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 and all other pages of this exam. Make sure your exam contains six problems on ten pages.

Name

Student ID

<table>
<thead>
<tr>
<th>Problem</th>
<th>Score</th>
<th>Max Score</th>
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<td>TOTAL</td>
<td>_____</td>
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Problem 1 – Representing and Reasoning with Logic (28 points)

a) 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 below each English sentence.)

---

All birds can fly except for penguins and ostriches or unless they have a broken wing.

---

There was a student in CS 540 Fall 1999 who was born in a country in South America.

---

John sold Mary his CS 540 textbook (and, hence, this book that John formerly owned is now owned by Mary). [You must use situation calculus here.]
b) Provide a formal interpretation that shows that the following translation from English to FOPC is incorrect. Be sure to explain your answer formally using the interpretation you provide.

\[ A \text{ book of Sue's is missing.} \quad \forall x \ [ \text{book}(x) \land \text{owner}(x, \text{Sue}) ] \rightarrow \text{missing}(x) \]

c) What is the most-general unifier (mgu) of these two wff's? _________________

Show your work.

\[ P(?x, ?x, f(?y)) \quad P(g(?a, ?b), g(1, ?b), ?b) \]

d) Why is And Elimination a legal inference rule but Or Elimination is not?
Problem 2 – Neural Networks (12 points)

a) Consider a perceptron that has two real-valued inputs and an output unit with a step function as its activation function. All the initial weights and the bias (“threshold”) equal 0.1. Assume the teacher has said that the output should be 0 for the input \(in_1 = 5\) and \(in_2 = -3\).

Show how the perceptron learning rule would alter this neural network upon processing this training example. Let \(\eta\) (the learning rate) be 0.2 and be sure to adjust the output unit’s bias during training.

\[ \text{Perceptron BEFORE Training} \]

\[ \text{Perceptron AFTER Training} \]

b) Qualitatively draw a (2D) picture of weight space where the backprop algorithm is likely to

i. do well

ii. do poorly

Be sure to explain your answers.
Problem 3 – Miscellaneous Questions (20 points)

a) What do you feel are the two (2) most important design choices you would need to make if you used CBR to choose the location of your next vacation? Briefly justify your answers.
   i. __________________________________________
   ii. __________________________________________

b) In a weird dream, you’re the simulated annealing algorithm. Currently you’re at node $A$ in a search space; $g(A) = 7$ and $h(A) = 5$. You next randomly select node $B$; $g(B) = 9$ and $h(B) = 8$. The temperature is a Wisconsin-like 10 degrees.
   Do you move to node $B$? _________ Show your work. (Lower $h$ values are better.)

c) Show an example of a cross over for a GA whose individuals/entities are 6-bits long.
d) On your way out of the hit feature *To Build a Decision Tree*, you are surprised to find out the movie theater is giving away prizes. You watch the people ahead of you choose their prize either from behind Door #1 or Door #2. Of those who chose Door #1, half received $5, 1% got a new bike worth $1000, and the rest got a worthless movie poster. Everyone who chose Door #2 got $10.

Assuming you want to maximize the likely dollar value of your prize, what door should you choose? ___________ Why?

e) Consider the *joint probability distribution* below.

<table>
<thead>
<tr>
<th>A</th>
<th>B</th>
<th>C</th>
<th>P(A, B, C)</th>
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<tr>
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<td>False</td>
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<td>0.07</td>
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<tr>
<td>True</td>
<td>True</td>
<td>True</td>
<td>0.33</td>
</tr>
</tbody>
</table>

i. What is $P(A = true)$? ______________  Show your work below.

ii. What is $P(A \rightarrow B)$? ______________  Explain.
Problem 4 – Important AI Concepts (10 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.)

---

*Soundness*

---

*Overfitting*

---

*Fitness Functions*

---

*Vector-Space Model*

---

*Negation by Failure*
Problem 5 – Bayesian Networks (12 points)
Consider the following Bayesian Network, where variables A-D are all Boolean-valued:

\[
\begin{array}{c|c|c}
A & B & P(A \text{=} \text{true} | A, B) \\
\hline
\text{false} & \text{false} & 0.1 \\
\text{false} & \text{true} & 0.5 \\
\text{true} & \text{false} & 0.4 \\
\text{true} & \text{true} & 0.9 \\
\end{array}
\]

\[
\begin{array}{c|c|c}
B & C & P(B \text{=} \text{true} | B, C) \\
\hline
\text{false} & \text{false} & 0.8 \\
\text{false} & \text{true} & 0.6 \\
\text{true} & \text{false} & 0.3 \\
\text{true} & \text{true} & 0.1 \\
\end{array}
\]

\[
\begin{array}{c|c|c}
A & B & P(C \text{=} \text{true} | A, B) \\
\hline
\text{false} & \text{false} & 0.1 \\
\text{false} & \text{true} & 0.5 \\
\text{true} & \text{false} & 0.4 \\
\text{true} & \text{true} & 0.9 \\
\end{array}
\]

\[
\begin{array}{c|c|c|c}
B & C & P(D \text{=} \text{true} | B, C) \\
\hline
\text{false} & \text{false} & 0.8 \\
\text{false} & \text{true} & 0.6 \\
\text{true} & \text{false} & 0.3 \\
\text{true} & \text{true} & 0.1 \\
\end{array}
\]

\[
\begin{array}{c|c|c}
A & B & P(A \text{=} \text{true}) \\
\hline
\text{false} & \text{false} & 0.1 \\
\text{false} & \text{true} & 0.5 \\
\text{true} & \text{false} & 0.4 \\
\text{true} & \text{true} & 0.9 \\
\end{array}
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\[
\begin{array}{c|c|c}
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\text{false} & \text{true} & 0.5 \\
\text{true} & \text{false} & 0.4 \\
\text{true} & \text{true} & 0.9 \\
\end{array}
\]

a) What is the probability that all four of these Boolean variables are false? ______________

b) What is the probability that C is true, D is false, and B is true? ______________

c) What is the probability that C is true given that D is false and B is true? ______________
Problem 6– More Probabilistic Reasoning (18 points)

a) Imagine that 99% of the time RE Disease (RED) causes red eyes in those with the disease, at any point in time 2% of all people have red eyes, and at any point in time 1% of the population has RED.

You have red eyes. What is the probability you have RED? _______________

b) Assume we have one diagnostic random variable (call it $D$) and two measurement variables (call them $M_1$ and $M_2$). For simplicity, assume that the $M$’s variables have three possible values (e.g., low, medium, and high) and that $D$ is Boolean-valued.

We collect data on 300 episodes and find out the following:

$D$ was true 100 times and for these cases:
- $M_1$=low 50 times, $M_1$=med 30 times, and $M_1$ = high 20 times
- $M_2$=low 10 times, $M_2$=med 80 times, and $M_2$ = high 10 times

$D$ was false 200 times and for these cases:
- $M_1$=low 20 times, $M_1$=med 80 times, and $M_1$ = high 100 times
- $M_2$=low 180 times, $M_2$=med 10 times, and $M_2$ = high 10 times

Making the assumption that $M_1$ and $M_2$ are conditionally independent given $D$,

i. Show how Bayes rule can be used to compute $P(D | M_1, M_2)$ given the data above and under the stated assumptions. [Do this algebraically – i.e., as an equation.]
ii. On a new episode we find $M1=\text{low}$ and $M2=\text{low}$. What is the most likely diagnosis? ____________ This time justify your answer numerically.

iii. Draw the Bayesian network that one would construct from the above data (do not add any "pseudo" counts to the above statistics; we won’t worry about dealing with probabilities equaling zero). Be sure to explain your solution.

Have a good vacation!