UNIVERSITY OF CALIFORNIA
College of Engineering
Department of Electrical Engineering and Computer Sciences

EECS 40 Fall 2003
Introduction to Microelectronic Circuits Prof. King

MIDTERM EXAMINATION #2

November 3, 2003
Time allotted: 50 minutes

NAME: _____, _____
(print) **Last** **First**

Signature: _____ STUDENT ID#: _____

Discussion Section: _____

1. This is a **CLOSED BOOK** exam. However, you may use 2 sheets of notes and a calculator.
2. **SHOW YOUR WORK or REASONING** on this exam.
   (Make your methods clear to the grader.)
3. **Write your answers clearly (legibly) in the spaces (lines, boxes, or plots) provided.**
4. Remember to specify the units on answers whenever appropriate.

SCORE: **1 _____ / 16**

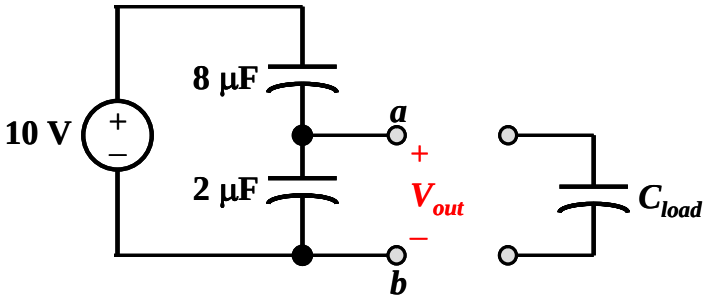
2 _____ / 17

3 _____ / 17

Total: _____ / 50

Problem 1: Energy-Storage Elements and 1st-Order Circuits [16 points in total]

a) Consider the capacitive voltage-divider circuit below. Find V_{out}. How will V_{out} change if a small load capacitance $C_{load} < 2$ μF is connected between terminals ***a*** and ***b***? **[4 pts]**

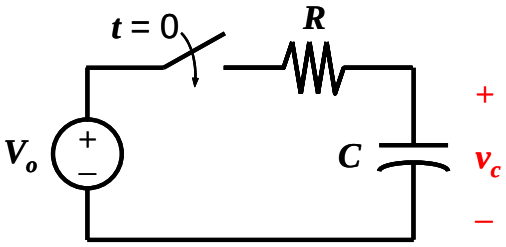


V_{out} = _____

V_{out} will [increase, decrease, not change] (circle one) when C_{load} is connected, because

_____

b) Consider the following RC circuit:



Provide a physical reason why it takes longer for v_c to reach its final value if R is increased. (Why is the characteristic time constant τ proportional to R?) **[2 pts]**

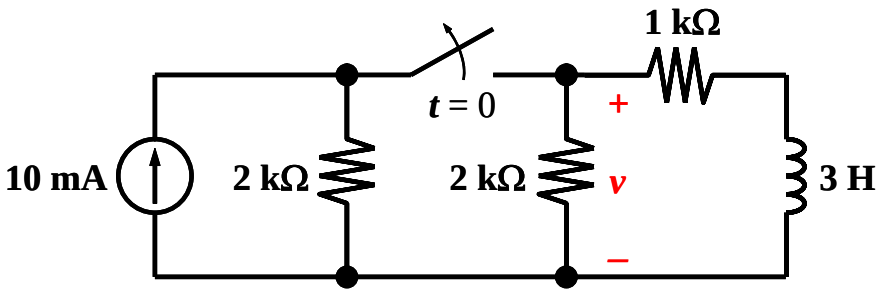
v_c will take longer to reach its final value if R is increased because

_____

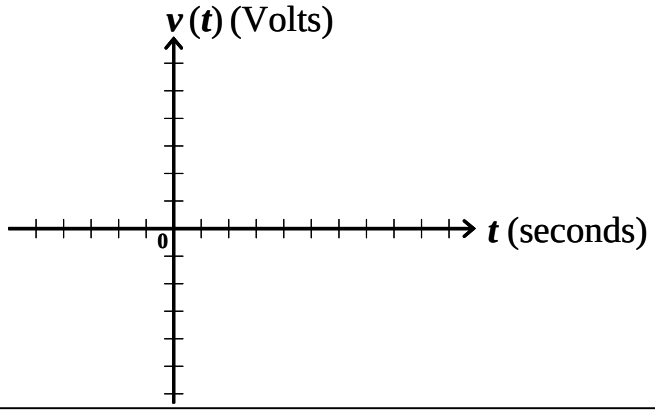
_____

Problem 1 (continued)

c) Assume that the circuit below is operating in steady state with the switch open for $t < 0$. Find and accurately sketch $v(t)$ for all t. **[10 pts]**



For $t < 0$: $v(t) =$ _____. **For $t > 0$:** $v(t) =$_____



Problem 2: Semiconductor Materials and Devices [17 points in total]

a) Consider a Si sample maintained at T = 300K, uniformly doped with Arsenic atoms to a concentration 3×10^{16} cm^{-3}. The electron mobility = 1000 cm^2/V•s; hole mobility = 400 cm^2/V•s.

i) Estimate the resistivity of this sample. (Use $q = 1.6\times10^{-19}$ C in your calculation.) **[4 pts]**

resistivity = _____

ii) How will the resistivity of this sample change if it were to be doped additionally with 3×10^{16} cm^{-3} Phosphorus atoms? **[3 pts]**

The resistivity will [increase, decrease, not change] (circle one)

by a factor that is [greater than, less than, equal to] (circle one) 2 when phosphorus is added because

_____

b) Explain (using 1 or 2 sentences) why a pn junction has capacitance. **[2 pts]**

A pn junction has capacitance because

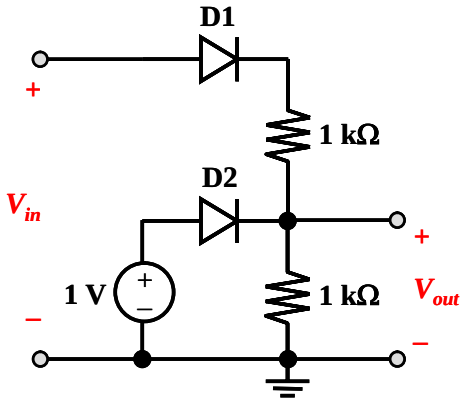
_____

_____

_____

Problem 2 (continued)

c) Assume the diodes in the circuit below can be modeled as perfect rectifiers.



i) For what values of V_{in} is D1 on? Explain your reasoning. **[3 pts]**

D1 is on for V_{in} _____ because

_____

_____

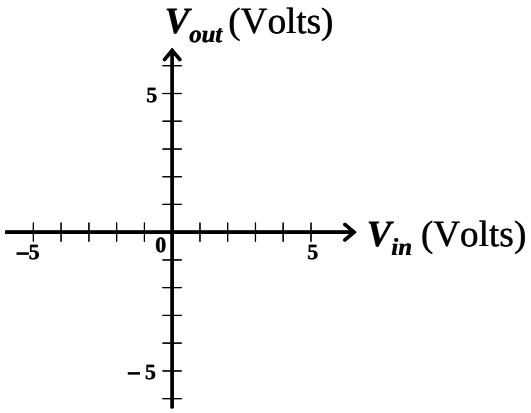
ii) For what values of V_{in} is D2 on? Explain your reasoning. **[2 pts]**

D2 is on for V_{in} _____ because

_____

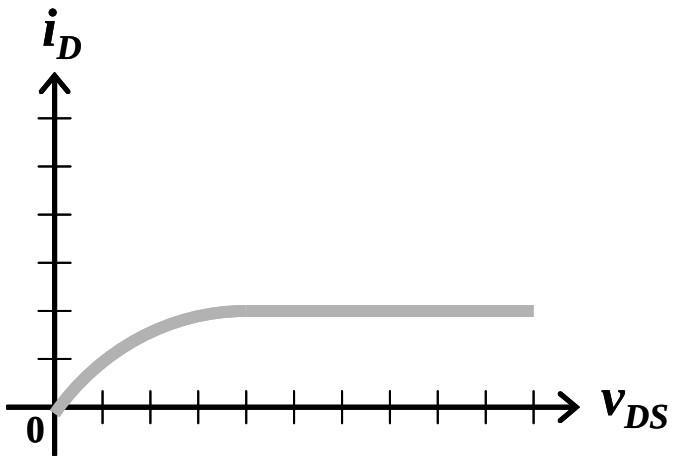
_____

iii) Accurately plot V_{out} *vs.* V_{in} on the axes provided. **[3 pts]**



<u>Problem 3</u>: MOSFET and Common-Source Amplifier [17 points in total]

a) The following is the i_D-v_{DS} characteristic of an n-channel MOSFET:



Indicate how this characteristic would change (by drawing the modified i_D-v_{DS} characteristic with appropriate changes in I_{DSAT}, V_{DSAT}, and slope at small values of v_{DS}):

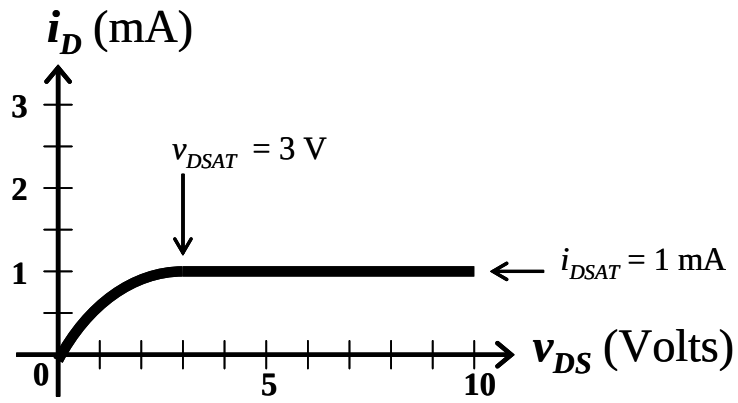
i) when V_T is lowered – **use a labeled solid line on the plot above [2 pts]**

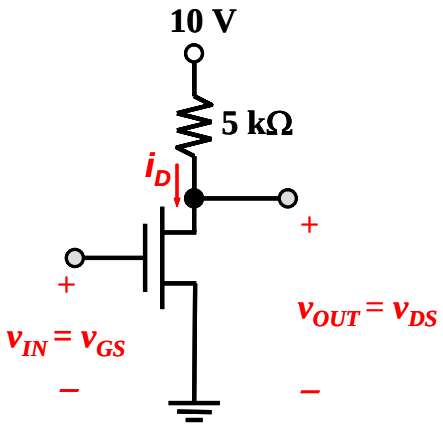
ii) when channel-length modulation is significant – **use a labeled dashed line on the plot above [2 pts]**

iii) when the current is limited by velocity saturation, rather than pinch-off – **use a labeled dotted line on the plot above [2 pts]**

Problem 3 (continued)

b) Below to the left is the i_D *vs.* v_{DS} characteristic for a long n-channel MOSFET with V_T = 1 V.





What is V_{GS}? **[2 pts]**

V_{GS} = _____

c) Suppose the MOSFET in part (b) is used in the amplifier circuit shown above to the right.

i) Draw the load line on the MOSFET i_D-v_{DS} plot (above to the left). **[3 pts]**

ii) In what region is the MOSFET operating? **[2 pts]**

The MOSFET is operating in the [linear, saturation, cutoff] (circle one) region because

_____

iii) What is the incremental change in the output voltage (*i.e.* v_{out}) for a -1 mV change in the input voltage (*i.e.* v_{gs} = -1 mV)? **[4 pts]**

v_{out} = _____