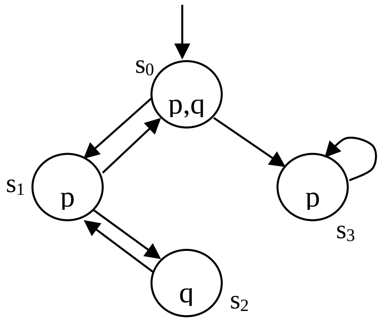
1. Given a transition system M = (S, S_0, L, R) (in the figure),

   i) complete the specification of M by substituting "..." with right symbols according to the figure;

   S = {s0, … , s3}
   S_0= {s0}
   L : l(s0) = {p,q},
   l(s1) = {p}
   l(s2) = {...} ....
   l(s3) = {...} ....
   R = { <s0, s1> , ... }



   ii) Specify the transition relation $R \equiv \vee_{i,j} R_{i,j}$ of model M in symbolic form where $R_{i,j}$ specifies an individual transition, e.g. $R_{2,1} \equiv \neg p \wedge q \wedge p' \wedge \neg q'$. Try to simplify R if possible.

   iii) Find the states of M where following CTL formulas hold:

   a) AX(p) ....
   b) EG(p) ....
   c) ¬AG(p) ....
   d) EF EG(p) ....
   e) A(p U q) ....

2. Express the formulas below using minimal set of CTL operators EX, EG, EU and ¬:

   i. AX(p) ....
   ii. EF(p) ....
   iii. ¬AG(p) ....

3. Given a symbolic state: $\varphi \equiv x_1 \wedge \neg x_2$ and transition relation $R \equiv x_1 \wedge x_2 \wedge \neg x_1' \vee \neg x_2'$. Find symbolic pre-image EX(φ) of φ. For this, use the definition EX(φ) ≡ $\exists V' (R \wedge \varphi [V' / V])$ and ∃-quantifier elimination for simplification.

4. Draw a cyclic Uppaal process with total duration within interval [d1, d2] and which is started with initial synchronization via channel `ch`.