Mechanical Engineering
345 – Mechatronics

Midterm Exam 1

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Directions: take-home, all day, open notes, open book. Calculators, MATLAB, etc. allowed. Use your own paper, work neatly, and clearly mark your answers. Partial credit may be given.

Problem bupsrul

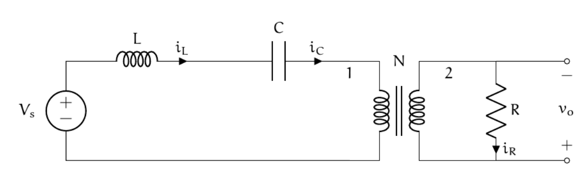
Write a one- or two-sentence response to each of the following questions and imperatives. The use of equations is acceptable when they appear in a sentence. Don't quote me (use your own words, other than technical terminology). ______/10 p.

a What is the piecewise linear diode model.
b What are the relationships between input and output voltage and current in a transformer? Why?
c The current through a capacitor becomes zero. What happens to the voltage across the capacitor?
d Explain the how the current from the drain to the source of a MOSFET changes as the gate voltage is varied. Assume the MOSFET is in the saturation region.
e When can we use impedance analysis?

Problem reorientator

Use the circuit diagram below to answer the following questions and imperatives. Let $V_s = A\sin(\omega t)$. Perform a full circuit analysis, including the transient response to find $v_o(t)$. The initial inductor current is $i_L(0) = 0$ and the initial capacitor voltage $v_C(0) = 0$. ______/40 p.

a Write the elemental, KCL, and KVL equations.
b Write the second-order differential equation for $v_C(t)$ arranged in the standard form.
c Convert the initial condition in i_L to a second initial condition in i_C.
d Let $R = 10\ \text{k}\Omega$, $L = 100\ \text{mH}$, $C = 100\ \mu\text{F}$, $N = 5$, $A = 5\ \text{V}$, and $\omega = 500\ \frac{\text{rad}}{\text{s}}$ and solve for $v_C(t)$.
e Derive an equation to find $v_o(t)$ from $v_C(t)$. This equation will include derivatives of $v_C(t)$. You don't need to add your solution to part **d** into this equation.



d. $\frac{d^2 v_c}{dt^2} + \frac{R}{LN^2}\frac{dv_c}{dt} + \frac{1}{LC} v_c = \frac{1}{LC} A\sin(\omega t)$

$\frac{d^2 v_c}{dt^2} + 4\times10^3 \frac{dv_c}{dt} + 10^5 v_c = 5\times10^5 \sin(500t)$

$\lambda^2 + 4\times10^3\lambda + 10^5 = 0$

$\lambda = \frac{-4\times10^3 \pm \sqrt{(4\times10^3)^2 - 4(10^5)}}{2}$

$\lambda = -25, -3975$

$V_{cp}(t) = C_1 e^{-25t} + C_2 e^{-3975t}$

$V_{ch}(t) = k_1 \sin(500t) + k_2 \cos(500t)$

$\frac{dv_{ch}}{dt} = 500 k_1 \cos(500t) - 500 k_2 \sin(500t)$

$\frac{d^2 v_{ch}}{dt} = -25\times10^4 k_1 \sin(500t) - 25\times10^4 k_2 \cos(500t)$

$-25\times10^4 k_2 + 2\times10^6 k_1 + 10^5 k_2 = 0$
$-25\times10^4 k_1 - 2\times10^6 k_2 + 10^5 k_1 = 5\times10^5$

$k_1 = -0.0136 \qquad k_2 = -0.249$

$V_{ch}(t) = -0.0136 \sin(500t) - 0.249 \cos(500t)$

$V_c(t) = V_{cp}(t) + V_{ch}(t)$
$= C_1 e^{-25t} + C_2 e^{-3975t} - 0.0186 \sin(500t) - 0.249 \cos(500t)$

$V_c(0) = 0 \qquad \left.\frac{dv_c}{dt}\right|_{t=0} = 0$

$\frac{dv_c}{dt} = -25 C_1 e^{-25t} - 3975 C_2 e^{-3975t} - 9.32\cos(500t) + 125 \sin(500t)$

$-25 C_1 - 3975 C_2 - 9.32 = 0$
$C_1 + C_2 - 0.249 = 0$

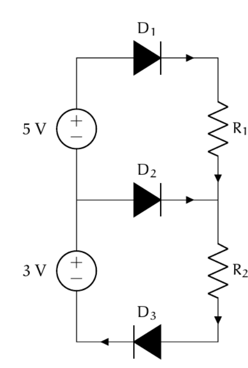
$C_1 = 0.253 \qquad C_2 = -0.0039$

$\boxed{V_c(t) = 0.253 e^{-25t} - 0.0039 e^{-3975t} - 0.0186 \sin(500t) - 0.249 \cos(500t)}$

Problem unrectangularization

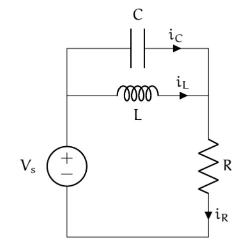
Use the circuit diagram below to answer the following questions. Assume $R_1 = R_2$ and that all diodes are ideal. ______/15 p.

a What state is each diode in?
b What is the voltage drop across each of the resistors?



Problem transidentilationism

For the circuit diagram below, perform a circuit analysis to solve for the steady state voltage across the resister R, $v_R(t)$. Assume $V_s = Ae^{j\frac{\pi}{2}}$ in sine phasor form and $A \in \mathbb{R}$. Express your answer in sine phasor form. ______/20 p.



Problem kirfunckle

Consider the circuit below with two constant voltage sources V_1 and V_2. Find the steady state voltage output v_o, assuming $R_1 = R_2 = R_3$. Hint: start solving with the equation $v_o = -v_{R_3}$. ______/15 p.