University of Moratuwa, Sri Lanka

B. Sc. Engineering Degree Course

Level 2 – Semester I Examination 2003/04

EE 201 - THEORY OF ELECTRICITY

Time Allowed: Three Hours — 06 January 2004.

Answer **All** Questions. — Maximum for the paper is 70 marks.

Permeability of free space $\mu_0 = 4\pi \times 10^{-7}$ H/m Permittivity of free space $\varepsilon_o = 8.854 \times 10^{-12}$ F/m

1 (a) Show that the power loss due to hysteresis in a magnetic material is proportional to the area of the B-H loop [2 marks]

(b) Explain very briefly why transformer cores are made from laminated material. [1 mark]

(c) A circuit consists of a choke (inductance L in series with a resistance r), and a practical capacitor (capacitance C in parallel with a resistance R) connected in series. Derive from first principles the condition for resonance (*You may use any convenient definition*). [4 marks]

Sketch the variation of the circuit current and phase angle of the current with variation of the supply frequency for a constant source voltage magnitude. [1 marks]

(d) Show from first principles that the energy stored in a pair of mutually coupled coils (self inductances L_1 and L_2 and mutual inductance M) is given by $\frac{1}{2}L_1I_1^2 + \frac{1}{2}L_2I_2^2 \pm M\,I_1I_2$, where I_1 and I_2 are the current carried by the respective coils. [2 marks]

2 Figure Q2 shows a mutually coupled circuit supplied from a variable frequency source across AB.

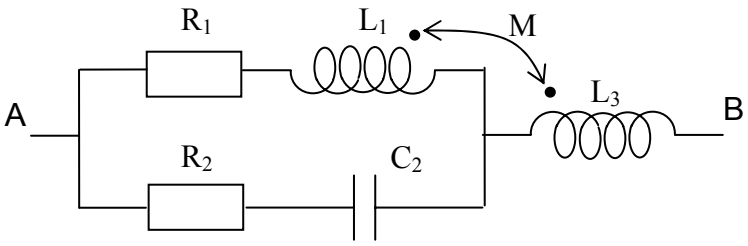

Figure Q2

(a) Determine an expression for the effective impedance between AB at an angular frequency ω. [4 marks]

(b) If the supply voltage is 100V at an angular frequency of 250 rad/s, and L_1 = 40 mH, R_1 = 20 Ω, R_2 = 0 Ω, C_2 = 80 μF, M = 20 mH, L_3 = 40 mH, simplify the expression for the effective impedance. [3 marks]

(c) Determine the currents in all the branches. [3 marks]

3 A certain type of single phase load consumes 110 W at a power factor of 0.707 lag when supplied at 220 V, 50 Hz. Several such loads are to be fed from a 240V, 50 Hz supply with an internal resistance of 1 Ω and negligible internal reactance.

(a) Determine from first principles the theoretical maximum active power that can be supplied from the source. [2 marks]

(b) What would then be the load voltage ? [1 marks]

(c) What would be the maximum number of the above type of loads that can be fed from the supply if the voltage is not to drop below 220 V ? [4 marks]

(d) What would be the active power delivered ? [1 marks]

4

(a) Convert the two voltage sources, across AB and across BC, shown in figure Q4 to equivalent current sources. [1 mark]

(b) Hence draw the circuit for nodal analysis, retaining the nodes A, B and C. Write down the branch admittance matrix and the branch-node incidence matrix and the nodal injected current source. [2 marks]

(c) Hence determine the nodal admittance matrix. [2 marks]

(d) Using matrix nodal analysis, determine the voltage at node A. [3 marks]

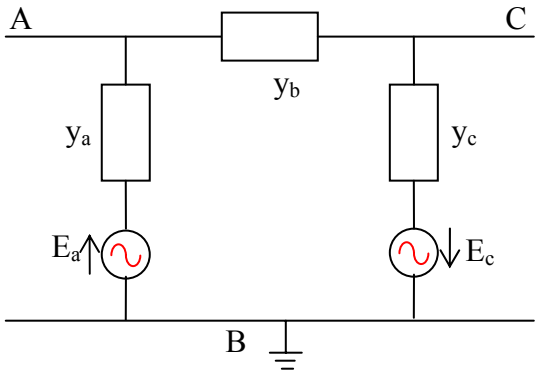

Figure Q4

(e) Simplify the expression for the voltage at node A if $y_a = y_b = y_c = y$ and $E_a = E_c = E$. [1 mark]

(f) Validate the result in (e) above, for the voltage at node A by applying Ohm's Law and Kirchoff's Law to the circuit shown in figure A4. [1 mark]

5 A 3 phase, 400 V, 50 Hz, 3-wire balanced supply ABC feeds an unbalanced star connected load. The voltages across the phases of the load are measured with respect to its star-point N by a voltmeter to be $V_{AN} = 346.4$ V, $V_{BN} = V_{CN} = 200$ V.

(a) Taking V_{AN} as reference, sketch a phasor diagram and determine the phase angles of V_{BN} and V_{CN}. [3 marks]

(b) Determine the Symmetrical Components of the phase "A" voltage, of the above. [4 marks]

(c) Sketch a phasor diagram showing how V_B is obtained from the symmetrical components determined. [3 marks]

6 A certain two port circuit may be represented by the two port admittance matrix

$$[Y] = \begin{bmatrix} y_a + y_b & -y_b \\ -y_b & y_a + y_b \end{bmatrix}.$$

(a) Determine an expression for the [ABCD] parameter matrix of this circuit [4 marks]

(b) Show that A.D – B.C = 1 [1 marks]

(c) If $y_b = y_a$ simplify the expression for the [ABCD] matrix [1 marks]

(d) If two of these circuits are connected in cascade, determine the overall [ABCD] parameter matrix. [3 marks]

(e) Show that A.D – B.C = 1 for the overall matrix. [1 marks]

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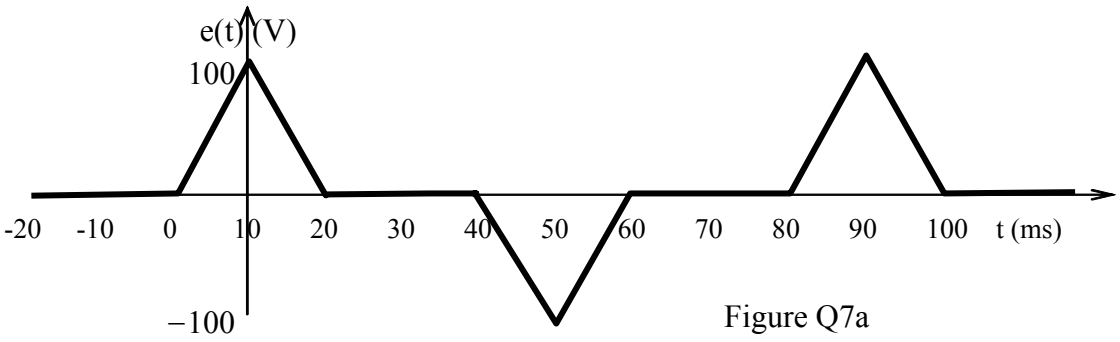

Figure Q7a

(a) Determine the average value, mean value, rms value, peak factor and the form factor of the periodic waveform e(t) shown in figure Q7a. [2 marks]

(b) Determine the first 3 significant terms of the Fourier Series of the above waveform e(t) shown. [8 marks]

(c) If the waveform e(t) is applied across the series L R circuit shown in figure Q7b, determine the Fourier Series of the resulting voltage v(t) across the resistor R. [4 marks]

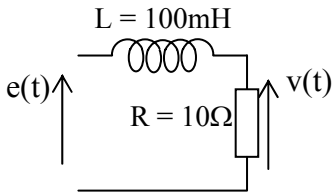

Figure Q7b

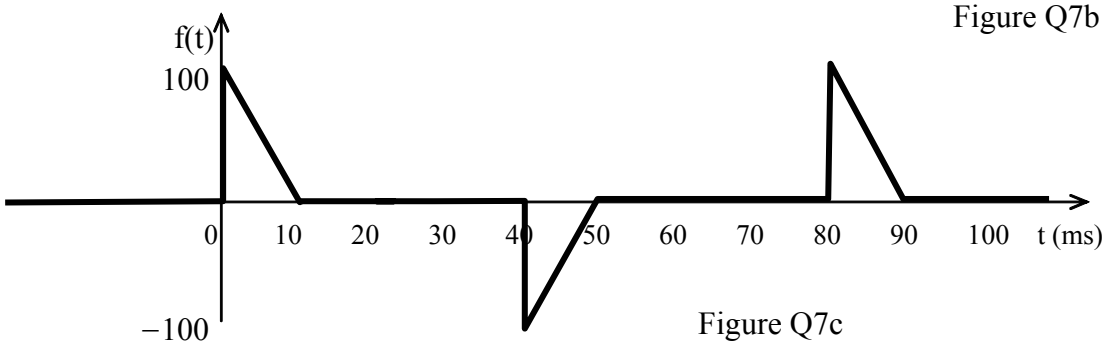

Figure Q7c

(d) Show that a shift in the time domain corresponds to an exponential in the Laplace Transform domain [2 marks]

(e) Determine the Laplace transform of the causal waveform f(t) shown in figure Q7c. [6 marks]