1. By emersion of the RBAC model, some researchers decided to combine the BLP and RBAC models. In fact, in this combinatorial model, we assign (statically or dynamically) a security level to each role. Propose a combinatorial model for this purpose.

You are free to consider or do not consider the following challenges.

- Can we assign a static security level to each role. In this case, is it possible to assign each arbitrary role to each arbitrary user (with a special clearance level)?
- Can we derive the security level of a role (in fact, the level required to play the role) based on the level of the objects on which the role has some permission?

2. Under what conditions two concurrent BLP secure systems $\Sigma(R, D, W, z_0)$ and $\Sigma(R', D', W', z'_0)$ preserve security. Specify the conditions formally.

3. Assume that the security policy is stated by the following assertion.

$$\{u, u'\}, \{c, \text{pass}(u, c)\} : |U| \text{ if } \neg \text{CHECK}(\text{previous}, u, c) \wedge (\text{CHECK}(\text{previous}, u', \text{pass}(u, c)) \Rightarrow \neg \text{last} = (u', \text{pass}(u, c))) \lor [\text{CHECK}(\text{previous}, u', \text{unpass}(u, c)) \wedge \text{last} = (u', \text{unpass}(u, c))].$$

And assume that

- $\text{CHECK}(w, u', \text{pass}(u, c)) = \text{CHECK}(w, (u', \text{pass}(u, c)), u, c) = \text{True}$
- $\text{CHECK}(w, u', \text{unpass}(u, c)) = \text{CHECK}(w, (u', \text{unpass}(u, c)), u, c) = \text{True}$
- $\text{CHECK}(\text{NIL}, u, c) = \text{False}$
- $\text{CHECK}(w, u'', *, *) = \text{CHECK}(w, (u'', *, *), u, c) = \text{True}$
- $\text{CHECK}(w, (u'', *, *), *, *) = \text{CHECK}(w, *, *)$

Apply the purge function to the following string where $v \in U$.

$$[[ (u, c), (u', \text{pass}(u, c)), (u'', d), (u''', \text{unpass}(u'', \text{pass}(u, c))), (u'', \text{pass}(u, c)), (u, c) ]]_v.$$
4. Nondeducibility is specified semi-formally in the lecture notes. Specify it fully formally using Set Theory notations.

5. Are systems $A$ and $B$, which are described in the lecture notes for describing non-composability of nondeducibility, GNI secure? If so, is their composition by hook-up GNI secure?