NAME:
COLLABORATOR(S): *Please write down the names of your collaborators. If none, please write so. Otherwise, you'll be deducted 10 points. You need to write your own solutions.*

CS480 – HOMEWORK 3
Assigned on: Saturday, 10/11/2014
Due: Sunday, 10/26/2014, 11:59pm

There are 4 questions. Please submit your solutions through blackboard assignment page.

1. **[10 points]** Convert the following PL sentences into CNF form.
   - **a.** $(P \wedge Q) \Rightarrow (R \wedge S)$
   - **b.** $(P \wedge Q) \Rightarrow (R \vee S)$
   - **c.** $(P \vee Q) \Rightarrow (R \wedge S)$
   - **d.** $(P \vee Q) \Rightarrow (R \vee S)$
   - **e.** $(\neg P \wedge Q) \Leftrightarrow (R \vee \neg S)$
2. **[30 points]** We are given the following KB, which is already in CNF form. Answer the following questions using proof by contradiction and resolution.

   R1: $\neg A \vee B \vee E$
   R2: $\neg B \vee A$
   R3: $\neg E \vee A$
   R4: $\neg E \vee D$
   R5: $\neg C \vee \neg F \vee \neg B$
   R6: $\neg E \vee B$
   R7: $\neg B \vee F$
   R8: $\neg B \vee C$

   - **a.** Does the KB entail $(\neg A \wedge \neg B)$? Normally, resolution stops only when either a contradiction is found or when resolution no longer can be applied. However, for this homework only, if you cannot reach a contradiction, you can stop after 30 steps of resolution.
   - **b.** Does the KB entail E? Normally, resolution stops only when either a contradiction is found or when resolution no longer can be applied. However, for this homework only, if you cannot reach a contradiction, you can stop after 30 steps of resolution.

3. **[20 points]** Write the following English sentences using FOL. Use the following predicates and constants only.

Occupation(p, o): Predicate. Person *p* has occupation *o*.
Customer(p_1, p_2) : Predicate. Person p_1 is a customer of person p_2.
Boss(p_1, p_2) : Predicate. Person p_1 is a boss of person p_2.
Doctor, *Surgeon*, *Lawyer*, *Actor*: Constants denoting some occupations. This list is not comprehensive. There are also other occupations not mentioned in this list.
Emily, *Joe*: Constants denoting some people. This list is not comprehensive. There are also other people not mentioned in this list.

   a. Emily is either a surgeon or a lawyer.
   b. Joe is an actor but he also holds another job.
   c. All surgeons are doctors.
   d. Joe does not have a lawyer (i.e., Joe is not a customer of any lawyer.)
   e. Every surgeon has a lawyer (i.e., "has a lawyer" is the same thing as "is a customer of a lawyer.)

4. **[20 points]** Convert the following FOL sentences into CNF form.
   a. $\forall x\ P(x) \Rightarrow Q(x)$
   b. $\forall x \forall y\ P(x,y) \Rightarrow Q(x)$
   c. $\exists x\ P(x) \wedge Q(x)$
   d. $\exists x \exists y\ P(x,y) \wedge Q(y,x)$
   e. $\exists x \forall y\ P(x,y)$
   f. $\forall x \exists y\ P(x,y)$
   g. $\forall x \forall y \exists z\ P(x,y,z)$
   h. $\exists x \forall y \forall z\ P(x,y,z)$
   i. $\forall x(\exists y\ P(x,y) \wedge Q(y)) \Rightarrow R(x)$
   j. $\forall x(\forall y\ P(x,y) \Rightarrow Q(y)) \Rightarrow R(x)$

5. **[20 points]** We are given the following pairs of FOL sentences. For each sentence, provide a substation to unify the sentences. If no such substation exists, please write so.
    - **a.** P(x)
    - **b.** P(A)

    - **c.** $P(x) \vee Q(x, A)$
    - **d.** $P(B) \vee Q(x, A)$

    - **e.** $P(x) \vee Q(A, x)$
    - **f.** $P(x) \vee Q(A, B)$

    - **g.** $P(x, A) \vee Q(A, x)$
    - **h.** $P(B, y) \vee Q(y, B)$

    - **i.** $P(x) \vee Q(F(x))$
    - **j.** $P(A) \vee Q(F(A))$

    - **k.** $P(x, A) \vee Q(F(x), x)$
    - **l.** $P(B, y) \vee Q(F(B), B)$

    - **m.** $P(x, A) \vee Q(F(x), x)$
    - **n.** $P(B, y) \vee Q(F(A), A)$

    - **o.** $P(x, y) \vee Q(F(A), B)$
    - **p.** $P(x, y) \vee Q(x, y)$

    - **q.** $P(x, y) \vee Q(F(A), A)$
    - **r.** $P(x, y) \vee Q(x, y)$

    - **s.** $P(x, y) \vee Q(F(x), y)$
    - **t.** $P(z, y) \vee Q(z, y)$