**Foundations of Constraint Programming**
**Tutorial 4 (on December 2nd)**

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**Exercise 4.1:**
Consider the following two CSPs with variables $x, y, z, w$:

a) $\langle x \neq y, z = x + y; x \in \{a, b\}, y \in \{b, c\}, z \in \{bb, cc\}\rangle$, where $+$ is the string concatenation

b) $\langle x \neq 10, x = y+1, \mathit{all\_different}(x, y, z), x+y+z = w; x \in [10..13], y \in [10..12], z \in [10..12], w \in [30..32]\rangle$

Are these CSPs consistent, node consistent, arc consistent, directionally arc consistent, hyper-arc consistent, path consistent, directionally path consistent? Can you find some $k$ for which these CSPs are not $k$-consistent? Explain your answers.

**Exercise 4.2:**
Consider the following CSP $P$:

$$\langle x + y < 5, y + x \neq 2, y + z \leq 3, z + x \leq 4; x, y, z \in [1..4]\rangle$$

a) Is $P$ normalized? If not, normalize it.

b) Apply the path consistency rules from slide 18 (lecture 4) to the normalized version of $P$.

**Exercise 4.3:**
Consider the following CSP $P$:

$$\langle x \leq y, w \leq y, v \leq y, u + v = z; x, y, z \in [2..6], u, v, w \in [3..8]\rangle$$

with the linear ordering on the variables:

$$x \prec y \prec z \prec u \prec v \prec w.$$

Draw the graph associated to $P$. For each node indicate its $\prec$-width. What is the width of the graph?