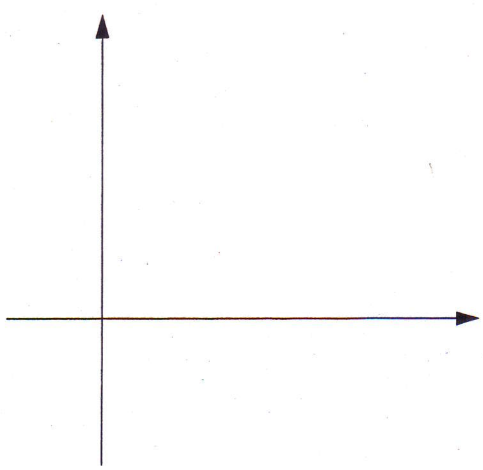
$v(\infty)$ =

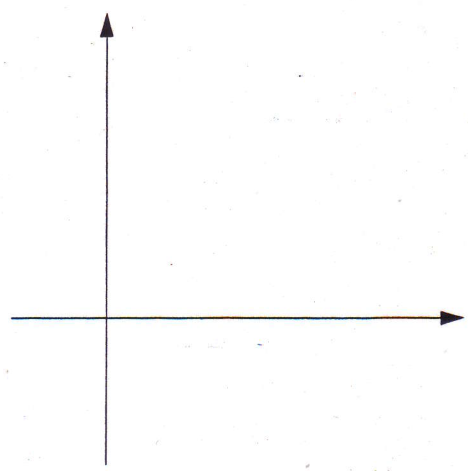
$i(\infty)$ =

[7] (v) Determine $v(t)$ and $i(t)$ for $t > 0$. Also, sketch $v(t)$ and $i(t)$ for all time. Clearly indicate all the important quantities on the graphs.

$v(t)$ =

$i(t)$ =

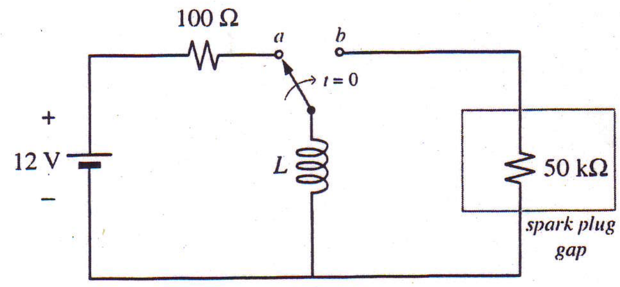




Question 3: Transient Analysis

PART B

The circuit on the right shows a 12V battery being used to establish a current through an inductor. This current is then used to generate a voltage of sufficient magnitude to cause breakdown of the atmosphere (for example, vapourized gasoline-air mixture) in the spark-plug gap. The spark plug gap can be modelled by a 50kΩ resistor until the moment when breakdown occurs.



[2] (i) Immediately after the switch is switched ($t=0^+$), what is the voltage generated across the gap?

$V_{gap,\, t=0^+} =$

[5] (ii) To ensure that breakdown occurs, it is desired that the required high voltage remain present for at least 5 ms. It is estimated that 75% of the initial voltage is sufficient to cause breakdown. Assuming that the spark plug gap resistance does not change, what is the magnitude of the inductance which will ensure that this design requirement is satisfied? Is this the minimum or maximum value?

$L=$

Minimum ☐

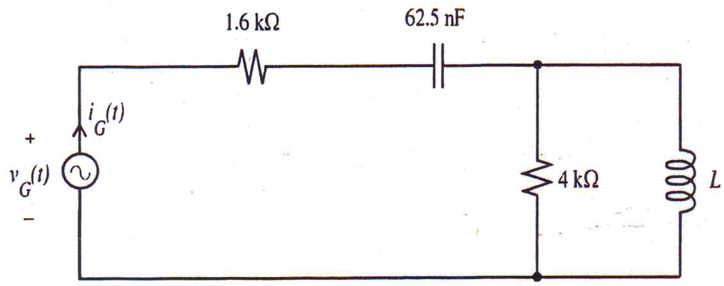
Maximum ☐

[3] (iii) Assume that after repeated switching, a resistive coating forms only on switch contact b. This coating may be represented by a resistor. What is the magnitude of this resistor which will cause the circuit to fail? (Failure, in this case, constitutes not producing the required voltage for breakdown, as defined above.)

$R_{contact} =$

Question 4: AC Circuits

PART A



[7] (i) The source voltage in the circuit is $v_G(t) = 96\ cos\ (\ 10000\ t\ )$ V. Find the value(s) of L such that $i_G(t)$ is in phase with $v_G(t)$.

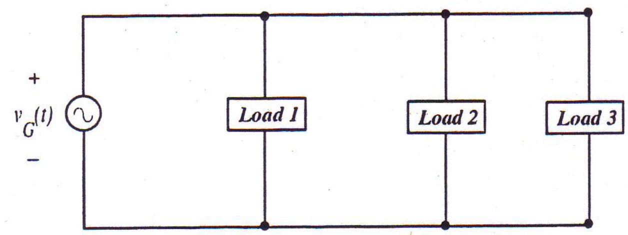
$L =$

[3] (ii) For the value(s) of L found in (i), determine the steady-state expressions for $i_G(t)$.

$i_G(t)=$

Question 4: AC Circuits

PART B



Load 1 is a 240 Ω resistor in series with an inductive reactance of 70 Ω; *Load 2* is a capacitive reactance of 120 Ω in series with a 160 Ω resistor; and *Load 3* is a 30 Ω resistor in series with a capacitive reactance of 40 Ω. The frequency of the voltage source is 60 Hz.

[2] (i) Draw the circuit described above in the frequency domain.

[3] (ii) Find the power factor of each load.

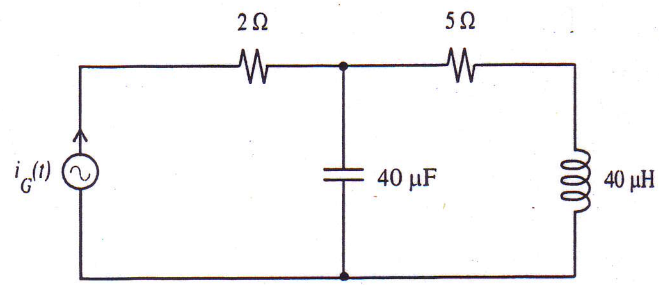
PF_1 =
PF_2 =
PF_3 =

[5] (iii) Find the power factor of the composite load seen by the voltage source.

PF =

Question 4: AC Circuits

PART C



[5] Find the average (real) and reactive powers delivered by the ideal current source, $i_G(t) = 30\,cos\,(\,25000\,t\,)$ mA.

P =
Q =