# CS 171, Intro to A.I., Winter Quarter, 2020 — Quiz # 2 — 25 minutes

NAME:________________________________________ UCINetID _______________________

YOUR ID#: ________ ID# TO RIGHT:__________ ID# TO LEFT:___________ ROW:______ SEAT:______

**NOTE:** For this quiz, each point value is stated as **(M pts, blank=N)** where N is the expected value of random guessing. If you don't know the answer, you can leave it blank and receive N points. The intent is to discourage random guessing. Your expected performance measure is the same whether you guess or not, because N was chosen that way. However, leaving it blank has a lower variance than guessing, and so a more reliable score.

**1. (30 pts, blank=15) CNF.** Convert the following sentence to CNF. **SHOW YOUR WORK.**

$A \Leftrightarrow (B \wedge C)$

$[\, A \Rightarrow (B \wedge C)\,] \wedge [\, (B \wedge C) \Rightarrow A \,]$ /* Replace $\alpha \Leftrightarrow \beta$ by $[\, \alpha \Rightarrow \beta \,] \wedge [\, \beta \Rightarrow \alpha \,]$ */

$[\, \neg A \vee (B \wedge C)\,] \wedge [\, \neg(B \wedge C) \vee A \,]$ /* Replace $\alpha \Rightarrow \beta$ by $[\, \neg\alpha \vee \beta \,]$ */

$[\, \neg A \vee (B \wedge C\,)] \wedge [\, (\neg B \vee \neg C) \vee A \,]$ /* deMorgan's Rule */

$(\neg A \vee B) \wedge (\neg A \vee C) \wedge (\neg B \vee \neg C \vee A)$ /* Distribute OR over AND and simplify */

**2. (30 pts total, 5 pts each; blank=15 pts total, 2.5 pts each) Logic-To-English.** For each of the following FOPC sentences on the left, write the letter corresponding to the best English sentence on the right. Use these intended interpretations: (1) "Butterfly(x)" is intended to mean "x is a butterfly." (2) "Flower(x)" is intended to mean "x is a flower." (3) "FeedsOn(x, y)" is intended to mean "x feeds on y."

| | | | |
|---|---|---|---|
| D | ∀b ∃f Butterfly(b) ⇒ [ Flower(f) ∧ FeedsOn(b, f) ] | A | Every butterfly feeds on every flower. |
| F | ∃f ∀b Flower(f) ∧ [ Butterfly(b) ⇒ FeedsOn(b, f) ] | B | For every flower, there is some butterfly who feeds on that flower. |
| B | ∀f ∃b Flower(f) ⇒ [ Butterfly(b) ∧ FeedsOn(b, f) ] | C | There is some butterfly who feeds on some flower. |
| E | ∃b ∀f Butterfly(b) ∧ [ Flower(f) ⇒ FeedsOn(b, f) ] | D | For every butterfly, there is some flower that the butterfly feeds on. |
| A | ∀b ∀f [ Butterfly(b) ∧ Flower(f) ] ⇒ FeedsOn(b, f) | E | There is some butterfly who feeds on every flower. |
| C | ∃b ∃f Butterfly(b) ∧ Flower(f) ∧ FeedsOn(b, f) | F | There is some flower that every butterfly feeds on. |

**See Section 8.2.6**

**Note that ⇒ or ⇔ is the natural connective to use with ∀.**

**Note that ∧ is the natural connective to use with ∃.**

NAME (Print Darkly & Clearly):______________________________ UCI NetID: __________

**3. (40 pts, blank=20) Resolution Theorem Proving.** Your Knowledge Base (KB) is:

$A \qquad A \Rightarrow (B \vee C) \qquad B \Rightarrow D \qquad (C \vee D) \Rightarrow F$

You are asked to prove that F is true, that is, your query sentence is F. In CNF your KB plus negated query is:

$A \qquad (\neg A \vee B \vee C) \qquad (\neg B \vee D) \qquad (\neg C \vee F) \qquad (\neg D \vee F) \qquad \neg F$

Obviously, F must be true. **Produce a Resolution Proof that F is true, ending with ( ) to indicate a contradiction.** The first one is done for you as an example. *Think about it, then find a proof that mirrors how you think.*

The shortest proof I know of is only five lines long. Longer proofs are OK provided they are correct. It is OK if you omit the logical OR connectives ($\vee$) in your answer; we know they are there.

Resolve ___ $A$ ___ with ___ $(\neg A \vee B \vee C)$ ___ to produce: ___ $(B \vee C)$ ___

Resolve ___ $(B \vee C))$ ___ with ___ $(\neg B \vee D)$ ___ to produce: ___ $(C \vee D)$ ___

Resolve ___ $(C \vee D)$ ___ with ___ $(\neg C \vee F)$ ___ to produce: ___ $(D \vee F)$ ___

Resolve ___ $(D \vee F)$ ___ with ___ $(\neg D \vee F)$ ___ to produce: ___ $F$ ___

Resolve ___ $F$ ___ with ___ $\neg F$ ___ to produce: ___ ( ) ___

Another perfectly good proof works backward from F. Many other proofs are possible.

Resolve ___ $\neg F$ ___ with ___ $(\neg D \vee F)$ ___ to produce: ___ $\neg D$ ___

Resolve ___ $\neg F$ ___ with ___ $(\neg C \vee F)$ ___ to produce: ___ $\neg C$ ___

Resolve ___ $\neg D$ ___ with ___ $(\neg B \vee D)$ ___ to produce: ___ $\neg B$ ___

Resolve ___ $\neg C$ ___ with ___ $(\neg A \vee B \vee C)$ ___ to produce: ___ $(\neg A \vee B)$ ___

Resolve ___ $\neg B$ ___ with ___ $(\neg A \vee B)$ ___ to produce: ___ $\neg A$ ___

Resolve ___ $\neg A$ ___ with ___ $A$ ___ to produce: ___ ( ) ___