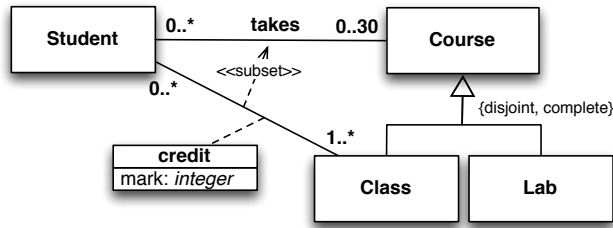


Exercise 1. Express the following UML class diagram in FOL.

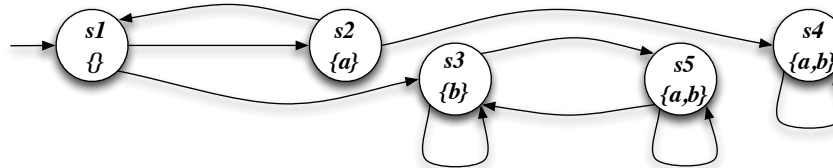


Exercise 2. Consider the above UML class diagram and the following (partial) instantiation.

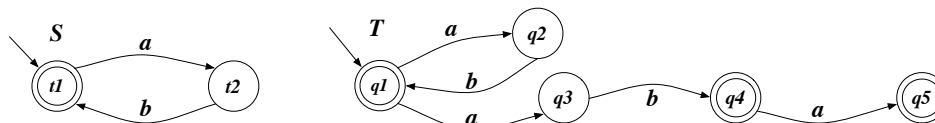
<i>Student</i>	<i>Class</i>	<i>Lab</i>	<i>credit/mark</i>			<i>takes</i>	
peter	calculus	IoT lab	peter	algorithm	30	peter	IoT lab
paul	AI	db lab	paul	calculus	27	paul	IoT lab
mary	FM	hacking lab	mary	algorithms	28	mary	FM
mary	AI		mary	AI	30	jane	db lab
jane	algorithms		jane	FM	30	jane	hacking lab
			jane	algorithms	30	jane	IoT lab

1. Check whether the instantiation (once completed) is correct (and explain why it is or it is not).
2. Express in FOL and evaluate the following queries:
 - (a) Return students that have taken at least 3 courses.
 - (b) Return students that have taken only classes.
 - (c) Check if there exists a student that has taken all labs.
 - (d) Check if there is a student that has taken all classes, but not for credit.

Exercise 3. Model check the Mu-Calculus formula $\nu X. \mu Y. ((a \wedge [next]X) \vee [next]Y)$ and the CTL formula $EF(\neg a \supset (EX a \wedge EX AG b))$ (showing its translation in Mu-Calculus) against the following transition system:



Exercise 4. Consider the following two transition systems:



Write the definition of bisimilarity and compute the bisimilarity relation for the two transition systems.

Exercise 5. Given the following conjunctive queries:

$q1(x) :- \text{edge}(x, y), \text{edge}(y, z), \text{edge}(z, x).$

$q2(x) :- \text{edge}(x, y), \text{edge}(x, w), \text{edge}(y, z), \text{edge}(z, x), \text{edge}(z, v), \text{edge}(v, y), \text{edge}(v, w), \text{edge}(w, z).$

check whether $q1$ is contained into $q2$, explaining the technique used and, in case of containment, showing the homomorphism between the canonical databases.