**CMSC 471 HW4 Spring 2022**

**Your Name (XYZZY@umbc.edu)**

Due April 12; total points: 100

Edit this file to include your answers either in Word or Google Docs. We done some of the for you as examples. Save both a hw4.docx and hw4.pdf version of the file with answers in your repository and commit and push them back to your GitHub repo.

**1. Checking Validity (10 points)**

1.a P ∨ ¬P

>>> tt\_true(expr('P | ~P'))  
True

1.b (P → Q) ↔ (¬P ∨ Q)

Your answer here

1.c P ∧ Q → (Q ∨ P)

Your answer here

1.d (P ∧ Q) → Q

Your answer here

1.e ((A ∧ B) → C) ↔ (A → (B → C))

Your answer here

1.f ((a → b) → a) → a

Your answer here

**2. Satisfiability (14 points)**

*2.a P ∧ Q*

*>>> dpll\_satisfiable(expr('P & Q'))  
{P: True, Q: True}*

2.b ALIVE ↔ ¬DEAD

Your answer here

2.c P → ¬ P v P

Your answer here

2.d ¬ (P ∨ ¬ P)

Your answer here

2.e P ∧ (P → Q)

Your answer here \

2.f P ∧ (Q →P)

Your answer here

2.g P ∧ (Q ∨ ¬P)

Your answer here

2.h P ∧ ¬Q ∧ (P → Q)

Your answer here

**3. Propositional Consequence (14 points)**

For each of the following entailment relations, say whether or not it is true. The text on the left of the entailment symbol (⊨) represents one or more sentences (separated by commas) that constitute a knowledge base. We've done the first one for you.

*3.a P ∧ Q ⊨ P*

*True*

3.b P ⊨ P ∨ Q

Your answer here

3.c ¬P ⊨ ¬ ¬ P

Your answer here

3.d P → Q ⊨ ¬ P → ¬ Q

Your answer here

3.e ¬ P ⊨ P → Q

Your answer here

3.f ¬ Q ⊨ P → Q

Your answer here

3.g P ∧ (P → Q) ⊨ Q

Your answer here

3.h ( ¬ P) ∧ (Q → P) ⊨ ¬ Q

Your answer here

**4. English to FOL (25 points)**

Translate the following English sentences into first order logic, describing the intended meaning of any non-obvious predicates. Feel free to optionally provide a more direct *paraphrase* of the meaning of your logic expression in English. If you think a sentence is ambiguous, describe the ambiguity and give logical expressions for all interpretations. We've done the first one for you using a notation with simple ASCII characters for logical operators (e.g., A:∀, E:∃, =>:→, <=>:↔, ^:∧, v:∨, ~:¬, >:>)

*4.1 There is no largest prime number.*

*~(Ex number(x)^prime(x)^(Ay number(y)^ prime(y) -> y >= x))*

***paraphrase:*** *It is not true that there is a prime number and it is greater than or equal to all prime numbers.* ***predicates:*** *number(x) is true if and only if x is a positive integer and prime(x) is true if and only if x is a prime number.*

4.2 Good food is not cheap and cheap food is not good.

Your answer here

4.3 John has exactly two brothers.

Your answer here

4.4 Every dog is either male or female and no dog can be both male and female.

Your answer here

4.5 The friend of your enemy is your enemy.

Your answer here

4.6 An ancestor of your ancestor is your ancestor.

Your answer here

**5. Expressing knowledge in CNF (15)**

Express each of the above as a set of clauses in conjunctive normal form (CNF)

*a. A ∨ (B ∧ C)*

*A ∨ B*

*A ∨ C*

b. A ∨ B ∨ C

Your answer here

c. A ∧ B ∧ C

Your answer here

d. (A ∧ B) ⇔ C

Your answer here

e. A => (B ⇔ C)

Your answer here

f. A => (( B => C) ∨ ~C)

Your answer here

**6. Solving a puzzle with SAT (22 points)**

The Three Stooges visited you recently and one of them ate the piece of pie you were saving in your refrigerator. You don't know who did it. But you do know that

* Only one of them ate the pie
* One of the three always tells the truth and the other two always lie

You don't know which one is the truthful one. So, you ask each one who ate the pie, and they give the following answers.

* Moe: "I ate the pie"
* Larry: "I did not eat the pie"
* Curly: "Moe did not eat the pie"

Maybe the stooges thought that they support one another by confusing you, but you were able to use logic to determine who the pie eater was. Explain your reasoning by (a) mapping the problem into propositional logic and (b) showing how the AIMA code can be used to solve this problem. These puzzles are hard for people because they are self-referential. Here's a suggestion.

* Start by trying to figure out the puzzle though a process of elimination
* Create variables to represent who ate the pie (e.g. P1 might be true if Moe ate the pie)
* Create sentences for each of the three statements (e.g., S1 is what Moe says: Moe ate the pie)
* Create sentences capturing the constraint that only one ate the pie and only one is telling the truth
* Use dpll\_statisfiable on a conjunction of these local sentences to see what model satisfies them

If you've done things correctly, the sentences will be satisfiable, and the model will reveal who ate your piece of pie.

Your answer here