Part A **(50 points)**

1. **(15 points)** Consider the following rule:

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p(Y) :- e(X,Y) & not p(X)
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   Let the EDB relation e consist of the three pairs $\{(a,b),\ (b,c),\ (c,a)\}$.

   (a) What is the well-founded model for p with this EDB? Justify or explain your reasoning.

   (b) There is no stable model for p with this EDB. Prove that there is no stable model.

   (c) Find another EDB (i.e., a relation for e) for which this rule has a stable model. What *is* the stable model for p with your chosen EDB?

2. **(15 points)** An object-oriented database system can represent OIDs (object identifiers) in several different ways.

   (a) Describe three significantly different approaches to representing OIDs.

   (b) Give the advantages and disadvantages of each approach, considering the ease of locating objects from their OIDs, ease of modifying the database, and the ability to support very large, distributed databases.

   (c) When objects are brought into main memory, their OIDs must be *swizzled*; that is, the OID must be replaced by a memory address before it can be used. Describe two significantly different approaches to swizzling OIDs.

3. **(10 points)** Here are three conjunctive queries:

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$Q_1$:  p(X,Y) :- e(X,A) & e(A,Y) & e(X,B)
$Q_2$:  p(X,Y) :- e(X,A) & e(A,Y) & e(A,C)
$Q_3$:  p(X,Y) :- e(X,A) & e(A,Y) & e(Y,D)
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   (a) For each pair of conjunctive queries above, tell whether they are equivalent, whether one is properly contained in the other, or whether neither is contained in the other. You need not prove your answers in this part.

   (b) For one of the containments that you find in part 3a, prove the containment by giving a containment mapping.

   (c) For one pair R and S of conjunctive queries for which you found in part 3a that $R \subseteq S$ is false, prove your claim by exhibiting a database for which R produces something S does not.

4. **(10 points)** Consider the relation schema $ABCD$ with functional dependencies $A \rightarrow B$, $B \rightarrow C$, and $D \rightarrow B$. We wish to decompose this schema into Boyce-Codd normal form (BCNF).

   (a) Suppose we choose as our first step the decomposition into ACD and BD. What dependencies hold in these two relations? You may give a minimal cover for each, rather than listing all the trivial dependencies that hold.

   (b) Is ACD in BCNF? If so, justify; if not, give a further decomposition into BCNF.