An answer sheet is attached to the back of this exam. Please put your name on your answer sheet and on your exam book. Also, please circle the name of your recitation instructor and the time of your recitation on your answer sheet.

Do all of your work in your exam book, and then record your answers on your answer sheet. Hand in both your exam book and your answer sheet at the end of the exam period. You may keep the exam questions.

You are welcome to use one double-sided page of notes while taking this exam.

Good luck!
Problem 1  —  30 Points

This problem studies the network shown below, which has a single port. In Parts (A), (B) and (C), the network stands alone; that is, \( i_1 = 0 \). In Part (D), the network is connected to a second network which is described graphically.

(A)  Assume that \( i_1 = 0 \). Find the node voltages \( e_1 \) and \( e_2 \) with respect to ground.

(B)  Find the Thevenin resistance \( R_T \) and voltage \( V_T \) for the network when viewed from its \( v_1-i_1 \) port.

(C)  Graph the \( v_1-i_1 \) relation for the network when viewed from its port assuming that \( V_1 > 0 \) and \( I_1 > 0 \). Clearly label all intercepts and slopes.

(D)  The network is connected to a second network having a \( v_2-i_2 \) terminal relation which is described graphically, as shown below. Find \( v_1 \) and \( i_1 \) in the presence of this connection.

All answers to Parts (A), (B) and (C) should be given in terms of the parameters \( V_1, I_1, R_1 \) and \( R_2 \). Part (D) may be answered additionally in terms of \( V_2, I_2, R_T, \) and \( V_T \).
Problem 2  –  35 Points

This problem studies the use of a mythical MOSFET-like device called a ZFET to construct an amplifier as shown below. The ZFET operates in its saturation region when \( v_{GS} \geq 0 \) and \( v_{DS} > 0 \). In this region, the drain-source terminal relation is \( i_{DS} = K v_{GS}^3 \), where \( K \) is a constant having units of \( \text{A/V}^3 \). When \( v_{DS} = 0 \), the ZFET exhibits a short circuit between its drain and source terminals, and is said to operate outside its saturation region. Similarly, the ZFET exhibits an open circuit for \( v_{GS} < 0 \) as it again operates outside its saturation region. Finally, the gate terminal always exhibits an open circuit. These characteristics are summarized in the figure below, beneath the symbol for the ZFET.

(A) Assuming saturated operation of the ZFET, determine \( v_{OUT} \) as a function of \( v_{IN} \).

(B) Over what range of \( v_{IN} \) will the ZFET operate in its saturation region?

(C) Assume that \( V_S = 10 \text{ V} \), \( R_L = 1 \text{ k\Omega} \) and \( K = 0.001 \text{ A/V}^3 \). Sketch and clearly label \( v_{OUT} \) as a function of \( v_{IN} \) for \(-1 \text{ V} \leq v_{IN} \leq 3 \text{ V} \) on the axes provided on the answer sheet.

(D) Given the parameters of Part (C), can the amplifier be used as an inverter that provides a valid output high voltage threshold of \( V_{OH} = 7 \text{ V} \). Why or why not? Assume that \( V_{IH} = 6 \text{ V} \) and \( V_{IL} = 2 \text{ V} \).

(E) Assume that the amplifier is biased at an input voltage \( v_{IN} \) such that the ZFET exhibits saturated operation; the corresponding bias output voltage is \( V_{OUT} \). For this case, derive the small-signal voltage gain \( v_{out}/v_{in} \) of the amplifier.
Problem 3  –  35 Points

This problem studies the circuit shown below in which a MOSFET is used as a switch to excite a parallel inductor and resistor. Prior to \( t = 0 \), \( v_{IN} < v_T \), the MOSFET is off, and \( i(t) = 0 \). At \( t = 0 \), \( v_{IN} \) steps above \( v_T \) until \( t = T \), and then steps below \( v_T \) for the rest of time as shown below. The goal of this problem is to find \( i(t) \) and \( v_{OUT}(t) \) for \( t \geq 0 \) using the switch-resistor MOSFET model shown below, first with \( R_{ON} = 0 \), and then with \( R_{ON} > 0 \).

(A) Assume that \( R_{ON} = 0 \). Determine \( i(t) \) and \( v_{OUT}(t) \) for \( 0 \leq t \leq T \).

(B) Continuing from Part (A), determine \( i(t) \) and \( v_{OUT}(t) \) for \( t \geq T \).

(C) Sketch and clearly label \( i(t) \) and \( v_{OUT}(t) \) as found in Parts (A) and (B) on the axes provided on the answer sheet. In doing so, assume \( T \approx L/R \).

(D) Assume that \( R_{ON} > 0 \). Determine \( i(t) \) for \( 0 \leq t \leq T \).
Problem 1

(A) \( e_1 = \) ~ \( e_2 = \)

(B) \( R_T = \) ~ \( V_T = \)

(C) 

(D) \( v_1 = \) ~ \( i_1 = \)
Problem 2

(A) \( v_{\text{OUT}} = \)

(B) \( v_{\text{IN}} \) Range:

(C) \[ \begin{array}{c|c|c|c|c|c} \hline v_{\text{OUT}} & 10V & 5V & \hline v_{\text{IN}} & -1V & 0V & 1V & 2V & 3V \hline \end{array} \]

(D) Circle One: Yes No

(E) \( v_{\text{out}} / v_{\text{in}} = \)

Problem 3

(A) \( i(t) = \)

(B) \( i(t) = \)

(C) \[ \begin{array}{c|c|c|c} \hline i(t) \quad \text{v}_{\text{OUT}}(t) \quad \hline v_T \quad t \quad v_T \quad t \hline \end{array} \]

(D) \( i(t) = \)

(E) \( v_{\text{OUT}}(t) = \)