Data Provided: None.

The University Of Sheffield.

DEPARTMENT OF ELECTRONIC AND ELECTRICAL ENGINEERING

Autumn Semester 2009 - 2010 (2 hours)

CIRCUITS AND SIGNALS 1

Answer **THREE** questions. Solutions will be considered in the order in which they are presented in the answer book and **no marks will be awarded for an attempt at a fourth question.** 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.**

Unit multipliers: p = $\times 10^{-12}$, n = $\times 10^{-9}$, μ = $\times 10^{-6}$, m = $\times 10^{-3}$, k = $\times 10^{3}$, M = $\times 10^{6}$ G = $\times 10^{9}$

1 For the circuit of figure 1a,

(i) Work out the resistance of the circuit from the point of view of V_S and hence evaluate I_S. *{5}*

(ii) Use your answer to part **(i)** to find V_A, the voltage at node **A**, with respect to the reference node. *{2}*

(iii) Write down the current sum equation that results from the application of Kirchhoff's current law to node **A** of the circuit. *{3}*

(iv) Either by extending the result of part **(iii)** to a nodal analysis of the circuit or by using loop analysis, find the value of I_2. *{5}*

(v) A current source is now added to the circuit as shown in figure 1b. Use any method you like to find I_3 and the power dissipated in R_1. *{5}*

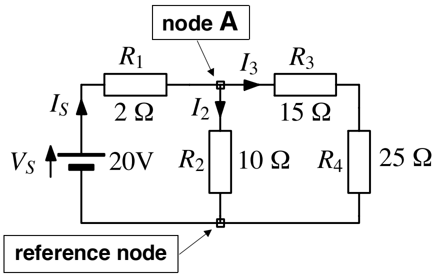

Figure 1a

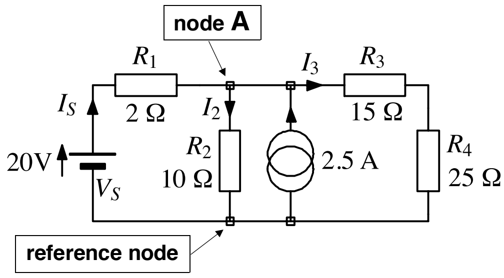

Figure 1b

2 **(a)** Figure 2a (i) is a potential divider circuit. Derive expressions for the Thevenin equivalent parameters V_{Th} and R_{Th} of figure 2a (ii) that will make the behaviour of the two circuits identical from the point of view of a load connected between nodes **A** and **B**. {*4*}

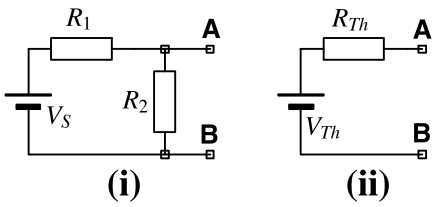

Figure 2a

(b) **(i)** Using Thevenin to Norton transformations, simplify the circuit of figure 2b to one consisting of five elements in parallel. Draw your simplified circuit and label the transformed sources with magnitudes and directions and the transformed resistances with their values. {*4*}

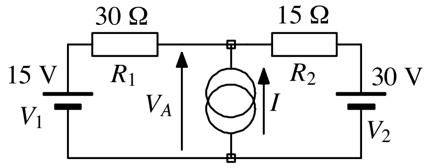

Figure 2b

(ii) Either by using your simplified circuit or by other means, find the value of I necessary to give a V_A of 0 V. {*2*}

(c) **(i)** At $t = 0$ the switch in the circuit of figure 2c is switched from position **B** to position **A**. Show that for $t > 0$, I is given by

$$I(t) = \frac{V_S}{R} e^{-\frac{t}{RC}} .$$

Assume that the switch was in position **B** for all $t < 0$ and remains in position **A** for all $t > 0$. {*6*}

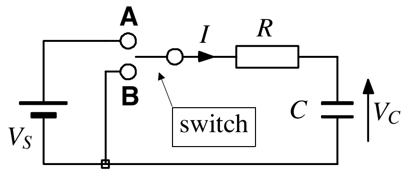

Figure 2c

(ii) Use the result of question **2 (c) (i)** to find V_C as a function of time. {*4*}

3 **(a)** In the circuit of figure 3a, V_S is a sinusoidal source with a frequency of 500 Hz and an amplitude of 10 V.

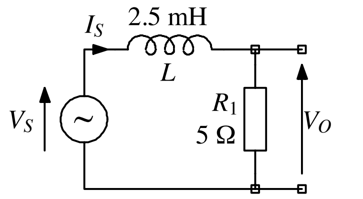

Figure 3a

(i) Draw a phasor diagram for the circuit and use it to evaluate the phase of I_S with respect to V_S. **{*3*}**

(ii) Using the "*j*" notation work out the impedance V_S/I_S of the circuit and express it in the form $a + jb$. Evaluate the magnitude of this impedance. **{*3*}**

(b) The circuit of figure 3b is driven by two sinusoidal sources with amplitudes and phases as given on the diagram. The next three parts of the question relate to this circuit.

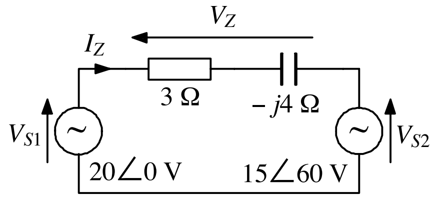

Figure 3b

(i) Sketch a phasor diagram to sum the voltages in the loop and hence find the amplitude of V_Z. (You may need to use the cosine rule given below to solve this question.) **{*5*}**

(ii) Express both V_{S1} and V_{S2} in the form $a + jb$. **{*3*}**

(iii) Using the "*j*" notation find I_Z and express it in a form $a + jb$. What is the magnitude and phase of I_Z? **{*6*}**

The cosine rule, $a^2 = b^2 + c^2 - 2bc \cos \varphi$, defines the length of the third side (a) of a triangle when two sides (b and c) and the angle between them (φ) are known.

4 **(a)** **(i)** What is meant by the term resonance in the context of an electronic circuit? **{*2*}**

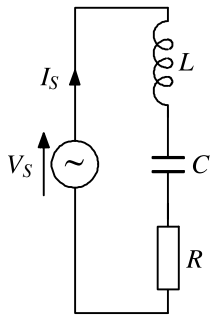

Figure 4a

(ii) Work out the impedance of the circuit of figure 4a and hence show that the circuit resonant frequency is $f_r = \dfrac{1}{2\pi\sqrt{LC}}$. **{*5*}**

(iii) The *q* factor for this circuit is $q = |V_L| / |V_R|$ at resonance. Express *q* in terms of the circuit parameters. **{*3*}**

(iv) Resonant circuit impedance can appear inductive or capacitive depending on the frequency. Which of the two descriptions would apply to figure 4a when $f < f_r$? Briefly explain your reasoning. **{*2*}**

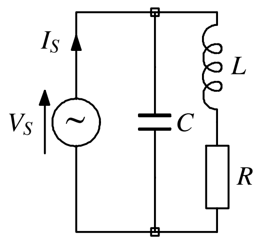

Figure 4b

(b) **(i)** Show that the impedance of the circuit of figure 4b is

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

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

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