

**First name:** \_\_\_\_\_

**Last name:** \_\_\_\_\_

**Matriculation number:** \_\_\_\_\_

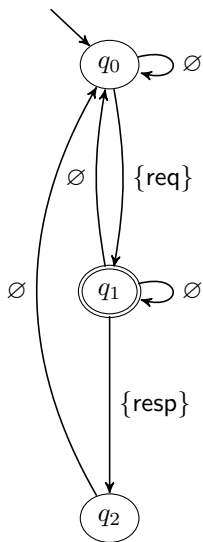
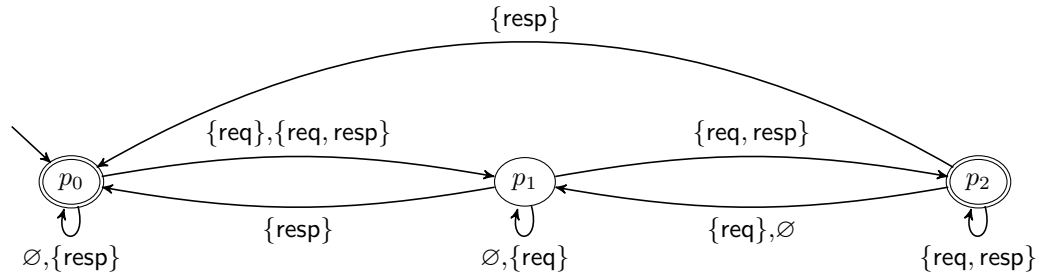
- Please answer all exercises in a readable and precise way.
- Please cross out solution attempts which are replaced by another solution.
- Please do not remove the staples of the exam.
- Cheating is not allowed. Everyone who is caught will fail the exam.

Exercise	Maximal points	Points
1	18	
2	19	
3	13	
4	20	
$\Sigma$	70	
Grade		

**Exercise 1 (9+3+2+4 points)**

The GNBA  $\mathcal{A}_1 = (\{p_0, p_1, p_2\}, \Sigma, p_0, \delta_1, \{p_0, p_2\})$  accepts  $\mathcal{L}(\varphi)$  for some LTL-formula  $\varphi$ . Moreover, we also have a GNBA  $\mathcal{A}_2 = (\{q_0, q_1, q_2\}, \Sigma, q_0, \delta_2, \{q_1\})$  which encodes a transition system  $TS$ , i.e.,  $\mathcal{L}(\mathcal{A}_2) = \text{Traces}(TS)$ .

- (i) Construct the GNBA  $\mathcal{A}$  for the intersection of  $\mathcal{A}_1$  and  $\mathcal{A}_2$ . Only write down those states which are reachable from the initial state.



- (ii) Write down the final states set(s) of  $\mathcal{A}$  explicitly. Again, you only have to mention the reachable states.

- (iii) Is  $\mathcal{L}(\mathcal{A}) = \emptyset$ ? If not, provide a word which is contained in  $\mathcal{L}(\mathcal{A})$ .

- (iv) Is it possible to answer “ $TS \models \varphi$ ?” using only the answer to part (iii)? Explain your answer shortly.

**Exercise 2 (6 + 13 points)**

Consider the LTL-formula

$$\varphi = \neg(\text{true U}(\text{req} \wedge \text{X}(\neg \text{resp U req})))$$

(i) Formulate the meaning of  $\varphi$  in words where **req** and **resp** represent a *request* and *response*, respectively.

(ii) Construct major parts of the GNBA for  $\psi$  using the *improved* translation from LTL to GNBA.

- $cl'(\psi) = \text{req}, \text{resp},$

- $(c_1, \dots)^T \in \delta((b_1, \dots)^T, (d_1, d_2)^T)$  iff

- Write down the set(s) of final states.

$$F_1 = \{(b_1, \dots)^T \mid$$

**Exercise 3 (2 + 4 + 7 points)**

Consider a buffer which consecutively reads commands *in* (to store something in the buffer) or *out* (to read something out of the buffer). Initially the buffer is empty.

There is the requirement that the buffer cannot output something if it is empty. To this end some properties have been identified for the allowed command sequences.

- (i) The command sequence may not start with *out*.
- (ii) At each moment, exactly one of the commands *in* and *out* is present.
- (iii) The command sequence may not start with  $(\text{in out})^*\text{out}$ .

Provide three LTL formulas  $\varphi_1$ ,  $\varphi_2$ , and  $\varphi_3$  for these properties. Here, for  $\varphi_3$  you can already assume that properties (i) and (ii) are satisfied.

**Exercise 4 (20 points)**

Consider the following nanoPromela statement.

```
do
  :: a => if :: b => c ! b ; d ! e
           :: true => skip
           fi ;
  a := false;
od
```

Formally derive all transitions that are possible from this initial statement. You may use abbreviations like “do ... od” and “if ... fi”.