Write your answers on these pages and show your work. If you feel that a question is not fully specified, state any assumptions that you need to make in order to solve the problem. You may use the backs of these sheets for scratch work.

Write your name on this page and initial all other pages of this exam. Make sure your exam contains eight problems on ten pages.

Name

________________________________________________________________

Student ID

________________________________________________________________

<table>
<thead>
<tr>
<th>Problem</th>
<th>Score</th>
<th>Max Score</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
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<td>10</td>
</tr>
<tr>
<td>2</td>
<td>_____</td>
<td>15</td>
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<tr>
<td>3</td>
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<td>6</td>
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<td>7</td>
<td>_____</td>
<td>6</td>
</tr>
<tr>
<td>8</td>
<td>_____</td>
<td>9</td>
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</tbody>
</table>

TOTAL  _____  100
Problem 1 – $K$-Nearest Neighbors (10 points)

Consider the training set below.

<table>
<thead>
<tr>
<th>Ex #</th>
<th>A</th>
<th>B</th>
<th>C</th>
<th>D</th>
<th>Output</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>True</td>
<td>True</td>
<td>False</td>
<td>True</td>
<td>True</td>
</tr>
<tr>
<td>2</td>
<td>True</td>
<td>True</td>
<td>True</td>
<td>True</td>
<td>False</td>
</tr>
<tr>
<td>3</td>
<td>False</td>
<td>False</td>
<td>True</td>
<td>False</td>
<td>True</td>
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<tr>
<td>4</td>
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<td>5</td>
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<td>False</td>
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</tr>
<tr>
<td>6</td>
<td>True</td>
<td>False</td>
<td>True</td>
<td>True</td>
<td>False</td>
</tr>
</tbody>
</table>

Assume you wish to use the $K$-nearest neighbors algorithm on this dataset and set aside the last two examples as a tuning set.

Would you prefer $K=1$ or $K=3$? $K = \underline{\hspace{2cm}}$

Justify your answer below.
Problem 2 – Bayesian Networks (15 points)
Consider the following Bayesian Network, where variables A-D are all Boolean-valued:

\[
\begin{array}{c|c|c}
A & B & P(C = \text{true} | A, B) \\
\hline
\text{false} & \text{false} & 0.2  \\
\text{false} & \text{true} & 0.3  \\
\text{true} & \text{false} & 0.1  \\
\text{true} & \text{true} & 0.6  \\
\end{array}
\]

\[
\begin{array}{c|c|c}
B & C & P(D = \text{true} | B, C) \\
\hline
\text{false} & \text{false} & 0.9  \\
\text{false} & \text{true} & 0.8  \\
\text{true} & \text{false} & 0.4  \\
\text{true} & \text{true} & 0.3  \\
\end{array}
\]

a) What is the probability that all four of these Boolean variables are false? ____________
[Be sure to show your work for Parts a-c.]

b) What is the probability that A is true, C is true, and D is false? ____________

c) What is the probability that A is true given that C is true and D is false? ____________
Problem 3 – Probabilistic Reasoning and Learning (20 points)
a) In the general population, 5 in a 100,000 people have the dreaded Senioritis disease. Fortunately, there is a test (test4it) for this disease that is 99.9% accurate. That is, if one has the disease, 999 times out of 1000 test4it will turn out positive; if one does not have the disease, 1 time out of 1000 the test will turn out positive.

You take test4it and the results come back true. Use Bayesian reasoning to calculate the probability that you actually have Senioritis. That is, compute:

\[ \text{Prob(} \text{haveSenioritis} = \text{true} \mid \text{test4it} = \text{true}) = \ ]

Be sure to show your work below. It is fine if your answer is an arithmetic expression that contains only numbers and *, /, +, and/or -. It is not necessary to plug the numbers into a calculator and produce a single number as the answer.
b) Consider the first five examples of Question 1’s training set again (copied below), but this time use Naïve Bayes and do not create a tuning set.

<table>
<thead>
<tr>
<th>Ex #</th>
<th>A</th>
<th>B</th>
<th>C</th>
<th>D</th>
<th>Output</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>True</td>
<td>True</td>
<td>False</td>
<td>True</td>
<td>True</td>
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<tr>
<td>2</td>
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<td>5</td>
<td>True</td>
<td>True</td>
<td>False</td>
<td>False</td>
<td>True</td>
</tr>
</tbody>
</table>

Calculate the ratio below, showing your work below it and putting your (numeric) answer on the line to the right of the equal sign.

\[
\frac{\text{Prob}(\text{Output} = \text{True} \mid A = \text{False}, B = \text{False}, C = \text{False}, D = \text{False})}{\text{Prob}(\text{Output} = \text{False} \mid A = \text{False}, B = \text{False}, C = \text{False}, D = \text{False})} = \underline{\text{_______}}
\]


c) Draw a Bayesian Network for the task in Part b that is different from Naïve Bayes, and explain how it is different from Naïve Bayes. You only need to create the Conditional Probability Table (CPT) for one node, but do use the data in the table in Part b.
Problem 4 – Representing Knowledge with First-Order Logic (15 points)

Convert each of the following English sentences into First-Order Predicate Calculus (FOPC), using reasonably named predicates, functions, and constants. If you feel a sentence is ambiguous, clarify which meaning you’re representing in logic. (Write your answers in the space below each English sentence.)

Everyone except Paul knows someone taller than they are.

Often students take cs540 the semester after they took cs367.
[You must use the notation of Markov Logic Networks here.]

Passing the ball from one player to another changes who has it, but not the team they are on.
[You must use situation calculus here.]
Problem 5 – Propositional Reasoning (15 points)

a) Is the following wff valid, satisfiable, or unsatisfiable? Justify your answer formally.

\[(P \rightarrow Q) \leftrightarrow (P \lor \neg Q)\]

b) Put these wff’s in clausal form; show your work below and put your answers on the right.

\[
(-P \lor Q) \lor (R \rightarrow \neg S)
\]

\[
(P \lor Q) \rightarrow (R \lor S)
\]

---

c) We wish to use search to find an interpretation that satisfies all the clauses below. Show how this set of clauses can be simplified before starting the search. Justify your simplification(s).

\[(P \lor \neg Q \lor \neg R \lor \neg W)\]

\[(-P \lor Q \lor S)\]

\[(P \lor Q \lor \neg R)\]

\[(P \lor \neg Q \lor \neg S)\]

\[(W)\]
Problem 6 – FOPC Reasoning (10 points)

a) What is the *most-general unifier* (mgu), if any, of these two wff’s? ________________

\[ P(\xi, \eta, \zeta) \quad P(\eta, f(1, \xi), \zeta) \]

b) Given the following background knowledge:

1. \( \forall x \ \{ p(x) \leftrightarrow \{ q(x) \lor r(x) \} \} \)
2. \( \forall y \ \{ \neg q(y) \rightarrow p(y) \} \)
3. \( p(1) \)
4. \( p(2) \)
5. \( q(1) \)
6. \( \neg q(2) \)

Show: \( \exists z \ r(z) \) by filling out the table below, using as many lines as needed.

<table>
<thead>
<tr>
<th>Number</th>
<th>WFF</th>
<th>Justification</th>
</tr>
</thead>
<tbody>
<tr>
<td>7.</td>
<td></td>
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<td>11.</td>
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<tr>
<td>12.</td>
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</tbody>
</table>
Problem 7 – Neural Networks (6 points)

Consider a perceptron that has two real-valued inputs and an output unit that uses a step function as its output function. All the initial weights and the output unit’s threshold equal 0.1. Assume the teacher has said that the output should be 0 for the input \( in1 = 0.7 \) and \( in2 = 0.4 \).

Show how the perceptron learning rule (also called the delta rule) would alter this neural network upon processing this training example. Let \( \eta \) (the learning rate) be 0.25. You do not need to adjust the output unit’s threshold during training.

Perceptron BEFORE Training

Perceptron AFTER Training

Did these changes improve the network? _________
Explain your answer.
Problem 8 – Important AI Concepts (9 points)

Describe each of the following AI concepts and briefly explain its most significant aspect. (Write your answers in the space below the AI concept.)

<table>
<thead>
<tr>
<th>AI Concept</th>
<th>Description</th>
<th>Significance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tree Pruning</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Multiple Restarts</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Uniform Cost</td>
<td></td>
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</tr>
</tbody>
</table>

Have a good vacation!