2nd Midterm Exam – Wednesday November 18
100 points, 120 minutes, Open book and notes

1. [15 points]
You are given the English sentence “The box contains only red shirts” and different logical expressions:

1. \(\exists x \text{ Shirt}(x) \land \text{InBox}(x) \Rightarrow \text{Red}(x)\)
2. \(\forall x \text{ Shirt}(x) \land \text{Red}(x) \Rightarrow \text{InBox}(x)\)
3. \(\forall x \text{ InBox}(x) \Rightarrow \text{Shirt}(x) \land \text{Red}(x)\)
4. \(\forall x \text{ Shirt}(x) \land \text{InBox}(x) \Rightarrow \text{Red}(x)\)
5. \(\exists x \text{ Shirt}(x) \land \text{InBox}(x) \land \text{Red}(x)\)

1. Is one of the translations from English to logic correct? if yes, which one?
2. For each of the logical sentences that are not a correct translation of the sentence given above, write in English what the logical sentence is actually saying.

2. [15 points]
Specify if each of the following expressions represents correctly the corresponding English statement. If not explain why not and correct it.

1. Every cat owner likes all animals.
   \(\forall x \forall z [\text{Person}(x) \land \exists y \text{ Cat}(y) \rightarrow \text{Owns}(x, y)] \rightarrow \text{Likes}(x, z)\)
2. Anyone who owns a bird does not own any cat.
   \(\forall x \forall y \forall z \text{ Cat}(y) \land \text{Bird}(z) \land \text{Owns}(x, z) \land \neg \text{Owns}(x, y)\)
3. No person would harm a cat.
   \(\forall x \forall y \text{ person}(x) \land \text{cat}(y) \land \neg \text{Harm}(x, y)\)
4. Birds do not like cats.
   \(\forall y \text{ Cat}(y) \land \neg [\exists x \text{ Bird}(x) \land \text{Likes}(x, y)]\)
5. Only birds fly.
   \(\exists x \text{ Bird}(x) \land \text{Flyes}(x)\)

3. [15 points]
Convert these English sentences to predicate calculus, using the following predicates: \(\text{City}(x) = x \) is a city; \(\text{In}(y, x) = x \) is in \( y \); \(\text{FF}(x) = x \) is a fastfood.

1. Every city has a fastfood.
2. At least one city has a fastfood.
3. Fastfoods are in all the cities.
4. McDonald is a fastfood.
5. There is only one fastfood in Morris.
4. [15 points]
Prove by resolution that the following set of propositional clauses is unsatisfiable:

1. \( \neg P \lor \neg Q \lor R \)
2. \( \neg S \lor Z \)
3. \( \neg Z \lor P \)
4. \( S \)
5. \( \neg R \)
6. \( \neg S \lor U \)
7. \( \neg U \lor Q \)

5. [20 points]

1. Write the following statements in predicate calculus:
   1. Trucks are bigger than SUVs.
   2. SUVs are cars.
   3. There is a SUV that is bigger than every car.
   4. An F150 is a truck.
   5. A Camry is a car.
   6. Bigger is transitive, i.e. if \( x \) is bigger than \( y \) and \( y \) is bigger than \( z \) then \( x \) is bigger than \( z \).

2. Convert them to conjunctive normal form. Pay attention to how you skolemize the existentially quantified variable in 3. Recall that a Skolem constant cannot be unified with another constant except itself, but it can be unified with a variable.

3. Prove by resolution that “An F150 is bigger than a Camry.”

6. [10 points]

Answer these questions about CSP briefly but precisely.

1. Describe briefly one advantage and one disadvantage of backtracking search compared to local search for solving CSPs.
2. When solving a CSP, what are the advantages, if any, of including forward checking in backtracking search?

7. [10 points]

Answer these questions about logic briefly but precisely.

1. In propositional logic you can prove that \( KB \models Query \) by showing that \( KB \Rightarrow Query \) is a tautology. Explain why.
2. In predicate calculus, if resolution with refutation fails to produce the empty clause, what can you conclude? Is the same true for propositional calculus? Why?