For Quiz #3, of the 77 students who sat the Quiz:
(Due to rounding, numbers shown below are only an approximate estimate.)

Because EEE does not return to you these numbers, in full transparency:

<u>For Total Quiz #3 Score:</u>
"Perfect" (100%): ~29% (22 students)
"A" range (90-100%): ~47% (36 students)
"B" range (80-89%): ~23% (18 students)
"C" range (70-79%): ~9% (7 students)
"D" range (60-69%): ~13% (10 students)
"F" range (<60%): ~8% (6 students)

Please, if you are not scoring as highly as you would like to score: attend both lecture and discussion section (and pay attention; do not "multi-task"), attend office hours with the TA or me, schedule an off-hours office meeting with us, review the lecture notes, re-read your book, work the old tests as study guides, and do the homework. Please see the "Study Habits" section on the class website. In short --- OVER-STUDY!!

For each question on Quiz #3, "Zero" gives the percentage of students who received zero, "Partial" gives the percentage who received partial credit, and "Full" gives the percentage who received 100%.

<u>Problem 1:</u>
full credit: ~38% (29 students)
partial credit: ~62% (48 students)
zero credit: 0% (0 students)

Common errors with Problem 1: Using universal quantification in combination with conjunction; and using existential quantification in combination with implication.

<u>Problem 2:</u>
full credit: ~69% (53 students)
partial credit: ~25% (19 students)
zero credit: ~6% (5 students)

Common errors with Problem 2: Same old, same old. Attempting to resolve two literals in one step; and attempting to smuggle unavailable facts into the KB. Both of these error types were made regrettably often.

No student produced a proof for Problem 2 that was shorter than 5 lines long. It is our opinion (entirely unproven and unsupported; a Bonus Point is still offered for a shorter 4-line proof) that a shorter proof does not exist. A rationale from the TA runs approximately as follows:

The KB is sound, so a proof must contain the negated goal sentence. Obviously, you will need the sentence '((¬ A) (¬ B) (¬ C) (¬ D))' ("At least one blue fish"). To resolve that entirely, you will need at least four lines, because that sentence contains four literals. You can cancel ¬B with B, the negated goal sentence. But not all the other literals (A, C, D) are readily available. You can cancel two of those three and absorb the remainder into simplification after resolution. But, you'll still need at least one more line to supply the one literal that's missing.

CS-171, Intro to A.I. — Quiz#3 — Winter Quarter, 2015 — 25 minutes

Problem #1 (and its common mistakes) was discussed thoroughly in lecture on Tue., 17 Feb., and appears in the lecture slides for that date as slides #37-56. It also appears as Problem #7 on the Final Exam key for WQ'2014. If you attend lecture and pay attention, or if you review the lecture slides off-line and understand them, or if you review and understand the old quizzes and exams that are provided as study guides, then this was an easy problem for you because you already had seen all of the correct answers and many of the common mistakes, which you easily avoided.

Remember that $\Rightarrow$ is the natural connective for $\forall$ and $\wedge$ is the natural connective for $\exists$.

closest FOPC (FOL) sentence (wff, or well-formed formula)

1.a (example) __D__ "Everybody likes somebody."

A. $\forall x\ \forall y\ Person(x) \wedge Person(y) \wedge Likes(x, y)$
B. $\forall x\ \exists y\ Person(x) \wedge Person(y) \wedge Likes(x, y)$
C. $\forall x\ \forall y\ Person(x) \Rightarrow (\ Person(y) \wedge Likes(x, y)\ )$
D. $\forall x\ \exists y\ Person(x) \Rightarrow (\ Person(y) \wedge Likes(x, y)\ )$

1.b (10 pts) __B__ "All persons are mortal."

A. $\forall x\ Person(x) \wedge Mortal(x)$
B. $\forall x\ Person(x) \Rightarrow Mortal(x)$
C. $\exists x\ Person(x) \wedge Mortal(x)$
D. $\exists x\ Person(x) \Rightarrow Mortal(x)$

1.c (10 pts) __C__ "For every food, there is a person who

A. $\forall x\ \exists y\ Food(x) \wedge Person(y) \wedge Eats(y, x)$
B. $\forall x\ \exists y\ [\ Food(x) \wedge Person(y)\ ] \Rightarrow Eats(y, x)$
C. $\forall x\ \exists y\ Food(x) \Rightarrow [\ Person(y) \wedge Eats(y, x)\ ]$
D. $\forall x\ \forall y\ Food(x) \wedge Person(y) \wedge Eats(y, x)$

1.d (10 pts) __A__ "Every person eats every food."

A. $\forall x\ \forall y\ [\ Person(x) \wedge Food(y)\ ] \Rightarrow Eats(x, y)$
B. $\forall x\ \forall y\ Person(x) \Rightarrow [\ Food(y) \wedge Eats(x, y)\ ]$
C. $\forall x\ \forall y\ Person(x) \wedge Food(y) \wedge Eats(x, y)$
D. $\forall x\ \exists y\ [\ Person(x) \wedge Food(y)\ ] \Rightarrow Eats(x, y)$

1.e (10 pts) __B__ "There is someone at UCI who is sma

A. $\forall x\ Person(x) \wedge At(x, UCI) \wedge Smart(x)$
B. $\exists x\ Person(x) \wedge At(x, UCI) \wedge Smart(x)$
C. $\forall x\ [\ Person(x) \wedge At(x, UCI)\ ] \Rightarrow Smart(x)$
D. $\exists x\ Person(x) \Rightarrow [\ At(x, UCI) \wedge Smart(x)\ ]$

1.f (10 pts) __C__ "Everyone at UCI is smart."

A. $\forall x\ Person(x) \wedge At(x, UCI) \wedge Smart(x)$
B. $\exists x\ Person(x) \wedge At(x, UCI) \wedge Smart(x)$
C. $\forall x\ [\ Person(x) \wedge At(x, UCI)\ ] \Rightarrow Smart(x)$
D. $\exists x\ Person(x) \Rightarrow [\ At(x, UCI)\ ] \wedge Smart(x)$

1.g (10 pts) __D__ "Every person eats some food."

A. $\forall x\ \exists y\ [\ Person(x) \wedge Food(y)\ ] \Rightarrow Eats(x, y)$
B. $\forall x\ \exists y\ Person(x) \wedge Food(y) \wedge Eats(x, y)$
C. $\forall x\ \forall y\ Person(x) \wedge Food(y) \wedge Eats(x, y)$
D. $\forall x\ \exists y\ Person(x) \Rightarrow [\ Food(y) \wedge Eats(x, y)\ ]$

1.h (10 pts) __A__ "Some person eats some food."

A. $\exists x\ \exists y\ Person(x) \wedge Food(y) \wedge Eats(x, y)$
B. $\exists x\ \exists y\ [\ Person(x) \wedge Food(y)\ ] \Rightarrow Eats(x, y)$
C. $\exists x\ \exists y\ Person(x) \Rightarrow [\ Food(y) \wedge Eats(x, y)\ ]$
D. $\forall x\ \forall y\ Person(x) \wedge Food(y) \wedge Eats(x, y)$

1.a **"Everybody likes somebody."**
A. Everything(x,y) is a person and everything(x) likes everything (y).
B, Everything(x) is a person and there is some person(y) that is liked by x.
C. If something(x) is a person then everything(y) is a person and x likes y.
D. Correct.

1.b **"All persons are mortal."**
A. Everything(x) is a mortal person.
B. Correct.
C. There is something(x) that is a mortal person.
D. Vacuously true if there is anything(x) that is not a person.

1.c **"For every food, there is a person who eats that food."**
A. Everything(x) is a food and there is some person(y) who eats x.
(Note:This implies that every person(x) is a food eaten by a person(y)).
B. Vacuously true if there is anything(y) that is not a person.
C. Correct.
D. Everything(x) is a food and everything(y) is a person and y eats x.

1.d **"Every person eats every food."**
A. Correct.
B. If something(x) is a person then everything(y) is a food and x eats y.
C. Everything(x) is a person and everything(y) is a food and x eats y.
D. Vacuously true if anything(y) is not a food.

1.e. **"There is someone at UCI who is smart."**
A. Everything(x) is a person and at UCI and smart.
B. Correct.
C. If something(x) is a person and at UCI then that thing is smart.
D. Vacuously true if anything(x) is not a person.

1.f **"Everyone at UCI is smart."**
A. Everything(x) is a person and at UCI and smart.
B. There is something(x) that is a person at UCI and is smart.
C. Correct.
D. Vacuously true if anything(x) is not a person.

1.g **"Every person eats some food."**
A. Vacuously true if there is anything(y) that is not a food.
B. Everything(x) is a person and there is a food(y) and x eats y.
C. Everything(x) is a person and everything(y) is a food and x eats y.
D. Correct.

1.h **"Some person eats some food."**
A. Correct.
B. Vacuously true if there is anything(x) that is not a person or anything(y) that is not a food.
C. Vacuously true if there is anything(x) that is not a person.
D. Everything(x) is a person and everything(y) is a food and x eats y.

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

2. (30 pts total) 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. **Among them they had exactly <u>three red fish</u> and <u>one blue fish</u>.**

You translate this fact into Propositional Logic (in prefix form) as:

<u>/* Ontology: Symbol A/B/C/D means that Amy/Betty/Cindy/Diane had a red fish. */</u>

(or (and A B C (¬ D)) (and A B (¬ C) D)
(and A (¬ B) C D) (and (¬ A) B C D))

See R&N Section 7.5.2.

Their waiter reported:
**"Amy and Cindy had the same color fish; I don't remember which color it was.
Cindy and Diane had the same color fish; I don't remember which color it was."**

You translate these facts into Propositional Logic (in prefix form) as:

(<=> A C) (<=> C D)

Betty's daughter asked, "Is it true that my mother had a blue fish?"
You translate this query into Propositional Logic as "(¬ B)" and form the negated goal as "(B)".

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

(A B) (A C) (A D) (B C) (B D) (C D) **"Three red fish."**
((¬ A) (¬ B) (¬ C) (¬ D)) **"One blue fish."**
((¬ A) C) (A (¬ C)) ((¬ C) D) (C (¬ D)) **A <=> C <=> D.**
(B) **Negated goal.**

<u>Write a resolution proof that Betty had a blue fish.</u>
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. **<u>(A Bonus Point is offered for a shorter proof.)</u>** Longer proofs are OK provided they are correct. *<u>Obviously, it must be that Amy, Cindy, and Diane had the three red fish, so Betty must have had a blue fish. Think about it, then find a proof that mirrors how you think.</u>*

Resolve <u>((¬ A) (¬ B) (¬ C) (¬ D))</u> with <u>((¬ C) D)</u> to produce: <u>((¬ A) (¬ B) (¬ C))</u>

Resolve <u>((¬ A) (¬ B) (¬ C))</u> with <u>((¬ A) C)</u> to produce: <u>((¬ A) (¬ B))</u>

Resolve <u>((¬ A) (¬ B))</u> with <u>(B)</u> to produce: <u>(¬ A)</u>

Resolve <u>(A C)</u> with <u>(A (¬ C))</u> to produce: <u>(A)</u>

Resolve <u>(¬ A)</u> with <u>(A)</u> to produce: <u>( )</u>

Other proofs are OK, provided they are correct.

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!). Note that in every line in the proof above, the resolvent has fewer literals than in the longest clause that produced it. Look for cases where the two input clauses share other literals, which will be simplified. For example, on line #1 the literal (¬ C) is shared in both input clauses, so the net result is simply to cancel the (¬ D) in the first clause. Look for cases where one clause is a singleton, which <u>always</u> reduces the number of literals that result in the resolvent. For example, in line #3 the singleton clause (B) simply cancels the (¬ B) in the first clause. Look for opportunities to produce new singleton clauses, which can be used later to reduce the number of literals in other productions. For example, the singleton (¬ A) produced in line #3 is used later in line #5 to reduce the number of literals to zero, thereby achieving the goal ( ).

Resolve ______

Resolve ______

Resolve ______

Resolve ______

Resolve ______

Other proofs are OK provided that they are correct. For example, another correct proof is:

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

These three true sentences state that Amy, Cindy, and Diane had the red fish.

The contradiction arises because B cannot be true in any world in which A, C, and D are true.

Note that in every line in the proof above, the resolvent has fewer literals than in the longest clause that produced it.