1. How would the following string of characters be represented using run-length encoding? (6%) What is the compression ratio? (4%)

   AAAABBBCCCCCCCCDDDD hi there EEEEEEEEEFF

2. Huffman encoding is a text compression technique.
   a) Upon what are Huffman codes based? (5%)
   b) Given the following Huffman codes, encode the string "codat". (5%)

Huffman Code	Character
00	a
01	o
10	t
110	d
1110	g
1111	c

3. Give the truth table in the right, design a circuit to implement the following truth table. using only AND, OR, and NOT gates. (10%)

a	*b*	*output*
0	0	1
0	1	1
1	0	0
1	1	1

4. Suppose for an RSA key, p is 7, q is 19, and e is 5. Find the n and d. (10%)

5. Find NFA and DFA for the regular expression: $(a \cup ab)^*$. (10%)

6. Consider the grammar: S → A1B; A → 0A|ϵ; B → 0B|1B|ϵ. Give parse trees for the strings: (10%)
   a) 00101
   b) 1001

7. Suppose that you are working on a True-False test with 10 questions. Let p_i be the probability that you get answer i correct. Assume that the probabilities are independent.
   a) What is the probability of getting all of the answers wrong (expressed as a formula involving $p_1, p_2, \ldots, p_{10}$). (3%)
   b) If $p_i = 1 - 2^{-i}$, what is your expected number of correct answers? (7%)

8. Use a truth table to decide whether $P \rightarrow Q$ is equivalent to $\neg(P \wedge \neg Q)$. (10%)

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9. Suppose you run the following assembly program on a computer. The computer consists of 4 memory registers (`M[1]` to `M[4]`), 2 input registers (`I[A]` and `I[B]`), and one output register (`OUT`). Consider the operations and controls for the assembly.

```
12 MOV I[A] M[1]
13 MOV I[B] M[1]
14 ADD I[A] I[B]
15 MOV I[A] OUT
16 MOV I[B] M[3]
17 ADD I[A] I[B]
18 MOV M[4] OUT
19 HALT
```

OPERATIONS AND CONTROLS
1: MOVE X Y: X = Y
2: ADD X Y: OUT = X + Y
3: SUB X Y: OUT = X - Y
4: HALT: halt

Suppose the initial contents of the registers are: `M[1]` = 0100; `M[2]` = 0011; `M[3]` = 0010; `M[4]` = 1000. Answer the questions below. Write your answers in the format of 4-digit decimal numbers.

a) What is the value of `M[4]` after the instruction at location 15 completes? (3%)

b) What is the value of `OUT` when the program halts? (2%)

c) What is the value of `I[A]` after the instruction at location 16 completes? (2%)

d) What is the value of `M[4]` when the program halts? (3%)

10. The following program finds the common elements in two different integer arrays (fibArray and primeArray) and stores them in another array called commonArray. At the end of the program, it prints out how many common elements there are. Identify the bugs and then fix them. (10%)

```
1  int main()
2  {
3      int fibArray[] = { 1, 2, 3, 5, 8, 13, 21, 34, 55, 89 };
4      int primeArray[] = { 2, 3, 5, 7, 11, 13, 17, 19, 23, 29 };
5      int commonArray[];
6      int i, j;
7      for ( i = 0; i < 10; ++i )
8      {
9          for ( j = 0; j < 10; ++j )
10         {
11             if (fibArray[i] = primeArray[j])
12             {
13                 commonArray[j] = primeArray[j];
14                 ++n;
15             }
16         }
17     }
18     printf("The total number of common elements is %n\n", n);
19     return 0;
}
```

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