

**UNIVERSITY OF TORONTO  
FACULTY OF APPLIED SCIENCE AND ENGINEERING**

**FINAL EXAMINATION**

APRIL 2002

EXAM TYPE: A

First Year Programs: CIV, LME, MEC, IND, CHE, MMS

<b>Q1</b>	<b>/25</b>
<b>Q2</b>	<b>/25</b>
<b>Q3</b>	<b>/25</b>
<b>Q4</b>	<b>/25</b>
<b>Total</b>	<b>/100</b>

**ECE110H1 S: ELECTRICAL FUNDAMENTALS**

EXAMINERS: N.P. Kherani, B. Wang, S. Zukotynski (*Co-ordinator*)

**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:**

$$e = 1.6 \times 10^{-19} \text{ C}$$

$$\epsilon_0 = 8.85 \times 10^{-12} \text{ F/m}$$

$$\mu_0 = 4\pi \times 10^{-7} \text{ H/m}$$

**Question 1: Electricity and Magnetism****PART A: General**

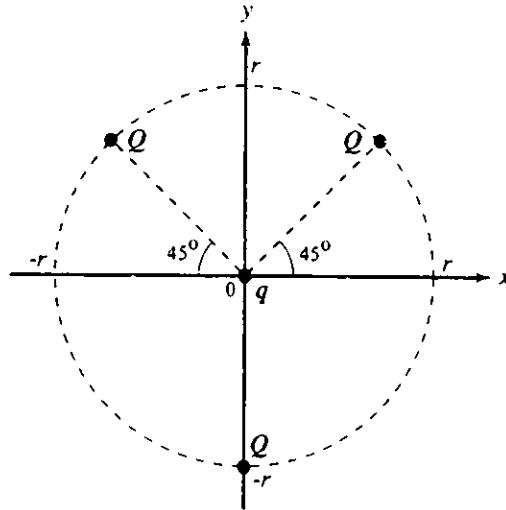
Answer the following questions.

- [1] (i) The mathematical relationship which describes the interaction between stationary charges is known as \_\_\_\_\_.
- [1] (ii) The electric and gravitational forces of attraction between an electron and a proton separated by a distance  $r$  illustrate the significance of the electric force. The relative strength (i.e., the ratio) of the electric force to the gravitational force ( $|\vec{F}_E|/|\vec{F}_G|$ ) between an electron and a proton is (circle the correct answer)
- (a)  $\sim 10^{-39}$   
(b)  $\sim 10^{-13}$   
(c)  $\sim 1$   
(d)  $\sim 10^{13}$   
(e)  $\sim 10^{39}$ .
- [1] (iii) It is recognized that a current carrying conductor creates a *magnetic field* around itself, and that a *magnetic force* is observed between current carrying conductors.  
Explain why some materials inherently have a strong magnetic field around themselves while others have a weak or essentially no magnetic field around themselves.
- [2] (iv) Explain how/why a coil of wire subjected to an externally applied *emf* (electromotive force) generates an opposing *emf*.

### Question 1: Electricity and Magnetism

#### PART B: Coulomb's Law

Three point charges are positioned as shown on a circle of radius  $r$ . The three point charges are of equal magnitude  $Q$  and  $Q > 0$ . A test charge  $q$  is located at the origin of the circle.  $q$  has a magnitude of  $-e$ .



- [5] (i) Determine the electric force (magnitude and direction) on the test charge  $q$  due to the three point charges on the circle.

$$\mathbf{F} =$$

- [1] (ii) If  $q$  had a magnitude of  $+e$ , what would be the electric force (magnitude and direction) on the test charge  $q$  due to the three point charges on the circle.

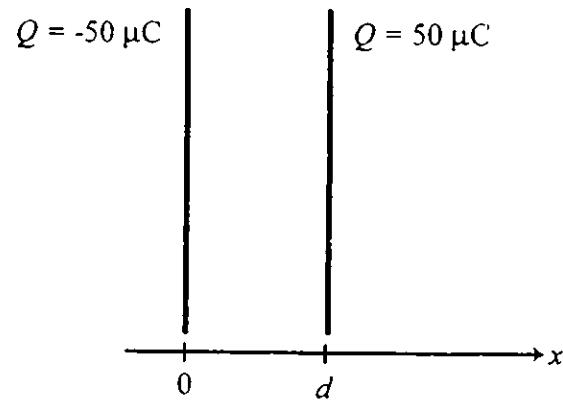
$$\mathbf{F} =$$

### Question 1: Electricity and Magnetism

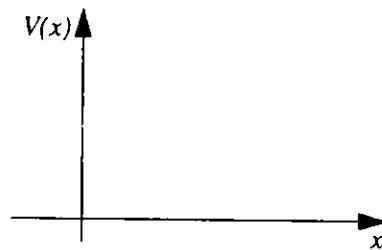
#### PART C: Electric Field, Potential, and Capacitance

- [3] (i) Consider two thin parallel conducting plates separated by a distance  $d$ . Each conducting plate has an area of  $100 \text{ cm}^2$ . One plate has a charge of  $50 \mu\text{C}$  while the other plate has a charge of  $-50 \mu\text{C}$ . Assume that the charged conducting plates can be represented as infinite sheets of charge. Find the electric field strength between the plates and outside the plates. Also, on the figure below show the direction of the electric field lines.

$$|E| =$$



- [3] (ii) If the separation  $d$  is 5 mm, find the potential  $V(x)$  for all values of  $x$ . Assume that the plate at  $x=0$  is at ground potential. Sketch the potential as a function of  $x$ .



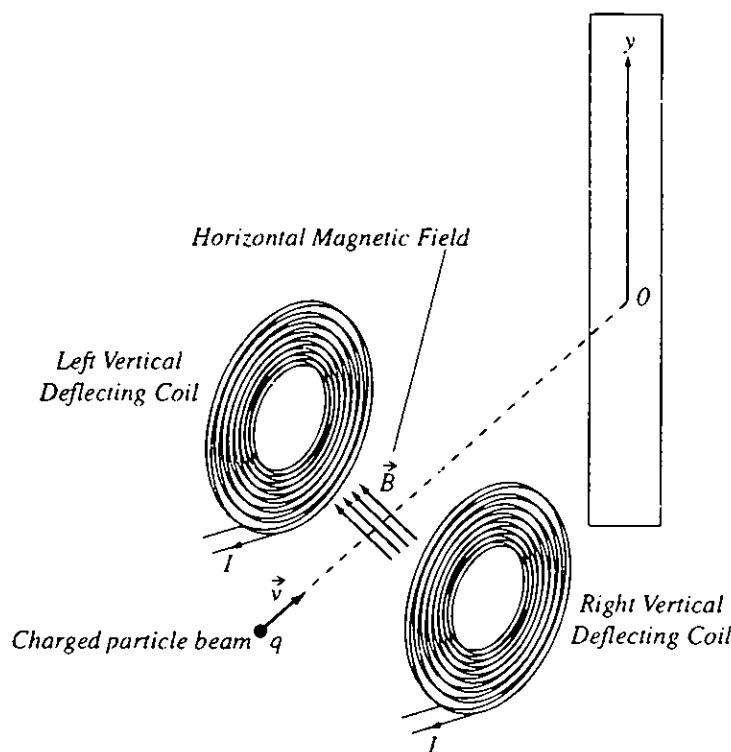
- [1] (iii) Find the capacitance of the parallel plates.

$$C =$$

### **Question 1: Electricity and Magnetism**

**PART D: Magnetism**

Magnetic field is used to deflect charged particles in a variety of applications. The diagram below illustrates the deflection of a charged particle beam (particle charge  $q$  and velocity  $\vec{v}$ ) by a horizontal magnetic field ( $\vec{B}$  which is perpendicular to  $\vec{v}$ ). The magnetic field is generated by a pair of coils; the electrical current in the coils is  $I$ . Assume that the electric field is negligible.



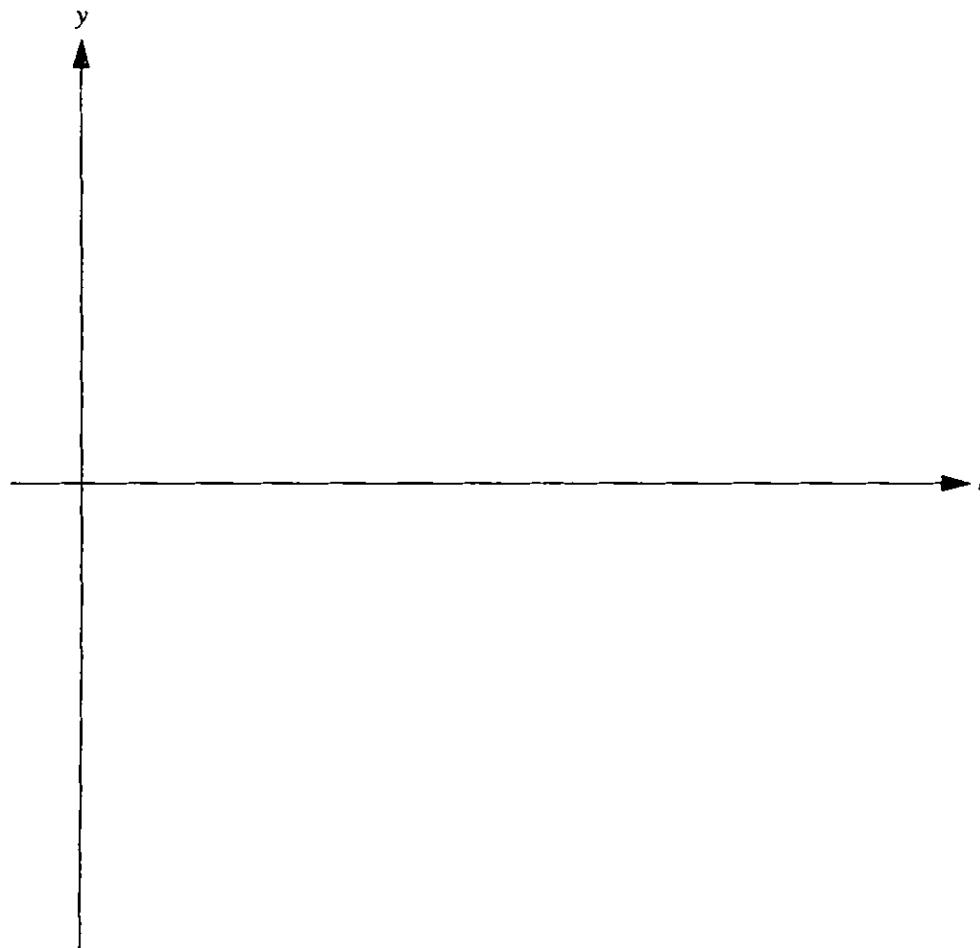
- [1] (i) In order to generate the magnetic field in the direction shown, what is the direction of the current  $I$ ? Explain your answer?

[2] (iii) If  $q$  is positive and the magnetic field direction is as shown, what is the direction of deflection (i.e., *up* (positive  $y$ ) or *down* (negative  $y$ ))? Explain your answer.

**Question 1: Electricity and Magnetism**

- [1] (iv) What is the direction of deflection if the charged particle beam consists of electrons?

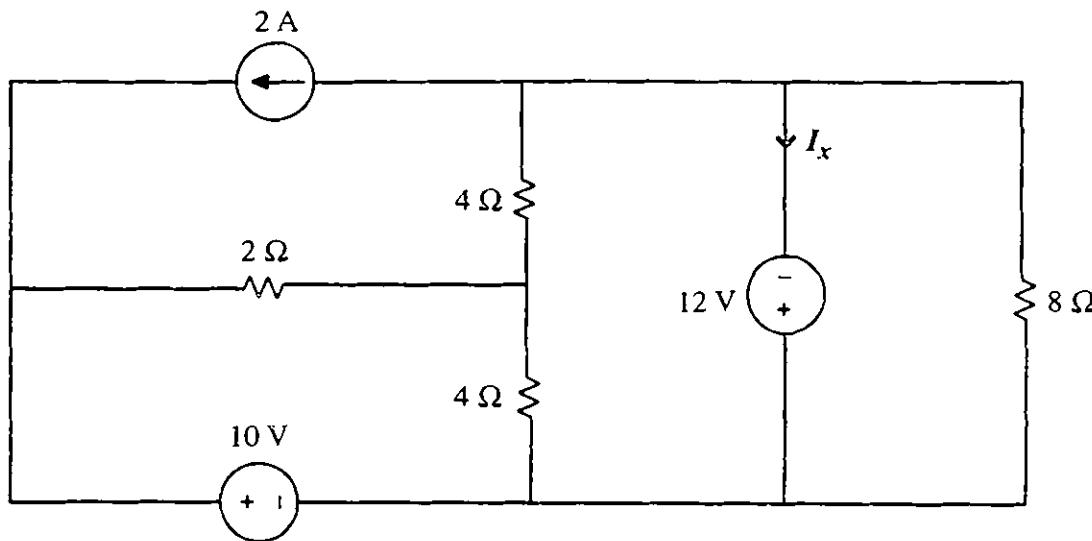
- [2] (v) If the charged particle beam consists of electrons and the current in the coils is of the form  $I(t) = I_p \sin(\omega t)$ , where  $I_p$  is the peak current and  $\omega$  is the angular frequency, sketch the position of the deflected beam as a function of time.



- [1] (vi) How would you achieve the capability to deflect the charged particle beam horizontally (in addition to vertical deflection)?

**Question 2: DC Circuits****PART A: Superposition**

Consider the circuit shown below.



- [8] (i) Using superposition find the current  $I_x$ .

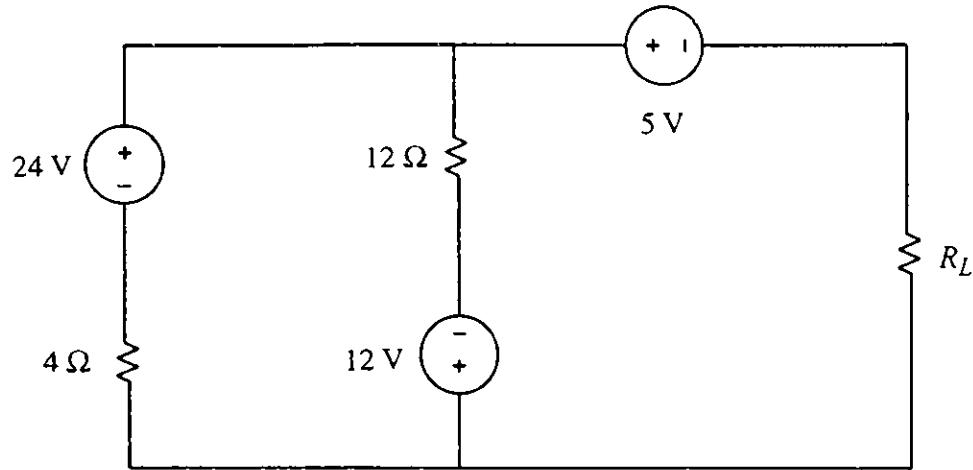
$$I_x =$$

- [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 <input type="checkbox"/>
	Supplying <input type="checkbox"/>

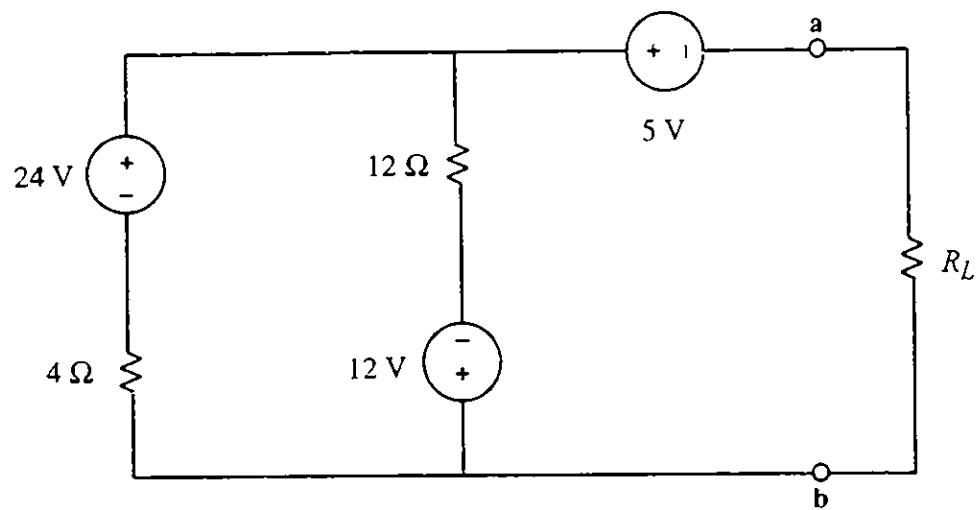
**Question 2: DC Circuits****PART B: Nodal Analysis and Thévenin & Norton Equivalent Circuits**

For the following circuit:



- [4] (i) Write a set of equations whose solution would yield all the nodal voltages (having defined a node as a point where terminals of two or more components meet). Label the node voltages  $V_1, V_2, \dots$ . Also, specify the reference node,  $V_r$

Set of Equations

**Question 2: DC Circuits**

- [7] (ii) Find the Norton equivalent circuit to the left of terminals **a-b** (that is, having removed the load resistor  $R_L$ ) using any method of your choice. The circuit has been reproduced above for your convenience.

Norton equivalent circuit

**Question 2: DC Circuits**

- [2] (iii) What is the maximum power that can be delivered to the load?

$$P_{\max} =$$

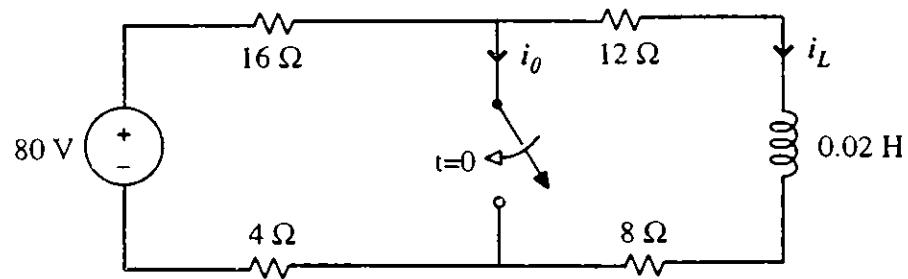
- [2] (iv) Determine the value of the load resistance,  $R_L$ , which will draw a current of 1.25 A.

$$R_L =$$

### Question 3: Transient Analysis

#### PART A

The switch is closed at time  $t=0$  in the circuit shown below. Assume that the switch was open for a long time prior to time zero.



- [7] (i) Find  $i_L(0^+)$ ,  $i_L(\infty)$ , and  $i_L(t)$  for  $t > 0$ .

$$i_L(0^+) =$$

$$i_L(\infty) =$$

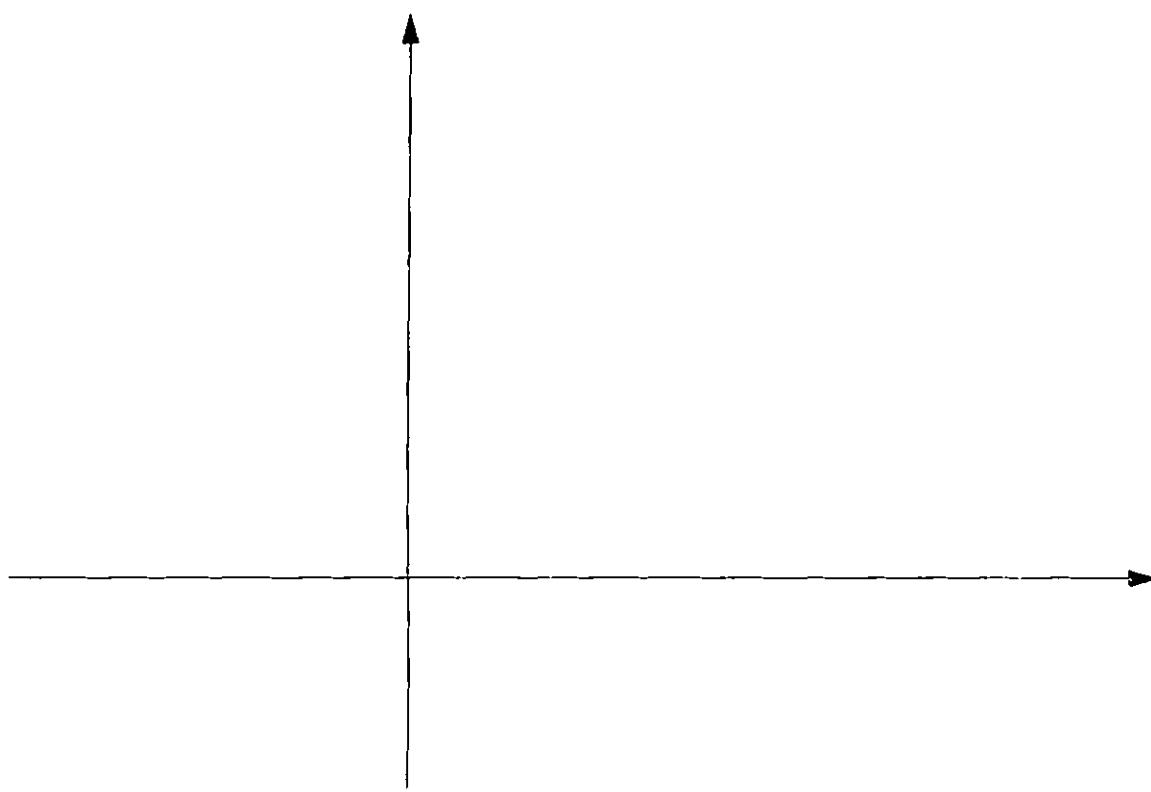
$$i_L(t) =$$

**Question 3: Transient Analysis**

- [3] (ii) How long does it take to lose 90% of the initially stored energy in the inductor (that is, the energy stored in the inductor at  $t = 0^-$ )?

$t =$

- [5] (iii) Determine  $i_0(t)$  for all  $t$  and sketch  $i_0(t)$  versus  $t$ . In particular, clearly indicate on your sketch  $i_0(0^-)$ ,  $i_0(0^+)$ , and  $i_0(\infty)$ .



**Question 3: Transient Analysis****PART B**

A small battery is used to charge a capacitor. A load is powered by switching the capacitor across it. You are provided with the following information:

- (a) the battery has a potential of 6 V dc and that it should not be operated with a current exceeding 100  $\mu$ A;
- (b) the resistance of the load is 10  $k\Omega$ ;
- (c) the capacitor is fully charged or discharged in five time constants; and
- (d) the source resistance of the battery is negligible.

[3] (i) Draw a circuit model that will represent the charging and discharging action of the capacitor.

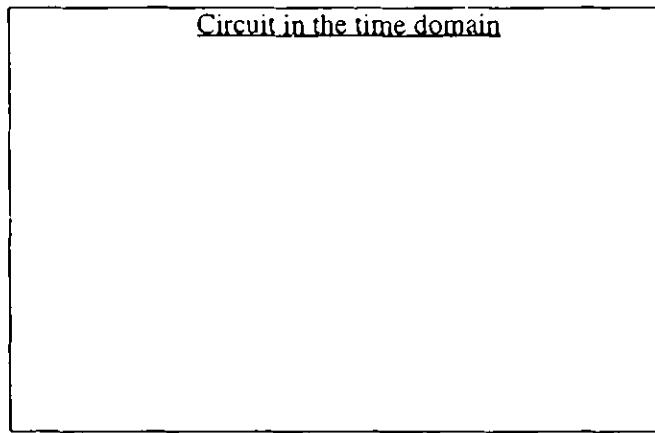
[7] (ii) It is required that the capacitor is charged within 5 seconds and that it is discharged within 0.5 second. Select the appropriate values for the circuit components in your circuit (that is, capacitance and resistance).

**Question 4: AC Circuits**

A sinusoidal current source of  $2 \text{ A}_{\text{rms}}$  at 1 kHz is connected to a load. The output impedance of the current source consists of a resistor,  $R_S = 20 \Omega$ , in series with a capacitor,  $C_S = 8 \mu\text{F}$ . The load consists of a resistor,  $R_L = 100 \Omega$ , in series with an inductor,  $L_L = 4 \text{ mH}$ .

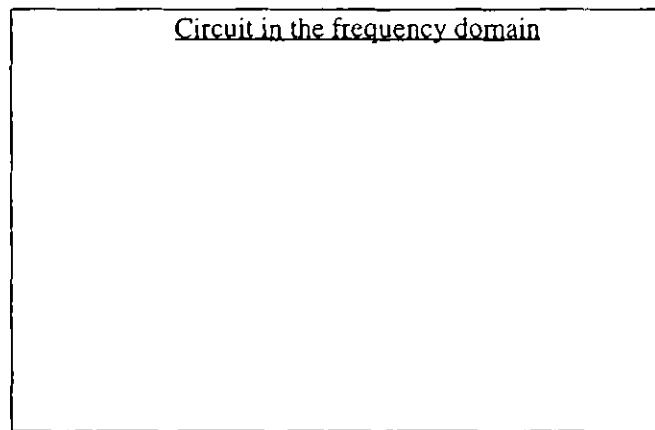
- [4] (i) Draw the circuit in the time domain. Clearly label all the circuit components.

Circuit in the time domain



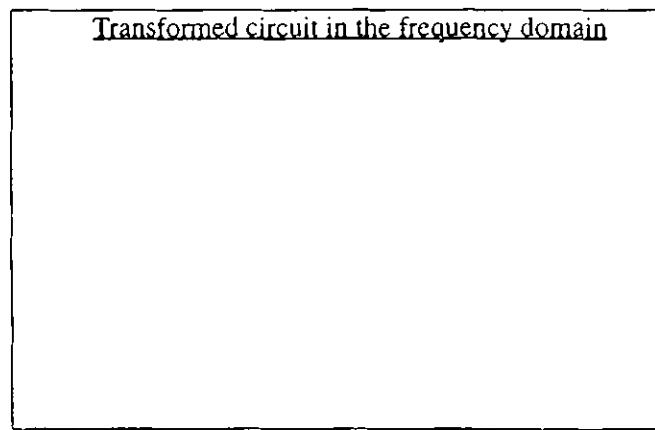
- [4] (ii) Draw the circuit in the frequency domain. Clearly label all the circuit components.

Circuit in the frequency domain



- [4] (iii) Using Norton and Thévenin equivalent circuits, transform the current source into a voltage source. *Hint: Carry out this transformation in the frequency domain.*

Transformed circuit in the frequency domain



**Question 4: AC Circuits**

- [6] (iv) Find the current phasor,  $\underline{I_L}$  and the current,  $i_L(t)$ , in the load.

$\underline{I_L} =$
$i_L(t) =$

- [7] (v) Find the apparent power, reactive power and real power delivered to the load. Also, state the load power factor and whether it is leading or lagging..

Apparent Power =
Reactive Power =
Real Power =
Power Factor =
Leading <input type="checkbox"/>
Lagging <input type="checkbox"/>