DEPARTMENT OF ELECTRICAL ENGINEERING, IIT KHARAGPUR
END-SEMESTER EXAMINATION (Autumn 2009-10)
SUBJECT: SIGNALS & NETWORKS (EE21101)

Date: 25 November 2009 Time: 2 P.M. --- 5 P.M. Full Marks: 100

Instructions:
(1) This question paper consists of SIX questions. Answer any FIVE questions.
(2) The symbols express their standard meanings as used for this subject.
(3) Make appropriate assumptions wherever necessary (with justifications).

QUESTION 1

(A) For the network shown in Fig. Q1A, the switch is in position 'a' for a long time and then is moved to position 'b' instantaneously at time $t=0$. Determine the current $y(t)$ for $t>0$ using s-domain equivalent circuit analysis. [10 *marks*]

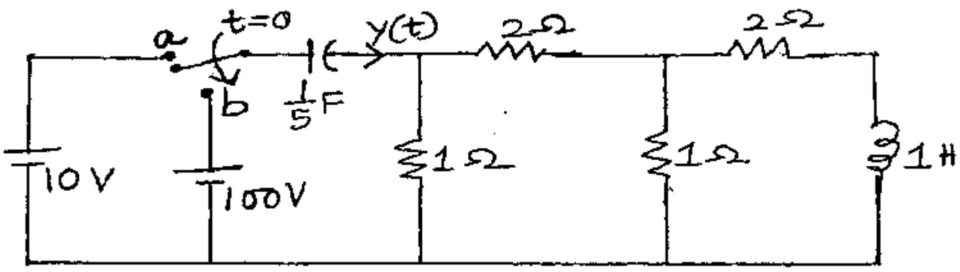

Fig. Q1A

(B) Using time-domain approach, find the unit impulse response of an LTI system specified by the differential equation { $x(t)$ = input and $y(t)$ = output}

$$\frac{d^2y(t)}{dt^2}+6\frac{dy(t)}{dt}+9y(t)=2\frac{dx(t)}{dt}+9x(t)$$ [4 *marks*]

(C) An LTI system is described by the differential equation { $x(t)$ = input and $y(t)$ = output}

$$\frac{d^2y(t)}{dt^2}+4\frac{dy(t)}{dt}+4y(t)=\frac{dx(t)}{dt}+x(t)$$

If $y(0^-)=2$, $\dot{y}(0^-)=1$ and $x(t)=e^{-t}u(t)$ { $u(t)$ is the unit-step signal}, solve the differential equation using Laplace transform to find $y(t)$. Determine the zero-input and zero-state components of the solution. [6 *marks*]

QUESTION 2

(A) For the network shown in Fig. Q2A, determine the voltage transfer ratio V_2/V_1 and the input impedance at port 1 if $Z_aZ_b=R_o^2$. [6 *marks*].

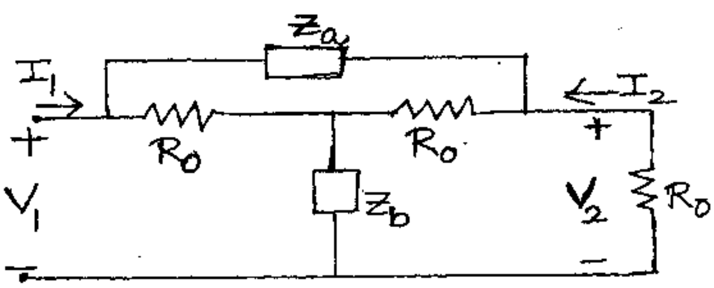

Fig. Q2A

(B) Sketch the asymptotic Bode plot of the following network function.

$$G(s) = \frac{10^4(s+40)}{s^2 + 410s + 4000}$$

Determine the value of $G(j800)$ from the Bode plot. [8 *marks*]

(C) In the network shown in Fig. Q2C, all initial conditions are zero. Determine the equivalent Thevenin network at the terminals *a-b*. $v_1(t) = u(t)$, where $u(t)$ is the unit-step signal. [6 *marks*]

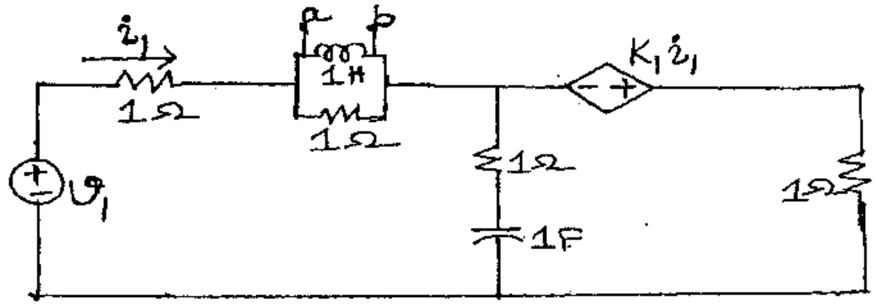

Fig. Q2C

QUESTION 3

(A) Determine the y-parameters of the two-port network shown in Fig. Q3A. [8 *marks*]

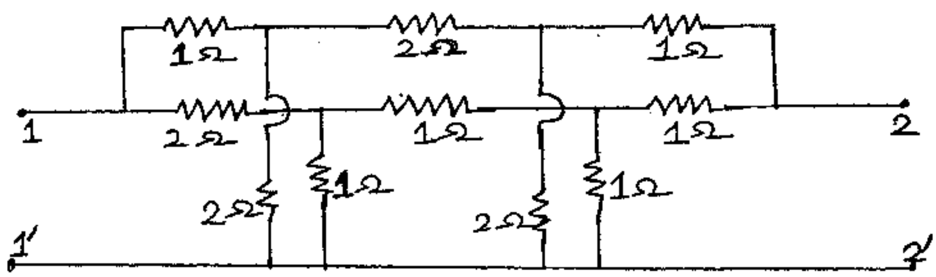

Fig. Q3A

(B) Derive a set of normal state equations for the circuit shown in Fig. Q3B. $v_s = 5\sin 2t\, u(t)$, where $u(t)$ is the unit-step signal. [6 *marks*]

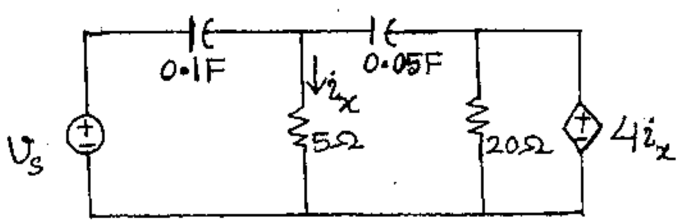

Fig. Q3B

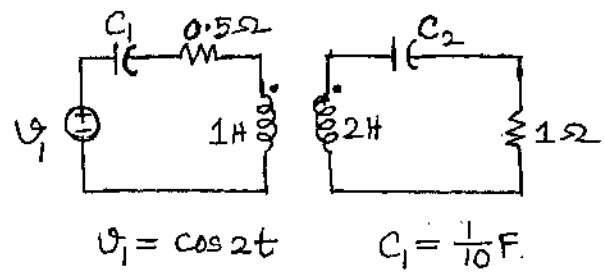

Fig. Q3C

(C) For the network shown in Fig. Q3C, what value of C_2 will result in maximum power delivery to the 1Ω resistor load? [6 *marks*]

QUESTION 4

(A) Use modified nodal analysis to derive the matrix equation that can be used to detremine the node volatges V_a, V_b and V_c in the circuit shown in Fig. Q4A.

[5 *marks*]

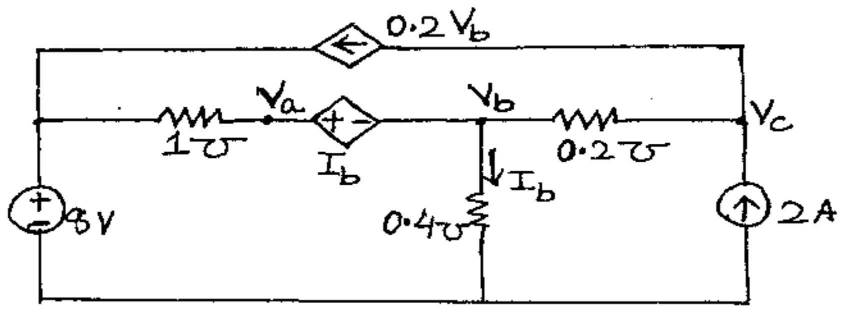

Fig. Q4A

(B) Derive the matrix equation using graph-theoritic nodal analysis of the network shown in Fig. Q4B and use it to determine all the branch voltages.

[8 *marks*]

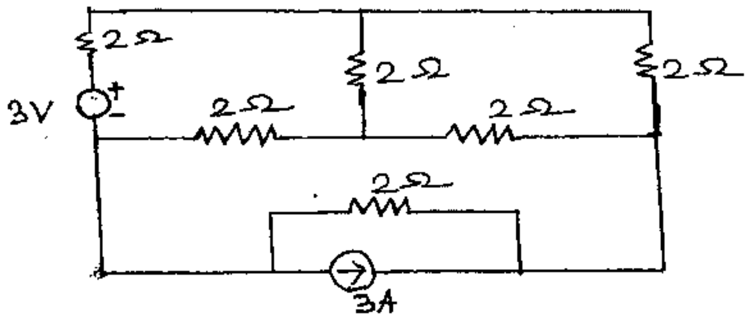

Fig. Q4B

(C) Derive the conditions for which the two networks shown in Fig. Q4C-1 and Fig. Q4C-2 have identical y- or z-parameters. [7 *marks*]

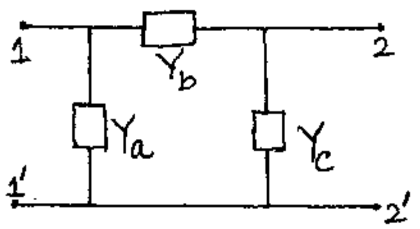

Fig. Q4C-1

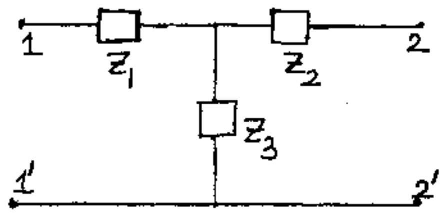

Fig. Q4C-2

QUESTION 5

(A) An LTI continuous-time system has unit impulse response, $h(t)$, given by

$$h(t) = u(t) - u(t-1)\text{, where } u(t) \text{ is the unit-step signal.}$$

(i) Which type of filter most accurately describes the behavior of this system?
(ii) What are the poles/zeros of this filter? Explain your answer.
(iii) Can you find the impulse response of the inverse system of this filter? If so, provide it.

[8 *marks*]

(B) Determine the transfer function of a fourth order Butterworth lowpass filter. Use this to find the transfer function of a corresponding bandpass filter with midband frequency of 1 rad/sec and bandwidth of 0.1 rad/sec.

[8 *marks*]

(C) A student suggests a possible lowpass-to-highpass filter transformation given by:

$$H_{hp}(s) = 1 - H_{lp}(s),$$

where $H_{lp}(s)$ is the trasnfer function of an ideal lowpass filter and $H_{hp(s)}$ is the transfer function of an ideal high pass filter. In general, will this transformation work? Explain.

[4 *marks*]

QUESTION 6

(A) Determine the amplitude and phase spectra for the currents i_1 and i_2 for the network shown in Fig. Q6A-1 when excited by the current source forcing function as shown in Fig. Q6A-2.

[8 *marks*]

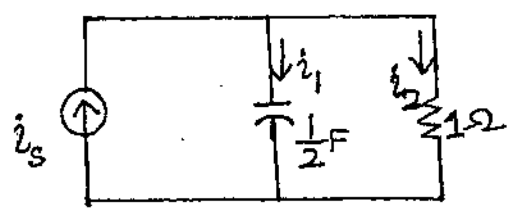

Fig. Q6A-1

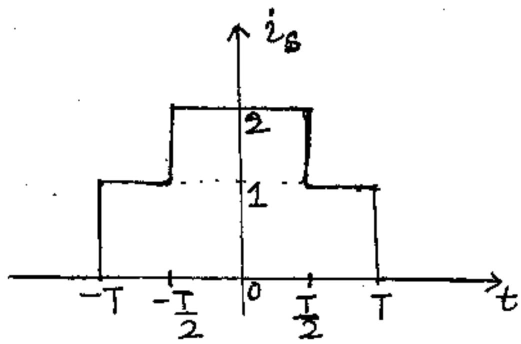

Fig. Q6A-2

(B) The signal $x(t)$, shown in Fig. Q6B, is approximated by the first $2N+1$ terms (from $n=-N$ to N) in its exponential Fourier series. Detremine the value of N if this $(2N+1)$-term Fourier series power is to be no less than 99.75% of the power of $x(t)$.

[6 *marks*]

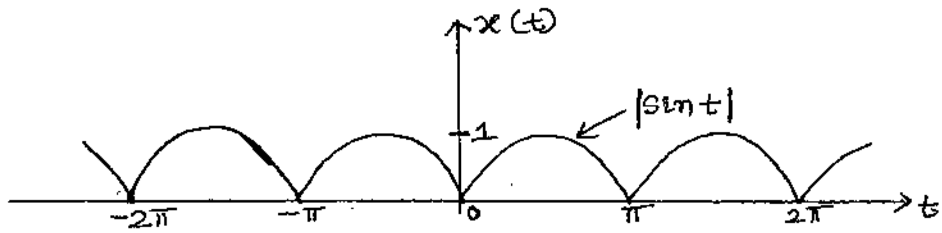

Fig. Q6B

(C) The following information about a discrete-time periodic signal $x[n]$ with a period of 8 and Fourier coefficients a_k is given:

(i) $a_k = -a_{k-4}$

(ii) $x[2n+1] = (-1)^n$

Sketch one period of $x[n]$.

[6 *marks*]