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

![UML class diagram]

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

<table>
<thead>
<tr>
<th>Workers</th>
<th>Director</th>
<th>TempDir</th>
<th>Department</th>
<th>Project</th>
<th>Role</th>
</tr>
</thead>
<tbody>
<tr>
<td>John</td>
<td>Jim</td>
<td>Ann</td>
<td>ICT</td>
<td>EU123</td>
<td>projectManager</td>
</tr>
<tr>
<td>Mary</td>
<td>Rick</td>
<td></td>
<td>HR</td>
<td>IT456</td>
<td>principalInvestigator</td>
</tr>
<tr>
<td>Joe</td>
<td></td>
<td></td>
<td>Management</td>
<td></td>
<td>partner</td>
</tr>
</tbody>
</table>

1. Check whether the above instantiation, once completed, is correct, and explain why it is or it is not.
2. Express in FOL the following queries and evaluate them over the completed instantiation:
   (a) Return the projects where the same department participates in different roles.
   (b) Return the projects in which each participating department participates with exactly one role.

Exercise 3. Model check the Mu-Calculus formula $\nu X.\mu Y.((a \land \langle \text{next} \rangle X) \lor (\neg b \land \langle \text{next} \rangle Y))$ and the CTL formula $\text{E}G\text{A}F a \lor \text{E}F\text{A}G b$ (showing its translation in Mu-Calculus) against the following transition system:

Exercise 4. Compute the weakest precondition for getting $\{x = 100\}$ by executing the following program:

```plaintext
x := y + 2;
if (x < 50) then {
    if (y < 0) then
        x := 2*x;
    else y := y*y
} else x := x + y;
y := y*y
```

Exercise 5. Given the following boolean conjunctive queries:

$q1() :- \text{edge}(r,b), \text{edge}(b,g), \text{edge}(g,r)$.
$q2() :- \text{edge}(x,y), \text{edge}(y,z), \text{edge}(z,x), \text{edge}(z,v), \text{edge}(v,y)$.

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