Below, for each problem on this test, “Perfect” is the percentage of students who received full credit, “Partial” is the percentage who received partial credit, and “Zero” is the percentage who received zero credit.

(Due to rounding, values below may be only approximate estimates.)

Problem 1.

Problem 2.

<u>We will release these numbers as they become available.</u>

CS-171, Intro to A.I. — Quiz#3 — Winter Quarter, 2016 — 20 minutes

YOUR NAME: ____

YOUR ID: ______________ ID TO RIGHT: _______________ ROW: __________ SEAT: __________

1. (60 pts total, 5 pts each) LOGIC CONCEPTS. For each of the following terms on the left, write in the letter corresponding to the best answer or the correct definition on the right. **The first one is done for you as an example.**

. A .	Agent	. A .	Perceives environment by sensors, acts by actuators.
C	Syntax	B	Chain of inference rule conclusions leading to a desired sentence.
I	Semantics	C	Specifies all the sentences in a language that are well formed.
L	Entailment	D	Describes a sentence that is true in all models.
J	Sound	E	Stands for a proposition that can be true or false.
K	Complete	F	Represented as a canonical conjunction of disjunctions.
E	Propositional Symbol	G	Possible world that assigns TRUE or FALSE to each proposition.
D	Valid	H	Describes a sentence that is false in all models.
M	Satisfiable	I	Defines truth of each sentence with respect to each possible world.
H	Unsatisfiable	J	An inference procedure that derives only entailed sentences.
B	Proof	K	An inference procedure that derives all entailed sentences.
G	Model	L	The idea that a sentence follows logically from other sentences.
F	Conjunctive Normal Form	M	Describes a sentence that is true in some model.

****** TURN PAGE OVER. QUIZ CONTINUES ON THE REVERSE. ******

The bold red numbers (1) to (4) show you the correspondences between the logical forms at different stages of the process.

2. (40 pts total for a correct proof. If no correct proof, then ... on step, -5 pts for each incorrect resolution step, but not more

ONE FISH, TWO FISH, RED FISH, BLUE FISH. (With apologies to Dr. Seuss.)

Amy, Betty, Cindy, and Diane went out to lunch at a seafood restaurant. Each ordered one fish. Each fish was either a red fish or a blue fish. Their waiter reported:

(1) **"They had exactly two red fish and two blue fish among them; I don't remember who had what."**
(2) **"Amy, Betty, and Cindy had exactly one red fish among them; I don't remember who had what."**
(3) **"Betty and Diane had fish of different colors; I don't remember who had what."**

You translate these facts into Propositional Logic (in prefix form, i.e., in Polish notation) as:

/* Ontology: Symbol A/B/C/D means that Amy/Betty/Cindy/Diane had a red fish. */
/* Ontology: Symbol (¬ A)/(¬ B)/(¬ C)/(¬ D) means that Amy/Betty/Cindy/Diane had a blue fish. */

See R&N Section 7.5.2.

```
(1)  (OR   (AND A B (¬ C) (¬ D) )          (AND A (¬ B) C (¬ D) )
           (AND A (¬ B) (¬ C) D)           (AND (¬ A) B C (¬ D) )
           (AND (¬ A) B (¬ C) D)           (AND (¬ A) (¬ B) C D) )
(2)  (OR   (AND A (¬ B) (¬ C) )            (AND (¬ A) B (¬ C) )
           (AND (¬ A) (¬ B) C) )
(3)  (<=>  B (¬ D) )
```

Betty's daughter asked, "Is it true that my mother had a blue fish?"

You translate this query sentence into Propositional Logic as "(¬ B)" and form the negated goal as **(4)** "(B)".

Your resulting knowledge base (KB) plus the negated goal (in CNF clausal form) is:

(1)	(A B C)	((¬ A) (¬ B) (¬ C))	(A B D)	((¬ A) (¬ B) (¬ D))
	(A C D)	((¬ A) (¬ C) (¬ D))	(B C D)	((¬ B) (¬ C) (¬ D))
(2)	((¬ A) (¬ B))	((¬ A) (¬ C))	((¬ B) (¬ C))	**(A B C)**
(3)	((¬ B) (¬ D))	(B D)		
(4)	(B)			

Note that (A B C) is produced by both (1) and (2), but appears in KB only once.

PROBLEM: Write a resolution proof that Betty had a blue fish.

For each step of the proof, fill in the first two blanks with CNF sentences from KB that will resolve to produce the CNF result that you write in the third (resolvent) blank. The resolvent is the result of resolving the first two sentences. Add the resolvent to KB, and repeat. Use as many steps as necessary, ending with the empty clause. The empty clause indicates a contradiction, and therefore that KB entails the original goal sentence.

The shortest proof I know of is only five lines long. **(A Bonus Point is offered for a shorter proof.)** Longer proofs are OK iff they are correct. *Clearly, if Amy, Betty, and Cindy had one red fish among them, then Diane had a red fish, so Betty had a blue fish. Think about it, and then find a proof that mirrors how you think.*

Resolve ___((¬ B) (¬ C))___ with ___(A C D)___ to produce: ___(A (¬ B) D)___

Resolve ___((¬ A) (¬ B))___ with ___(A (¬ B) D)___ to produce: ___((¬ B) D)___

Resolve ___((¬ B) D)___ with ___(B)___ to produce: ___(D)___

Resolve ___(B)___ with ___((¬ B) (¬ D))___ to produce: ___((¬ D))___

Resolve ___((¬ D))___ with ___(D)___ to produce: ___( )___

Resolve ________ with ________ to produce: ________

Resolve ________

Other proofs are OK, provided they are correct.

Resolve ________

Resolve ________

Other proofs are OK provided that t

STRATEGY HINT: Always try to reduce the number of literals. Look for cases where the number of literals will decrease (eventually, you need to decrease the number of literals to zero!). Look for cases where the two input clauses share other literals, which will be simplified. Look for cases where one clause is a singleton, which always reduces the number of literals that result in the resolvent. Look for opportunities to produce new singleton clauses, which can be used later to reduce the number of literals in other productions.

Resolve ((¬ A) (¬ B)) with (A C D) to produce: ((¬ B) C D)

Resolve ((¬ B) C D) with (B) to produce: (C D)

Resolve ((¬ B) (¬ C)) with (B D) to produce: ((¬ C) D)

Resolve (C D) with ((¬ C) D) to produce: (D)

Resolve (B) with ((¬ B) (¬ D)) to produce: ((¬ D))

Resolve ((¬ D)) with (D) to produce: ( )

Several bright and clever students found shorter proofs than I had been able to find (and so won a Bonus Point). For example, one such proof is:

Resolve (A C D) with ((¬ A) (¬ B)) to produce: ((¬ B) C D)

Resolve ((¬ B) C D) with ((¬ B) (¬ D)) to produce: ((¬ B) C)

Resolve ((¬ B) C) with ((¬ B) (¬ C)) to produce: ((¬ B))

Resolve ((¬ B)) with (B) to produce: ( )