Department of Electrical and Computer Engineering
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Midterm 2
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EE 306 Introduction to Computing Systems
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Name: _______________________________

Problem 1 (20pts) ____________
Problem 2 (20pts) ____________
Problem 3 (20pts) ____________
Problem 4 (20pts) ____________
Problem 5 (20pts) ____________

Total (100pts) ________________

GOOD LUCK!!
Problem 1 (20pts)

Assuming that the TEN Memory locations at DATA have already been filled in before
the program executes,

```assembly
.ORIG x3000
LEA R0, DATA
AND R1, R1, #0
ADD R1, R1, #9
LOOP1
ADD R2, R0, #0
ADD R3, R1, #0
LOOP2
JSR SUB1
ADD R4, R4, #0
BRzp LABEL
JSR SUB2
LABEL
ADD R2, R2, #1
ADD R3, R3, #-1
BRp LOOP2
ADD R1, R1, #-1
BRp LOOP1
HALT
DATA .BLKW 10 x0000
SUB1 LDR R5, R2, #0
NOT R5, R5
ADD R5, R5, #1
LDR R6, R2, #1
ADD R4, R5, R6
RET
SUB2 LDR R4, R2, #0
LDR R5, R2, #1
STR R4, R2, #1
STR R5, R2, #0
RET
.END
```

a. After this program is assembled and loaded, what binary pattern is stored in memory
location x 3005
b. What is the function of subroutine SUB1

c. What is the purpose of the line 08 – ADD R4, R4, #0.

d. Find the relationship between the final values at DATA and the initial values at DATA
Problem 2 (20pts)

The following program fragment has an error in it.

```
ADD R3, R3, #30
ST R3, A
HALT
A .FILL #0
```

a. Identify the error and explain how to fix it.

b. Will this error be detected when this code is assembled or when this code is run on the LC-2?
Problem 3 (20pts)

a. Assemble the following program:

```
.ORIG x3000
STI R0, LABEL
OUT
HALT
LABEL .STRINGZ "\%"
.END
```
b. The programmer intended the program to output a % to the monitor, and then halt. Unfortunately, the programmer got confused about the semantics of each of the opcodes (that is, exactly what function is carried out by the LC-2 in response to each opcode). Replace exactly one opcode in the above program with the correct opcode, which will then make the program work as intended.

c. The original program from part 1 was executed. However, execution exhibited some very strange behavior. The strange behavior was in part due to the programming error, and in part due to the fact that the value in R0 when the program started executing was x3000. Explain what that strange behavior was and why the program behaved that way.
Problem 4 (20pts)

a. State the page number for each of the following LC-2 memory addresses:
   1. x12FE
   2. xA931
   3. x3110
   4. x3210
   5. x3310
   6. x3610

b. State the page offset for each of the above LC-2 memory addresses.
   1.
   2.
   3.
   4.
   5.
   6.
Problem 5 (20pts)

At location x3E00 we would like to put an instruction that does NOTHING! Many ISAs actually have an opcode devoted to doing nothing. It is usually called NOP, for NO OPERATION. The instruction is fetched, decoded, and executed. The execution phase is to do nothing!

a. Which of the following three instructions could be used for NOP and have the program still work correctly?

1. 0001 001 001 1 00000
2. 0000 111 000000001
3. 0000 000 00000000

b. What does the ADD instruction do that the others do not do?