I, the undersigned, do hereby affirm that the work contained in this exam is solely my own, and that none of the results were achieved by cheating. This includes using automated tools to generate answers, stealing the answers off the web, etc. Please do the work yourself.

Name ____________________________________________________________ (printed legibly)

Signature__________________________________________________________

9-digit Student ID ________________________________________________ (printed legibly)
# Grading

<table>
<thead>
<tr>
<th>Section</th>
<th>Possible Points</th>
<th>Actual Points</th>
</tr>
</thead>
<tbody>
<tr>
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<td></td>
</tr>
<tr>
<td>Floating Point Numbers</td>
<td>15</td>
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</tr>
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<td>20</td>
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<tr>
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<td>10</td>
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<td>15</td>
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<tr>
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<td></td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>100</strong></td>
<td></td>
</tr>
</tbody>
</table>
Problems 1-10 are about number representation and number conversion, no calculators allowed!

1) How many bits in a byte and bytes in a 64-bit word? (2 points)

__________________________________________, ____________________________

2) How many bits are required to represent 1015 unique patterns? How many are left over? (2 points)

__________________________________________, ____________________________

3) What is the binary equivalent of the hexadecimal number 0xABC0123? (2 points)

0b__________________________________________

4) What is the hexadecimal equivalent of the binary number 0b1100101101111? (2 points)

0x__________________________________________

5) What is the decimal equivalent of the binary number 0b0110101? (2 points)

__________________________________________

6) What is the binary equivalent of the decimal number 256 + 64 + 32 + 16 + 2 + 1 = 371? (2 points)

0b__________________________________________

7) What is the (fixed-point) binary equivalent of the decimal number 0.625? (2 points)

__________________________________________
8) What is the (fixed point) decimal equivalent of the binary number 1110.011? (2 points)

_____________________________________________

9) Translate the string “CS270” into decimal ASCII values (Hint: ASCII ‘A’ = 65, ASCII ‘0’ = 48). (3 points)

_____ _____ _____ _____ _____

10) What is the decimal value of the 8-bit 2’s complement binary number 0b11110110? (2 points)

_________________________________

11) Translate the decimal values below into 8-bit 2’s complement binary values and do the arithmetic. (6 points)

\begin{align*}
17 \quad 0b & \underline{\quad\quad\quad\quad\quad\quad\quad\quad\quad\quad\quad\quad\quad\quad\quad\quad\quad\quad}\quad 32 \quad 0b & \underline{\quad\quad\quad\quad\quad\quad\quad\quad\quad\quad\quad\quad\quad\quad\quad\quad\quad\quad}\quad \\
+ \quad 9 \quad 0b & \underline{\quad\quad\quad\quad\quad\quad\quad\quad\quad\quad\quad\quad\quad\quad\quad\quad\quad\quad}\quad + \quad -8 \quad 0b & \underline{\quad\quad\quad\quad\quad\quad\quad\quad\quad\quad\quad\quad\quad\quad\quad\quad\quad\quad}\quad \\
= \quad 26 \quad 0b & \underline{\quad\quad\quad\quad\quad\quad\quad\quad\quad\quad\quad\quad\quad\quad\quad\quad\quad\quad}\quad = \quad 24 \quad 0b & \underline{\quad\quad\quad\quad\quad\quad\quad\quad\quad\quad\quad\quad\quad\quad\quad\quad\quad\quad}\quad \\
\end{align*}

12) Show the result of the following logical operations in hexadecimal. Space is provided for binary values that may help you solve the problem but will not be graded (3 points)

\begin{align*}
0x76 & \quad 0x76 & \quad 0xFF \\
& \quad \& \quad 0xBD & \quad \mid \quad 0xBD & \quad \^ \quad 0x0F \\
= \quad 0x & \quad = \quad 0x & \quad = \quad 0x
\end{align*}
Problems 13-15 should be answered based on the IEEE 754 single-precision format.

HINT: 1 sign bit, 8 exponent bits, biased by 127, and 23 fractional bits, with an implicit 1.

13) What are the **binary** values of the fields of the IEEE 754 single-precision format of 12.25? (3 points)

Sign = _____

Exponent: ___________________

Mantissa: 1._________________________

14) What is the **decimal** number represented by 0b 0 10000011 1100000000000000000000000? (4 points)

Show your work for partial credit:

________________________________________

15) Fill in the values below for each step to add the floating point numbers $x = 2.25$ and $y = 4.125$. (8 points)

$x = 2.25 = 0x401000000$, $y = 4.125 = 0x40840000$, sum = $x + y$

What is the (unbiased) exponent of $x$, in decimal? __________

What is the (unbiased) exponent of $y$, in decimal? __________

What is the mantissa of $x$ in binary, with the implicit 1 shown? 1._________________________

What is the mantissa of $y$ in binary, with the implicit 1 shown? 1._________________________

What is the mantissa of the sum after normalization? 1._________________________

What is the (unbiased) exponent of the sum, after normalization? __________

What is the hexadecimal value of the sum? 0x_________________________

What is the decimal value of the sum? __________________
Problems 16-20 cover transistors, gates, and basic circuits.

16) Analyze the transistor circuits shown below and complete the truth table. Hint: A p-type transistor is closed with 0 input and open with 1 input, an n-type transistor the opposite. (4 points)

<table>
<thead>
<tr>
<th>A</th>
<th>B</th>
<th>T1 (p-type)</th>
<th>T2 (p-type)</th>
<th>T3 (n-type)</th>
<th>T4 (n-type)</th>
<th>C</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>0</td>
<td>Closed</td>
<td></td>
<td>Open</td>
<td>Open</td>
<td></td>
</tr>
<tr>
<td>0</td>
<td>1</td>
<td></td>
<td>Open</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>0</td>
<td></td>
<td>Closed</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>1</td>
<td>Open</td>
<td></td>
<td>Closed</td>
<td>Closed</td>
<td></td>
</tr>
</tbody>
</table>

17) How many select lines are needed for a 16 to 1 multiplexer? (2 points)

_______________________________________________________________________

18) For a 4-bit adder, what are the outputs for the inputs 0x8 and 0x9, if the CarryIn bit is 1. (4 Points)

Sum = 0x_______________, Carryout = __________
19) Analyze the combination logic shown below and complete the truth table. (6 Points)

![Logic Diagram]

<table>
<thead>
<tr>
<th>A</th>
<th>B</th>
<th>X</th>
<th>Y</th>
<th>Z</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>0</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>0</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>0</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

20) Connect the output of the appropriate AND gates to the OR gates to fulfill the truth table below. (4 points)

![Truth Table]

<table>
<thead>
<tr>
<th>A</th>
<th>B</th>
<th>X</th>
<th>Y</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>0</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>0</td>
<td>1</td>
<td>0</td>
<td>0</td>
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<tr>
<td>1</td>
<td>0</td>
<td>0</td>
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<tr>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
</tbody>
</table>
Problems 21 and 22 cover sequential logic and state machines.

21) Fill in the truth table for the D latch circuit shown below. (5 points)

<table>
<thead>
<tr>
<th>Data (D)</th>
<th>Enable (EN)</th>
<th>Previous State</th>
<th>Output (Q)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>0</td>
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<td>1</td>
<td>1</td>
</tr>
<tr>
<td>0</td>
<td>1</td>
<td>0</td>
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<tr>
<td>0</td>
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<tr>
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<td>1</td>
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<tr>
<td>1</td>
<td>1</td>
<td>0</td>
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</tr>
<tr>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
</tbody>
</table>
22) If the state machine below starts in State 0 and is sent the input pattern 92, 44, 44, 11, 82, 29, 65, 12, what is the output and final state? (5 points)

Output: ___ ___ ___ ___ ___ ___ ___ ___

Final State: _______
Problems 23-27 are related to LC-3 architecture and LC-3 assembly code.

23) What are the address space, word size, and number of registers on the LC-3 computer? (3 points)

_________________, _________________, _________________

24) Translate the following instruction into a hexadecimal value: AND R3,R6,#5 (3 points)

0x____________________________

25) Translate the following hexadecimal value into an assembly instruction: 0x94FF (3 points)

_____________________________________________

26) What is in the PC offset field of the following LC-3 branch instruction? (3 points)

BRnp LABEL
AND R2,R2,#0
AND R3,R3,#0
LABEL .FILL x1234

PC offset = ________________

27) What are the values in R0, R1, and R2 after the following code executes? (3 points)

BR MAIN
DATA0 .FILL xABCD
DATA1 .FILL x1234
DATA2 .FILL xFFF6
MAIN LD R0, DATA0
LD R1, DATA1
LD R2, DATA2
BRp NEXT1
AND R0,R0,#0
NEXT1 NOT R0,R0
BRp NEXT2
AND R2,R2,xF
NEXT2 ADD R1,R2,R1
HALT

R0 = 0x_______________
R1 = 0x_______________
R2 = 0x_______________
Questions 28-32 are related to the C program shown below, fill in what is printed. Note that the questions are in order of execution. (4 points each)

#include <stdio.h>

void doubleArray(int array[], int length) {
    for (int i = 0; i < length - 2; i++) {
        array[i] += array[i];
    }
    length += 5;
    printf("%d\n", length); // Question 29
}

int main(int argc, char *argv[]) {
    int integers[6] = {3, 4, 5, 6, 7, 8};
    int length = 6;

    printf("%d\n", integers[4]); // Question 28
    doubleArray(integers, length);
    printf("%d\n", *(integers + 3)); // Question 30
    printf("%d\n", *(integers + 4)); // Question 31
    printf("%d\n", length); // Question 32
}

28) ____________________________________

29) ____________________________________

30) ____________________________________

31) ____________________________________

32) ____________________________________
Appendix A) LC-3 Computer Schematic
Appendix B) LC-3 Instruction Set

![Instruction Set Table]

**Figure A.2** Format of the entire LC-3 instruction set. Note: + indicates instructions that modify condition codes.
Scratch paper, please do not put any answers here unless you reference this page in an answer!