



University of Moratuwa, Sri Lanka
Faculty of Engineering
Department of Electrical Engineering
B. Sc. Engineering Honours Degree Course
Level 2 (Repeat) Examination

EE2010 – THEORY OF ELECTRICITY

Time Allowed: 3 Hours

November 2011

Additional Material

Graph Paper will be provided if required.

A table of Laplace transforms is provided on the other side of this page.

Instructions to Candidates

This paper contains 7 questions in 6 pages, including the cover page.

Answer All Questions.

This examination accounts for 70% of the module assessment.

Each question carries a total 10 marks. Maximum marks allocated for each part of a question is indicated in square brackets at the end of the part.

Total allocation for the paper is 70 marks.

This is a closed book examination and only authorised calculators will be permitted.

Technical Data:

Permeability of free space μ_0 = $4\pi \times 10^{-7}$ H/m

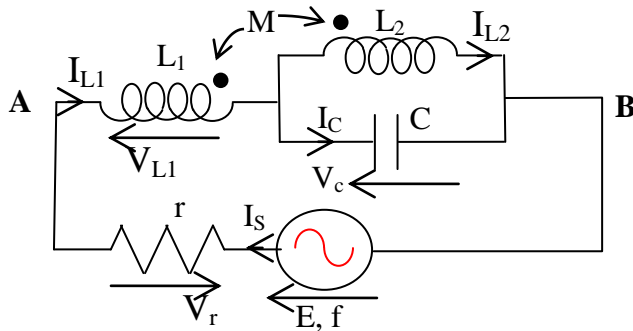
Permittivity of free space ϵ_0 = 8.854×10^{-12} F/m

Velocity of light in free space = 2.998×10^8 m/s

Table of Laplace Transforms of common causal functions $f(t)$

$f(t)$	$F(s) = L[f(t)]$
Unit impulse – δt	1
Unit step – $U(t)$	$\frac{1}{s}$
t	$\frac{1}{s^2}$
t^n	$\frac{n!}{s^{n+1}}$
e^{-at}	$\frac{1}{(s+a)}$
$1 - e^{-at}$	$\frac{a}{s(s+a)}$
$t e^{-at}$	$\frac{1}{(s+a)^2}$
$t^n e^{-at}$	$\frac{n!}{(s+a)^{n+1}}$
$e^{-at} - e^{-bt}$	$\frac{b-a}{(s+a)(s+b)}$
$\sin(\omega t)$	$\frac{\omega}{(s^2 + \omega^2)}$
$\sin(\omega t + \phi)$	$\frac{\omega \cos(\phi) + s \sin(\phi)}{(s^2 + \omega^2)}$
$t \sin(\omega t)$	$\frac{2\omega s}{(s^2 + \omega^2)^2}$
$\cos(\omega t)$	$\frac{s}{(s^2 + \omega^2)}$
$\cos(\omega t + \phi)$	$\frac{s \cos(\phi) - \omega \sin(\phi)}{(s^2 + \omega^2)}$
$t \cos(\omega t)$	$\frac{s^2 - \omega^2}{(s^2 + \omega^2)^2}$
$e^{-at} \sin(\omega t)$	$\frac{\omega}{(s+a)^2 + \omega^2}$
$e^{-at} \cos(\omega t)$	$\frac{s+a}{(s+a)^2 + \omega^2}$
$\sinh(\omega t)$	$\frac{\omega}{(s^2 - \omega^2)}$
$\cosh(\omega t)$	$\frac{s}{(s^2 - \omega^2)}$

Question 1



- $E_m = 150 \text{ V}$
- $f = 50 \text{ Hz}$
- $r = 10 \Omega$
- $L_1 = 80 \text{ mH}$
- $L_2 = 100 \text{ mH}$
- $M = 80 \text{ mH}$
- $C = 100 \mu\text{F}$

Figure Q1

Figure Q1 shows a circuit supplied from an alternating source $e(t) = E_m \sin \omega t$.

- (a) Write down an expression for the voltage drop across AB. [1 mark]
- (b) Calculate the impedance of the circuit across AB. [2 marks]
- (c) Calculate the current I_S supplied from the source. [1 mark]
- (d) Determine the currents I_{L2} and I_C . [2 marks]
- (e) Determine the voltages V_r , V_{L1} and V_C . [2 marks]
- (f) Sketch a phasor diagram showing all the voltages and currents in the circuit. [2 marks]

Question 2

- (a) For the circuit shown in figure Q2(a), obtain the Norton's equivalent circuit across AB and redraw the circuit. [2 marks]

Hence determine the voltage across R and the power delivered to it. [2 marks]

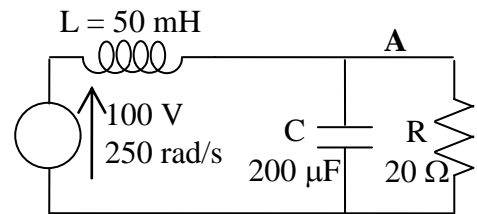


Figure Q2(a)

- (b) For the circuit shown in figure Q2(b), convert the 230V source with internal resistance 10Ω to an equivalent current source and redraw the circuit. [1 mark]

Write down the branch-node incidence matrix and the branch admittance matrix. [2 marks]

Hence determine the nodal admittance matrix. [1 mark]

Using matrix nodal analysis, obtain the nodal voltages. [2 marks]

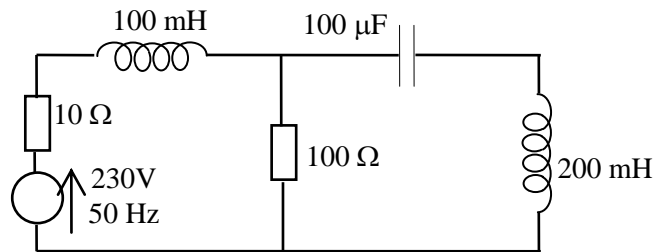


Figure Q2(b)

Question 3

- (a) Determine the Admittance parameter matrix of the two-port network shown in figure Q3(a). [3 marks]

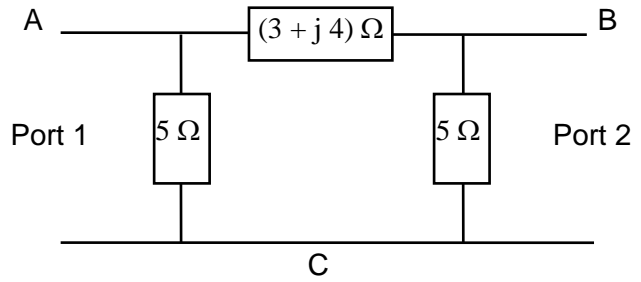


Figure Q3(a)

- (b) For the circuit shown in figure Q3(b), write down the Kirchoff's current law and voltage law equations. [2 marks]

Hence determine the current i_1 . [1 mark]

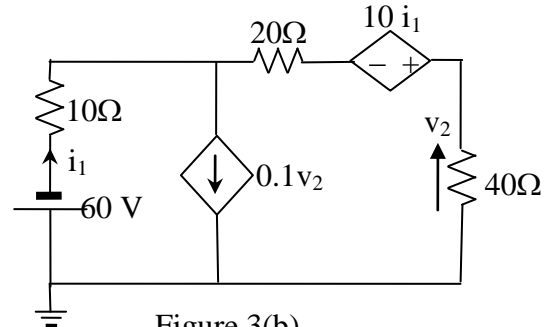


Figure 3(b)

- (c) A certain circuit consists of the following branches connected in parallel (i) a resistance of 5Ω in series with a variable inductance; and (ii) a resistance of 10Ω in series with a capacitance $50 \mu\text{F}$. If resonance occurs at a frequency of 50 Hz , determine the value of the inductance. Determine also the Q-factor of the circuit. [4 marks]

Question 4

- (a) The circuit shown in figure Q3(c) is supplied from a balanced 3-phase, 400V , 50 Hz source. If $L_1 = L_2 = 50 \text{ mH}$, and $R_1 = R_2 = R_3 = 50 \Omega$, determine the voltage of the star point S. [3 marks]

Hence determine the potential at A. [1 mark]

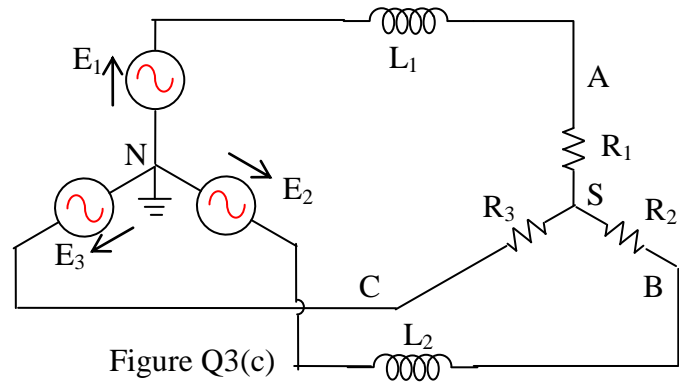


Figure Q3(c)

- (b) A 400 V , 3-phase, 50 Hz , balanced supply feeds (i) a three phase motor load of 4 kW at a power factor of 0.70 lag , and (ii) a 3-phase star-connected balanced load consisting of arms of value $(40+j30) \Omega$ each. Determine the line current, power factor and the active power at the supply. [2 marks]

Determine also the value of the delta connected capacitor bank required to improve the overall power factor to 0.95 lagging . [1 mark]

The phase components of voltage in an unbalanced system A-B-C is given as $V_A = 200\angle 0^\circ \text{ A}$, $V_B = 150\angle 60^\circ \text{ A}$ and $V_C = 200\angle -120^\circ \text{ A}$. Determine the sequence components of the voltages. [3 marks]

Question 5

- (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 mark]
- (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 $\frac{1}{2} L_1 I_1^2 + \frac{1}{2} L_2 I_2^2 \pm M I_1 I_2$ where I_1 and I_2 are the current carried by the respective coils. [2 marks]

Question 6

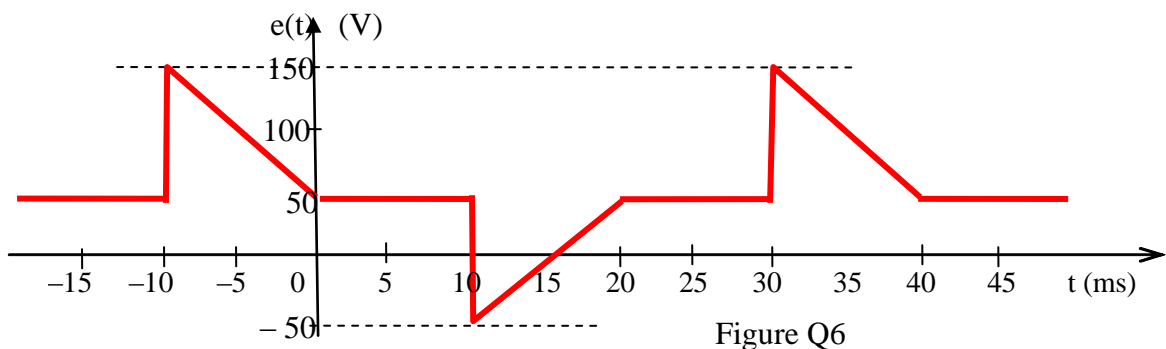


Figure Q6

- (a) For the voltage waveform $e(t)$ shown in figure Q6, determine the first 4 significant terms of the Fourier series. [8 marks]
- (b) If the voltage $v(t) = 10 + 100 \sin 100t + 30 \sin (300t + \pi/3) + 20 \sin(500t - \pi/6)$ is applied across a parallel combination of a resistor $R = 10 \Omega$ and capacitor $C = 100 \mu\text{F}$, determine the Fourier series of the resulting current $i(t)$. [2 marks]

Question 7

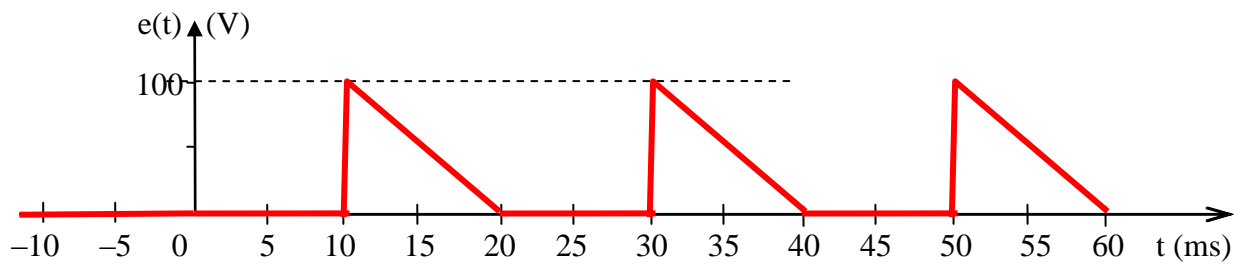


Figure Q7a

(a) Determine, from first principles, the Laplace transform of the causal waveform $e(t)$ shown in Figure Q7a. [6marks]

(b) Figure Q7b shows a circuit in which the capacitor C is initially charged to a voltage of $V_0 = 40\text{V}$ when the switch S is closed at $t = 0$. If $E_m = 100\text{ V}$, $\omega = 250\text{ rad/s}$, $L = 50\text{ mH}$, $r = 10\ \Omega$, $R = 100\ \Omega$, $C = 40\ \mu\text{F}$, draw the equivalent circuit in the Laplace domain, indicating all significant values. [4 marks]

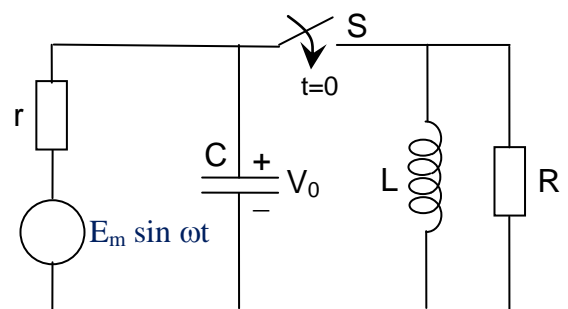


Figure Q7b

[END OF QUESTION PAPER]