Data Provided: None

The University Of Sheffield.

DEPARTMENT OF ELECTRONIC AND ELECTRICAL ENGINEERING

Spring Semester 2015-16 (3.0 hours)

EEE117 Electrical Circuits & Networks

Answer **FOUR** questions. **No marks will be awarded for solutions to a fifth question.** Solutions will be considered in the order that they are presented in the answer book. Trial answers will be ignored if they are clearly crossed out. **The numbers given after each section of a question indicate the relative weighting of that section.**

1.

a. For the network shown in Figure 1.1, using **loop analysis**:

(i) Calculate the voltage developed between points A and C, and thereby calculate the total power delivered by the 30A current source. **(6)**

(ii) Is the battery 'Batt2' sinking or sourcing current? **(2)**

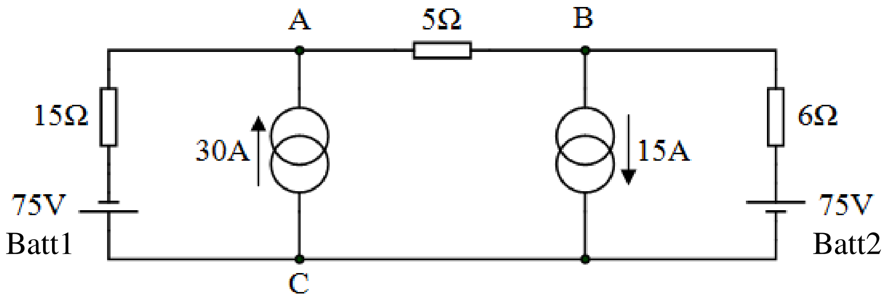

Figure 1.1

b. **(i)** For the network shown in Figure 1.1, derive the equivalent **Thevenin** circuit of the network if the 5Ω resistor is considered to be the load as shown below in Figure 1.2.

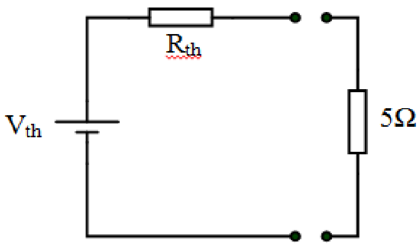

Figure 1.2 **(4)**

(ii) Calculate the power dissipated in the 5Ω resistor **(2)**

c. A 15V battery with an internal impedance of 1Ω is now placed between points A and B of Figure 1.1 with the positive terminal connected to point B. Draw the new circuit diagram and using Norton and Thevenin transformations, calculate the new power dissipated in the 5Ω resistor. **(6)**

2.

a. The network shown below in Figure 2.1 is initially in steady-state with the switch S1 connected to position A, and the capacitor is fully discharged. At a given time, the switch is commutated to position B and allowed to return to steady state.

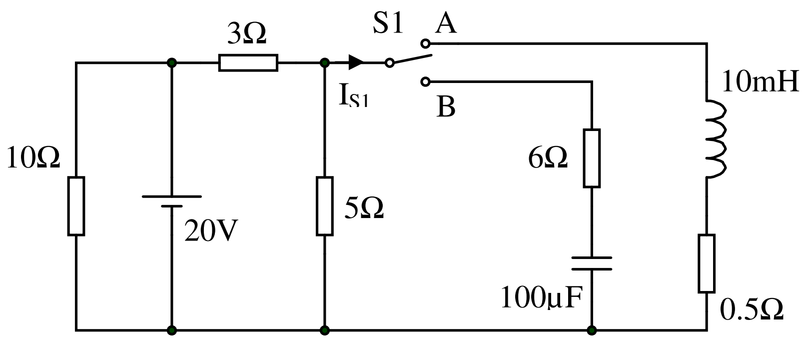

Figure 2.1

(i) Calculate the values of current, I_{S1}, immediately before the commutation of the switch, immediately after the commutation of the switch, and in position B at steady state. **(6)**

(ii) For each of the steady-state switch positions, calculate the total energy stored in the capacitor and in the inductor. **(4)**

(iii) Considering your answers to parts (i) and (ii), are there any practical implications to the sudden commutation from A to B in this network? **(2)**

(iv) For each of the steady-state switch positions, calculate the total power dissipated in the circuit, assuming ideal reactive components. **(2)**

(v) By inspection (or otherwise) derive a simplified RC circuit from Figure 2.1 when the switch S1 is in position B, and thereby calculate the time-constant of the circuit when in position B.

Would it be valid to assume that steady-state operation could be measured 2 milli-seconds after the switch had commutated to position B? Justify your answer. **(6)**

3. The circuit of Figure 3.1 is typical of a power factor corrected fluorescent lamp fitting.

a. **(i)** Show that the impedance V/I of the RLC combination shown in Figure 3.1 is given by:

$$Z = \frac{R + j\omega L}{1 - \omega^2 LC + j\omega CR}$$

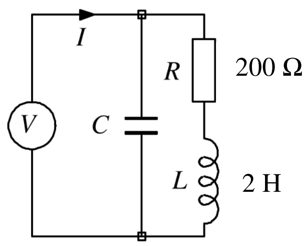

Figure 3.1

(3)

(ii) Using this result, show that the system can be made resonant at a particular value of ω by choosing C as:

$$C = \frac{L}{R^2 + \omega^2 L^2}$$ **(3)**

(iii) The lamp itself is represented by the 200 Ω resistor. If the supply voltage and frequency are 230 V_{rms} and 50 Hz, calculate the power dissipated in the lamp. (In the context of a lamp, supply power can be dissipated as heat or as light output - the total dissipation is required here.) **(4)**

b. An a.c. network consisting of a 1kHz a.c. supply, lossy transmission line and unknown load, Z, is shown below in Figure 3.2

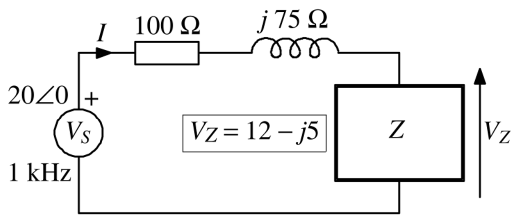

Figure 3.2

(i) Evaluate I and Z for the circuit of Figure 3.2 and express the results in both Polar and Cartesian forms. You may assume V_Z follows the Cartesian description given in Figure 3.2. **(6)**

(ii) Z consists of two components in series. Deduce what two component types make up Z and work out their values. **(4)**

4.

A single-phase transformer with a primary to secondary turns ratio of 12:1 has the following measured parameters:

Primary winding resistance	$R_1 = 9\Omega$
Primary winding leakage reactance	$X_1 = 11\Omega$
Secondary winding resistance	$R_2 = 0.06\Omega$
Secondary winding leakage reactance	$X_2 = 0.09\Omega$
Magnetising reactance	$X_m = 2.8\text{k}\Omega$
Core Loss resistance	$R_m = 43\text{k}\Omega$

(Note: The secondary reactance and resistance given are non-referred values)

The transformer primary is connected to a 3300 V_{rms}, 50Hz, sinusoidal AC supply. The secondary is connected to a load which has an impedance of $Z = (4 + j3)\ \Omega$.

a. Listing any assumptions that you make, draw an equivalent circuit for the transformer including numerical values for all impedances. The transformer secondary impedance and the load should be referred to the primary side. **(4)**

b. Calculate the magnitude and phase of the no-load current drawn by the transformer when the secondary load is disconnected. **(2)**

c. Calculate the transformer core losses when the secondary load is disconnected. **(1)**

d. With the secondary load connected, calculate the following:

(i) Magnitude and phase of the actual load current **(2)**

(ii) Magnitude and phase of the primary input current **(2)**

(iii) Magnitude and phase of the output voltage and the voltage regulation **(3)**

(iv) Copper losses in the transformer windings **(2)**

(v) Real component of the output power and the transformer efficiency **(2)**

e. The transformer above is constructed with a laminated iron core. What would be the effect of using a solid iron core for the magnetic circuit in order to lower the manufacturing costs for the device? **(2)**

5.

(a) A car assembly plant has an incoming 3-phase, 6600Vrms (line to line), 50Hz sinusoidal AC supply which is connected to various transformers and loads along the assembly line. The effective impedance per phase of the combined loads and transformers when the plant is at full capacity is $8.1 + j6.7\Omega$. The loads and transformers are all star connected.

(i) Calculate the magnitude and phase of the line current drawn by the plant when operating at full capacity. **(2)**

(ii) Calculate the real power, the reactive power, and the VA drawn by the plant when operating at full capacity. **(3)**

(b) In order to improve the power-factor, the owners of the plant investigate the possibility of including a 3-phase, delta-connected bank of capacitors into the plant.

(i) Calculate the values of the capacitors which would be required in each phase to achieve an overall power-factor of 0.95 lagging for the plant when operating at full capacity. **(5)**

(ii) Calculate the magnitude and phase of the line current drawn by the plant when operating at full capacity with the power factor correction capacitors connected. **(2)**

(iii) What is the maximum voltage rating of the capacitors? **(1)**

(iv) Briefly state an advantage to the network of including power factor correction capacitors into the plant. **(1)**

(c) Before installing the capacitor bank the owners decide to add a new engine assembly line to the existing plant. A 3-phase, star-connected, synchronous motor operating at a leading power-factor will be used to provide an **additional** 1.2MW of power and also correct the overall power-factor of the plant to 0.95 lagging without the need for the capacitor bank.

(i) Calculate the reactive power that the synchronous machine has to provide to achieve an overall power-factor of 0.95 lagging, without the capacitor bank. **(2)**

(ii) Hence calculate the VA rating of the synchronous motor and the power-factor at which it operates. **(2)**

(iii) Calculate the effective phase impedance of the synchronous motor when operating under these conditions. **(2)**

6.

a. Figure 6.1 shows a schematic of an inductor which consists of a circular silicon iron core which includes a small airgap. The core has a fixed relative permeability of 2000. When a DC current of 4A flows in the coil the flux density in the airgap is 0.8T. You may assume the airgap has the same cross-sectional area as the core and the permeability of air, $\mu_0 = 4 \times \pi \times 10^{-7}$H/m.

(i) Calculate the length of the airgap in the core. **(4)**

(ii) Calculate the self-inductance of the inductor. **(1)**

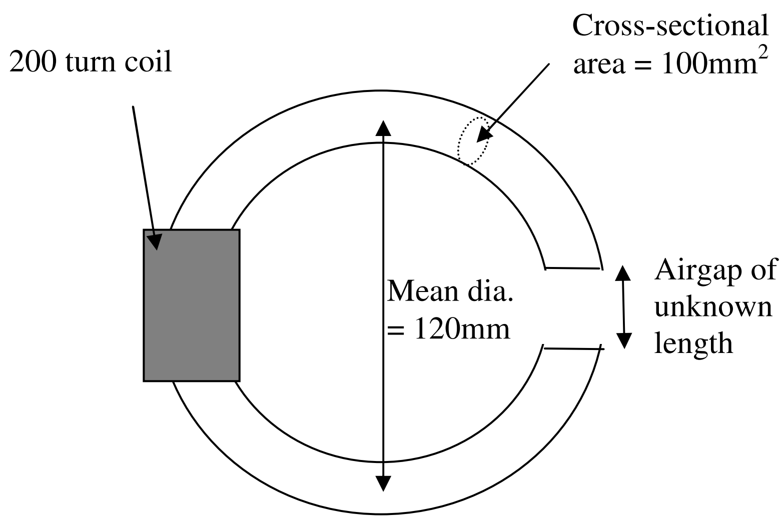

Figure 6.1

b. The inductor of Figure 6.1 is now connected to a $100V_{rms}$ sinusoidal AC supply. If the coil has a resistance of 5Ω, calculate the frequency required to provide a maximum flux density of 0.8T in the airgap. **(4)**

c. An electromagnetic actuator which is used in an industrial production process has a self-inductance of 0.09H and a resistance of 0.3Ω. The actuator is driven by a current, i, which varies with time, t, as $i(t) = 8t^2$. The duration of the process is 4.5 seconds. Calculate the following:

(i) The instantaneous voltage across the actuator at t = 1.5s **(3)**

(ii) The instantaneous power dissipation in the resistor at t = 2s **(1)**

(iii) The maximum supply voltage which is required to enable the actuator to follow the desired current profile **(3)**

(iv) The total energy drawn from the electrical supply over the 4.5 second duration of the process and hence the average power drawn from the supply over this period. **(4)**

CRG/JKM