Exam III
April 18, 2001

Name: __________________________________

Student ID: _________________

CIRCLE YOUR DIVISION

Division:  201-1 (Bagwell);  201-2 (Capano);  201-3 (DeCarlo)

INSTRUCTIONS:
♦  NO CALCULATORS
♦  There are twelve (12) multiple choice worth 5 points each; there is one (1) workout
  problem worth 40 points.
♦  Our goal is to assess what you know, not what you do not know. To maximize our
  assessment of your knowledge and understanding, do NOT dwell on a single problem. If you get
  stuck, move on to the next problem and return later, time permitting. It is important to work
  patiently, efficiently, and in an organized manner.
♦  This is a closed book, closed notes exam. No scrap paper is permitted. You are
  permitted only a calculator.

All students are expected to abide by the usual ethical standards of the university, i.e., your
answers must reflect only your own knowledge and reasoning ability.
1. In the op amp circuit below, \( v_s(t) = t \ u(t) \ V \). The response \( v_{out}(t) \) is (in V):

(1) \(-u(t)\)  (2) \(-2u(t)\)  (3) \(-0.5u(t)\)
(4) \(-0.5t^2u(t)\)  (5) \(-t^2u(t)\)  (6) \(0.5u(t)\)
(7) \(u(t)\)

![Op Amp Circuit Diagram]

2. The total energy stored in the circuit is 16 J. Find \( i_L(t) \) (in amps) if \( v_c(t) \) has a maximum at \( t = 0 \).

![Inductor Circuit Diagram]

(1) \(4\cos(2t)\)  (2) \(4\cos(t/2)\)  (3) \(2\cos(2t)\)  (4) \(2\sin(2t)\)
(5) \(2\sin(t/2)\)  (6) \(4\sin(t/2)\)  (7) none of the above
3. For the circuit below, the characteristic equation is \( s^2 + 5s + 10 = 0 \). Which combination of \( L \) (in henrys) and \( C \) (in farads) satisfy this equation?:

(1) \( L = 0.2; \ C = 0.5 \)

(2) \( L = 2; \ C = 0.2 \)

(3) \( L = 0.2; \ C = 4 \)

(4) \( L = 25; \ C = 0.04 \)

(5) \( L = 0.5; \ C = 0.2 \)

(6) \( L = 5; \ C = 0.2 \)

(7) none of the above

4. For the circuit below, the response for the inductor current, \( i_L(t) \), is desired. If the general solution is of the form, \( x(t) = x_n(t) + X_F \), what is the value of \( X_F \) in appropriate units?:

(1) 75 V

(2) 0 V

(3) 3 A

(4) 4 A

(5) 150 V

(6) 6 A

(7) 0 A
5. In the circuit below, the switch OPENS (as shown) AT t = 0 sec. Find the correct expression for the capacitor voltage when t > 0 (in volts):

\[ v_c(t) = -8 \cos(2t) + 8 \sin(2t) \]  
\[ v_c(t) = 8 \cos(4t) - 8 \sin(4t) \]  
\[ v_c(t) = -4 \sin(2t) \]  
\[ v_c(t) = -4 \cos(0.25t) + 8 \sin(0.25t) \]  
\[ v_c(t) = -8 \cos(4t) - 8 \sin(4t) \]  
\[ v_c(t) = -4 \cos(0.25t) \]  
\[ v_c(t) = 4 \sin(2t) \]

6. The current \( I \) (in AMPS) is:

\[ 1 \angle 90^\circ \]  
\[ \sqrt{3} \angle 0^\circ \]

\[ 1 \angle 30^\circ \]  
\[ 2 \angle -30^\circ \]  
\[ 2 \angle 30^\circ \]  
\[ 2 \angle -150^\circ \]  
\[ \sqrt{3} \angle -150^\circ \]  
\[ 4 \angle 30^\circ \]  
\[ \text{none of above} \]
7. If \( v_s(t) = 10 \sin(10t) \text{ V} \), then \( i_s(t) \) equals (in A):

(1) \( \frac{5}{\sqrt{2}} \cos(10t + 45^\circ) \)

(2) \( 10 \cos(10t) \)

(3) \( 5 \sin(10t) \)

(4) \( 10 \sin(10t) \)

(5) \( \frac{5}{\sqrt{2}} \cos(10t - 45^\circ) \)

(6) \( 5 \cos(10t + 45^\circ) \)

(7) none of the above

8. For the circuit below, determine the equivalent admittance, \( Y_{in}(j\omega) \), assuming \( \omega = 10 \text{ rad/sec} \).

(1) \( 0.25 - j10 \)

(2) \( 0.25 + j0.75 \)

(3) \( 0.25 + j5 \)

(4) \( 4 - j0.2 \)

(5) \( 4 + j5 \)

(6) \( 4 + j0.75 \)

(7) none of the above
9. Let $v_{\text{in}}(t) = 2 \cos(2t)$ V. Then $v_{\text{o}}(t) =$ (in V):

\begin{align*}
\text{(1)} & \quad \cos(2t) \\
\text{(2)} & \quad \sqrt{2} \sin(2t) \\
\text{(3)} & \quad \sqrt{2} \cos(2t) \\
\text{(4)} & \quad \sqrt{2} \cos(2t - 45^\circ) \\
\text{(5)} & \quad \sqrt{2} \cos(2t + 45^\circ) \\
\text{(6)} & \quad \sqrt{2} \cos(2t + 135^\circ) \\
\text{(7)} & \quad \text{None of the above}
\end{align*}

10. The value of the phasor $I_C$ for the circuit below is:

\begin{align*}
\text{(1)} & \quad 0.5 \sqrt{2} \angle -45^\circ \\
\text{(2)} & \quad 1 \angle 45^\circ \\
\text{(3)} & \quad 0.5 \\
\text{(4)} & \quad 0.5 \angle 45^\circ \\
\text{(5)} & \quad 0.5 \sqrt{2} \angle 45^\circ \\
\text{(6)} & \quad 1 \sqrt{2} \angle 45^\circ \\
\text{(7)} & \quad \text{None of above}
\end{align*}
11. In the circuit below, the equivalent impedance is $Z_{\text{in}}(j\omega) = 1.5 - j2.0$ when the frequency is 1 rad/sec. Which selection below corresponds to the unknown circuit element in the box?

(1) 0.5 Ω resistor  
(2) 0.5 F capacitor  
(3) 2.0 H inductor  
(4) 0.9 Ω resistor  
(5) 2.0 F capacitor  
(6) 2.1 H inductor  
(7) none of the above
12. Which of the following graphs best approximates the magnitude frequency response of the impedance function

\[ Z_{in}(j\omega) = \frac{4 - \omega^2}{4 - \omega^2 + j0.2\omega} \]
Workout Problem. (40 points)

Consider the circuit below with input waveform as shown. Answer the associated questions.

\[ i_s(t) = -I_m u(1-t) + I_m u(t-1) - I_m u(t-10) \text{ A} \]

(i) (2 pts) At \( t = 0 \), the capacitor looks like __________________________

(ii) (2 pts) At \( t = 0 \), the inductor looks like __________________________

(iii) (2 pts) \( i_L(1^-) = \) __________

(iv) (2 pts) \( v_C(1^-) = \) __________

(v) (7 pts) Draw the equivalent circuit valid at \( t = 1^+ \), i.e., with the inductor and capacitor replaced by the appropriate source (4 pts), and determine the value of \( i_C(1^+) \) (3 pts).

(vi) (3 pts) What is the characteristic equation in terms of \( R, L, \) and \( C \).

(vii) (3 pts) The roots of the characteristic equation are to be at \(-2\) and \(-4\). If \( L = 1 \) H and \( C = 1/8 \) F, compute the value of \( R \) that leads to these roots.

(viii) (5 pts) Write down the FORM of the response, \( v_C(t) \), valid for \( 1 \leq t \leq 10 \) s, i.e., in terms of unknown constants and the roots, \(-2\) and \(-4\).

(ix) (12 pts) Compute the value of the unknown constants in your answer to part (viii)

(x) (2 pts) \( v_C(\infty) = \) __________
Solutions MC:
1. (3) – 0.5 u(t)
2. (6) 4sin(t/2)
3. (5) L = 0.5; C = 0.2
4. (6) 6 A
5. (3) $v_c(t) = -4 \sin(2t)$
6. (2) $2 \angle -30^\circ$
7. (3)
8. (4)
9. (5)
10. (5)
11. (5)
12. (6)
SOLUTION TO WORKOUT PROBLEM (2 PTS QUESTIONS ARE ALL OR NOTHING)

(i) (2 pts) At t = 0, the capacitor looks like an open circuit.

(ii) (2 pts) At t = 0, the inductor looks like a short circuit.

(iii) (2 pts) \( i_L(1^-) = -I_m. \)

(iv) (2 pts) \( v_C(1^-) = -2RI_m. \)

(v) (7 pts) Draw the equivalent circuit valid at \( t = 1^+ \), i.e., with the inductor and capacitor replaced by the appropriate source (4 pts), and determine the value of \( i_C(1^+) \) (3 pts).

(vi) (3 pts) The circuit looks like a series RLC when the current source is set to zero. Hence the characteristic equation is:

\[
s^2 + \frac{4R}{L}s + \frac{1}{LC} = 0
\]

(vii) (3 pts) The roots of the characteristic equation are to be at \(-2\) and \(-4\). If \( L = 1 \) H and \( C = \frac{1}{8} \) F, compute the value of \( R \) that leads to these roots. From part (vi)

\[
(s + 2)(s + 4) = s^2 + 6s + 8 = s^2 + \frac{4R}{L}s + \frac{1}{LC} = s^2 + 4Rs + 8
\]

Hence \( R = \frac{6}{4} = 1.5 \) \( \Omega \).

(viii) (5 pts) Write down the FORM of the response, \( v_C(t) \), valid for \( 1 \leq t \leq 10 \) s, i.e., in terms of unknown constants and the roots, \(-2\) and \(-4\).

\[
v_C(t) = K_1e^{-2(t-1)} + K_2e^{-4(t-1)} + X_f
\]

(ix) (12 pts) Compute the value of the unknown constants in your answer to part (viii)

\[
X_f = 2RI_m = 3I_m
\]
\[ v_C(1^+) = -2RI_m = K_1 + K_2 + 2RI_m \]

Thus,

\[ K_1 + K_2 = -4RI_m = -6I_m \]

\[ \frac{dv_C}{dt}(1^+) = 8i_C(1^+) = 16I_m = -2K_1 - 4K_2 \]

Hence

\[ -K_1 - 2K_2 = 8I_m \]

It follows that \[ K_2 = 4RI_m - 8I_m = 6I_m - 8I_m = -2I_m \text{ and } K_1 = -2K_2 - 8I_m = -4I_m. \]

(x) (2 pts) \[ v_C(\infty) = \text{ZERO} \]