Data Provided: None

The University Of Sheffield.

DEPARTMENT OF ELECTRONIC AND ELECTRICAL ENGINEERING

Spring Semester 2014-15   (3.0 hours)

EEE117 Electrical Circuits & Networks 1

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, find the value of the current through the 5Ω resistance using the method of superposition. Indicate the direction of the current. **(6)**

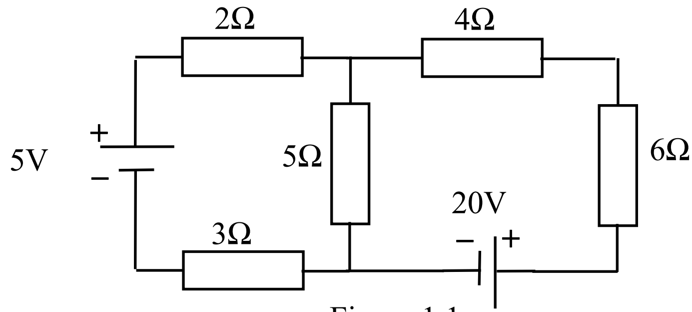

Figure 1.1

b. A constant current source of 5A is added to the network in parallel with the 6Ω resistor, as shown in Figure 1.2. Calculate the new current through the 5Ω resistor. **(4)**

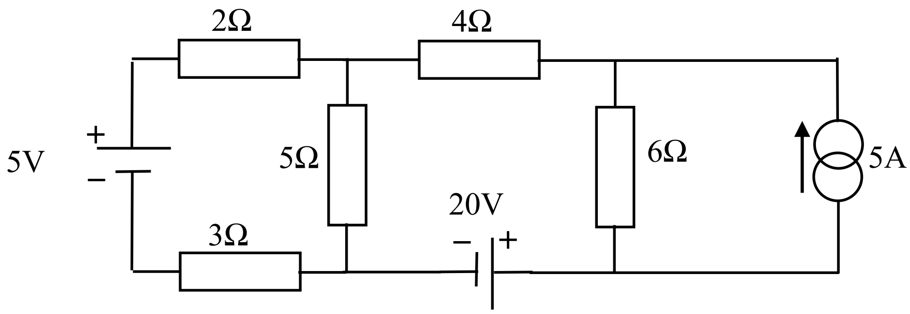

Figure 1.2

c. The network of Figure 1.1 is to be used as a source for a load resistor of 10Ω, which is connected between **A** and **B**, as shown in Figure 1.3. Derive the Thevenin equivalent circuit for the source and hence calculate the power dissipated in the load resistor. **(6)**

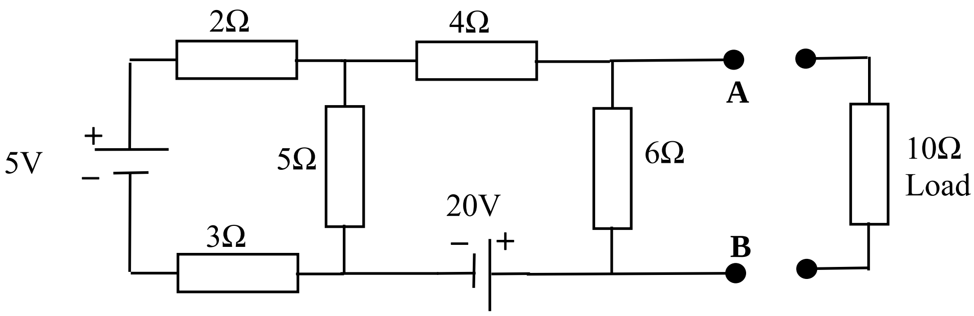

Figure 1.3

d. A rechargeable battery of nominal voltage of 5V is now connected between A and B (positive terminal connected to A) of Figure 1.3 in place of the 10Ω load resistor. Determine whether this battery will receive or deliver power and find the magnitude of the current passing through it when it is fully charged (5V). Assume that the battery has a negligible internal resistance. **(2)**

e. Calculate the Norton equivalent circuit for the source network shown in Figure 1.3 (i.e. not including the load resistor). **(2)**

2.

a. An inductance, L, capacitance, C, and resistance, R, are connected to form a series resonant circuit as shown in Figure 2.1.

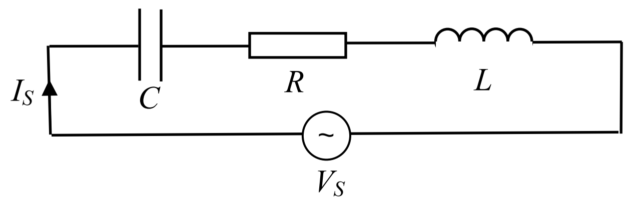

Figure 2.1

(i) Work out the impedance of the circuit shown in Figure 2.1 and hence show that the resonant frequency of the circuit, f_r, *is:*

$$f_r = \frac{1}{2\pi\sqrt{LC}}$$ **(3)**

(ii) Sketch the variation of the magnitude of the total impedance, Z, with frequency, f, over the frequency range $f << f_{resonant}$ to $f >> f_{resonant}$. **(2)**

(iii) Sketch a phasor diagram for the circuit at resonance showing the relative direction of the voltages across each component. Take the current phasor as reference. **(2)**

(iv) The Q factor for this circuit is $Q = |V_L|/|V_R|$ at resonance. Express Q in terms of the circuit parameters. **(2)**

(v) Given that f_r = 23.2kHz, Q = 6.86 and R = 100Ω, calculate suitable values for L and C. **(3)**

b.

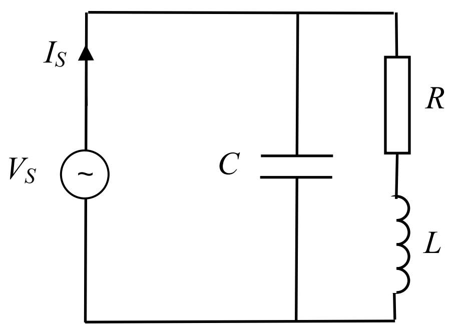

Figure 2.2

b. (i) Show that the impedance of the circuit shown in Figure 2.2 is:

$$Z = \frac{V_S}{I_S} = \frac{R + j\omega L}{1 + j\omega CR - \omega^2 LC}$$ **(3)**

(ii) Using the impedance given in part **b.(i)** above, derive an expression for the angular resonant frequency, ω_r of the circuit. **(5)**

3.

a. The circuit of Figure 3.1 is driven by a step waveform, V_i, that is −10V for all $t < 0$ and +20V for all $t > 0$. Work out I_R, I_L and I_C for all $t = 0^-$ and all $t = 0^+$ (i.e. immediately before and immediately after the step occurs).

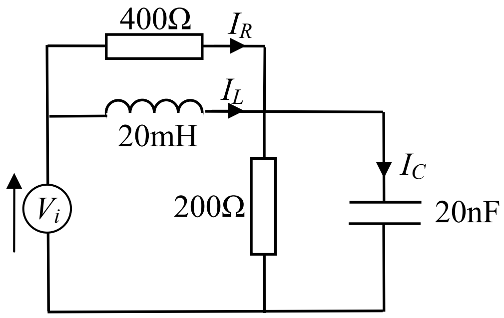

Figure 3.1 **(7)**

b. In the circuit of Figure 3.2 the capacitor C_1 is initially charged to 100V and C_2 is completely discharged. Calculate the energy stored in the system before, and a long time after, the switch S is closed. What has happened to the 'missing' energy?

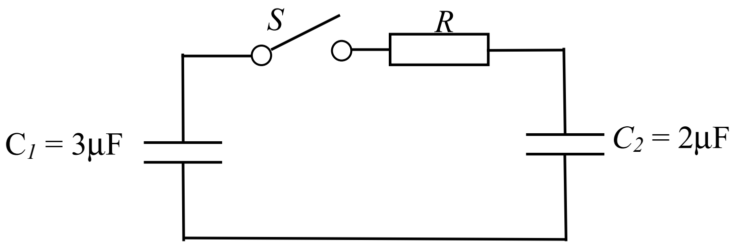

Figure 3.2 **(3)**

c. Figure 3.3 shows a circuit consisting of a battery of voltage V_S, a switch S, a resistor R, and a capacitor C, connected in series. Initially the switch S is open and the capacitor is fully discharged. After the switch S is closed, show that the change in the voltage across the capacitor, V_C, with time is given by:

$$V_C = V_S\left(1 - e^{\frac{-t}{RC}}\right)$$

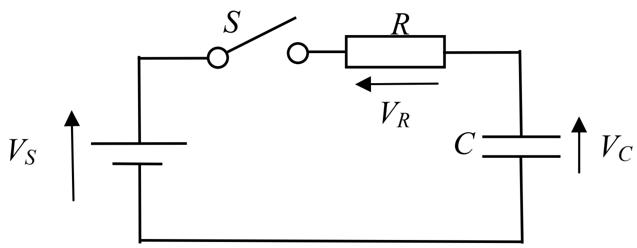

Figure 3.3 **(8)**

d. If the value of R is 100kΩ and C is 10μF, calculate the voltage across the capacitor after 2 seconds if the battery voltage is 10V. **(2)**

4.

A 15V_{rms} low-voltage lighting system is to be supplied from a 220V_{rms} 50Hz mains supply using a single-phase transformer. The lighting system consists of six, 20W, 15V_{rms} bulbs which are connected in parallel and the bulbs may be considered as a purely resistive load.

a. Assuming that the transformer is ideal and that the bulbs are delivering their rated power:

(i) calculate the required VA rating of the transformer and its turns ratio **(2)**

(ii) calculate the current which will flow in the primary and secondary windings **(2)**

b. In practice the transformer is not ideal. The primary and secondary windings have resistances of 5Ω and 0.2Ω respectively and leakage reactances of 15Ω and 1Ω respectively. *(note: secondary values are non-referred values).* In addition, when no bulbs are connected, the transformer draws an input current of 0.2A at 0.15 power-factor lagging.

(i) Sketch an approximate equivalent circuit model referred to the primary winding taking care to include the values of all the resistances and reactances. **(3)**

(ii) Calculate the actual input current to the transformer when the lighting system is connected. **(4)**

(iii) Calculate the power output from each bulb, and the voltage across each bulb, when the lighting system is connected. **(4)**

(iv) Calculate the copper losses in the transformer windings when supplying the lighting system. **(2)**

(v) Calculate the efficiency of the transformer when supplying the lighting system. **(2)**

c. If the maximum permissible flux in the transformer core is 2mWb calculate the actual number of turns on each winding. **(1)**

5.

A large supermarket is connected to the grid by means of a $400V_{rms}$ (line to line), 50Hz 3-phase sinusoidal mains supply. During normal opening hours the electrical loads within the supermarket consist of the following:

- Lighting load of 30kW (which can be assumed to be purely resistive)
- Centralised refrigeration compressor system which consist of **two** star-connected 3-phase induction motors, each of which is connected separately to the mains supply with each having an effective input impedance of $(3.6 + j1.2)\Omega$ per phase
- Miscellaneous general loads equivalent to 20kVA at a power-factor of 0.6 lagging

a. Calculate the real power drawn and the power-factor of the refrigeration system when **both** induction motors are operating during normal opening hours. **(5)**

b. Calculate the following during normal supermarket opening hours:

(i) Total real power in kW

(ii) Total reactive power in kVAr

(iii) Total apparrent power in kVA

(iv) Overall power-factor **(7)**

c. When the supermarket is closed, the electrical load is reduced to the following:

- Emergency lighting load of 4kW (assume purely resistive)
- The refrigerators are covered with insulating covers such that only **one** induction motor is required to maintain the desired refrigerator temperature
- The miscellaneous general loads reduce to 8kVA at a power factor of 0.6 lagging.

Calculate the total kVA and power factor when the supermarket is closed. **(3)**

d. Calculate the value of capacitance per phase, connected in a star configuration across the supply input to the supermarket, required to correct the overall power-factor to 0.98 lagging during **normal opening hours**. **(5)**

6.

a. Figure 6.1 shows an inductor which consists of a 500 turn coil wound on a rectangular iron core which contains an airgap of length 2mm. The mean length of each side of the iron core is 120mm and it has a cross-section of 30mm × 30mm. The relative permeability of the iron is 800. 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 maximum current which can be passed through the coil if the flux density in the core is to be limited to a 1.4T. **(4)**

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

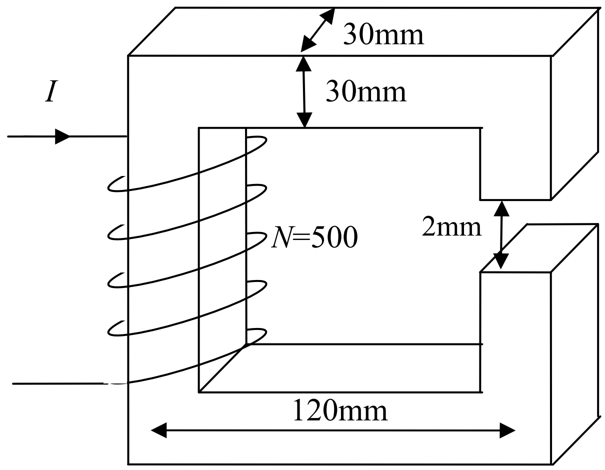

Figure 6.1

b. The inductor of Figure 6.1 is now connected to a 100Hz sinusoidal AC supply. Calculate the following given that the resistance of the coil is 30Ω:

(i) The maximum rms voltage which can be applied to the coil if the peak flux density in the core is to remain below 1.4T **(3)**

(ii) The average power dissipated in the coil for this maximum value of rms voltage **(2)**

(iii) The peak energy stored in the inductor for this maximum value of rms voltage **(1)**

c. The manufacturer of the inductor of Figure 6.1 wishes to modify the design to increase the maximum current which can be passed through the coil for a maximum core flux density of 1.4T. This will be achieved by increasing the airgap in the core. Calculate:

(i) The length of the airgap required to achieve a maximum current to 8A **(5)**

(ii) The new value of self inductance with this airgap. **(2)**

(iii) The rms voltage required to achieve a flux density of 1.4T in the airgap if the **<u>resistance of the coil is neglected</u>**. **(2)**

JKM