CSCE 625, HW #2
due: Tues, Nov 21, 2017 (hand-in print-out in class - not hand-written)

1. Translate the following sentences to FOL:

- Tomatos are either a fruit or vegetable.
- Some mushrooms are poisonous.
- Define 'triangle'.
- A plant can only produce seeds after it has been polinated.
- John's favorite movies are any movie by Stephen King except Cujo.
- The winner of a football game is the team that has the most points at the end.
- The warning light of a Ford Exporer will be on when its gas tank is more than 90% empty.
- Al and Bob bought their computers from the same manufacturer.
- All laptops sold by Dell in 2012 have at least 4 gigabytes of memory.

2. Convert the following sentence to CNF:

- $\forall x\ P(x) \rightarrow [\ \forall y\ P(y) \rightarrow P(f(x,y))\ ] \wedge [\neg \forall y\ Q(x,y) \rightarrow P(y)\ ]$

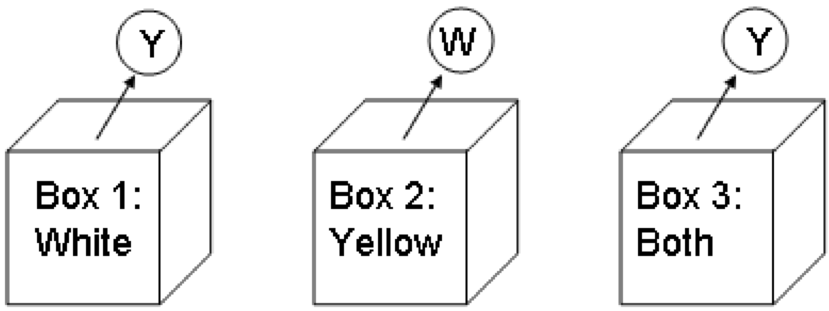
3. Consider the following situation: *Marcus is a Pompeian. All Pompeians are Romans. Ceasar is a ruler. All Romans are either loyal to Caesar or hate Caesar (but not both). Everyone is loyal to someone. People only try to assassinate rulers they are not loyal to. Marcus tries to assassinate Caesar.*

a) Translate these sentences to First-Order Logic.

b) Prove that ***Marcus hates Caesar*** using Natural Deduction.

c) Label all derived sentences with the prior sentences and unifier used.

4. You are the proprietor of Sammy's Sport Shop. You have just received a shipment of three boxes filled with tennis balls. One box contains only yellow tennis balls, one box contains only white tennis balls, and one contains both yellow and white tennis balls. You would like to stock the tennis balls in appropriate places on your shelves. Unfortunately, the boxes have been labeled incorrectly; the manufacturer tells you that you have exactly one box of each, but that each box is definitely labeled wrong. One ball is drawn from each box and observed (assumed to be correct). Given the initial (incorrect) labeling of the boxes above, and the three observations, use Propositional Logic to derive the correct labeling of the middle box.



- Use *binary predicates* in the following form: obs(1,Y) means a yellow ball was drawn (observed) from box 1, lab(1,W) means box 1 was initially labeled white, and cont(1,B) means box 1 actually contains both types of tennis balls.
- The initial facts describing this particular situation are: {obs(1,Y), obs(2,W), obs(3,Y), lab(1,W), lab(2,Y), lab(3,B)}

a. Write a knowledge base in FOL that captures the implications of what different observations or labels mean, as well as constraints inherent in this problem (e.g. all boxes have different contents). Do it in a complete and general way (writing down all the rules and constraints for this domain, not just the ones needed to make the specific inference about the middle box). *Do not include derived knowledge* that depends on the particular labeling of this instance shown above.

b. Prove that box 2 must contain white balls *cont(2,W)* using Natural Deduction.

5. Write a FOL knowledge base for playing tic-tac-toe. The rules are: players alternate placing pieces (X or O) on a 3x3 board; a win is defined as when a player has 3 of their pieces in a row, column, or diagonal.

Suppose we use a ternary predicate p(,,) to encode of the game state as follows: p(X,i,j) means there is an X in row i, column j, p(O,i,j) is for O pieces, and $b(i,j) \leftrightarrow \neg p(X,i,j) \wedge \neg p(O,i,j)$ indicates a blank position. For example, the board below is described by the following propositional sentence:
$\{p(X,1,1) \wedge b(1,2) \wedge b(1,3) \wedge p(O,2,1) \wedge b(2,2) \wedge b(2,3) \wedge p(O,3,1) \wedge b(3,2) \wedge p(X,3,3)\}$
(top-left is 1,1)

```
X |   |
---------
O |   |
---------
O |   | X
```

The goal is to write rules in FOL for where player 1 (the computer, assumed to be X) should place its next piece. In the board shown above, the best move would be in the middle (2,2), which we can represent as a proposition **move(X,2,2)**. The reason this is the optimal move is that X can win: **canWin(X,2,2**). In other situations, X might not be able to win, but is forced to make a move to block a potential win by O, as in the following: **forcedMove(X,3,2**). Note that you only need to make a forced move if there is no way X can win outright.

```
X |   |
---------
  |   | X
---------
O |   | O
```

Write rules to infer all desirable moves (for X) based on the above strategies. Note that there might be multiple optimal moves in a given situation (in which case, one could be chosen at random; this does not need to be encoded in your rules; see example below).

Hint: write sentences to define intermediate concepts such as **TwoInaRow(P,R), TwoInaCol(P,C),** and **TwoInaDiag(P,R,C)** and use them in the definition of higher-level concepts like **canWin(P,R,C)**.

(For a complete tic-tac-toe-playing program, there would be other cases you would need to handle as well, such as defining opening moves, and what to do if there are no positions where canWinX or forcedMoveX. An intelligent player-program might attempt to place two pieces in a row to setup a future situation where there will be two ways to win and the opponent can only block one. You might think about how to write rules for such sophisticated reasoning. However, they are not required for this homework.)

Your KB should be adequate to support the following inferences:

In this case, only **move(X,1,2)** should be inferrable (because X can win).

```
X |   | X
---------
  |   |
---------
O |   | O
```

In this case, only **move(X,2,3)** should be inferrable (because it is forced).

```
X |   | O
---------
O |   |
---------
  | X | O
```