1. Give a precise formulation of the following constraint satisfaction problems.

(a) Class scheduling: There is a fixed number of professors and classrooms, a list of classes to be offered, and a list of possible time slots for classes. Each professor has a set of classes that he or she can teach.

(b) The rectilinear floor-planning problem: Find non overlapping places in a large rectangle for a number of small rectangles.

2. Consider the following binary constraint network: There are 4 variables: $X_1, X_2, X_3, X_4$, with the domains:

$$D_1 = \{1, 2, 3, 4\}, \quad D_2 = \{3, 4, 5, 8, 9\}, \quad D_3 = \{2, 3, 5, 6, 7, 9\}, \quad D_4 = \{3, 5, 7, 8, 9\}.$$ $X_1 \geq X_2,$ $X_2 > X_3$ or $X_3 - X_2 = 2,$ $X_3 \neq X_4.$

(a) Write the constraints in a relational form and draw the constraint graph.

(b) Is the network arc-consistent? If not, compute the arc-consistent network.

(c) Is the network consistent? If yes, give a solution.

3. Consider the 8 squares positioned as follows:
The task is to label the boxes above with the numbers 1-8 such that the labels of any pair of adjacent squares (i.e. horizontal, vertical or diagonal) differ by at least 2 (i.e. 2 or more).

(a) Write the constraints in a relational form and draw the constraint graph.

(b) Is the network arc-consistent? If not, compute the arc-consistent network.

(c) Is the network consistent? If yes, give a solution.

4. Consider a tree constraint problem, with 15 variables $X_1, \ldots, X_{15}$, $D_1, \ldots, D_{15} = \{1, 2, 3, 4, 5\}$, the constraint graph is a perfect binary tree with degree 2, and the binary constraints $C_{ij}$ are $C_{ij} = X_i > X_j$ where $i$ is the parent of $j$ in the tree (The root is $X_1$, see figure 1).

(a) Enforce arc-consistency.

(b) Is the network consistent? If yes, compute a solution.

(c) Can you suggest an ordering for which backtrack search will be backtrack-free?

(d) Bound the complexity of solving any problem whose constraint graph is the same as for this problem.

5. (Problem 5.6 in Russel and Norvig) Solve the cryptarithmetic problem in Figure 5.2 by hand, using backtracking with Forward checking and with MRV and with least constraining value heuristics.
6. (Problem 5.11 in Russel and Norvig). Show how a single ternary constraint such as $A+B = C$ can be turned into 3 binary constraints by using auxiliary variables. You may assume finite domains. Next show how constraints with more than 3 variables can be treated similarly. Finally show how unary domains can be eliminated by altering the domains of variables. This completes the demonstration that any CSP can be transformed into a CSP with binary constraints only.

7. (Problem 11.3 in Nilsson) Use the min-conflict (local search) method to solve the Four-Queens problem. Start with the queens on a main diagonal. Break ties randomly.