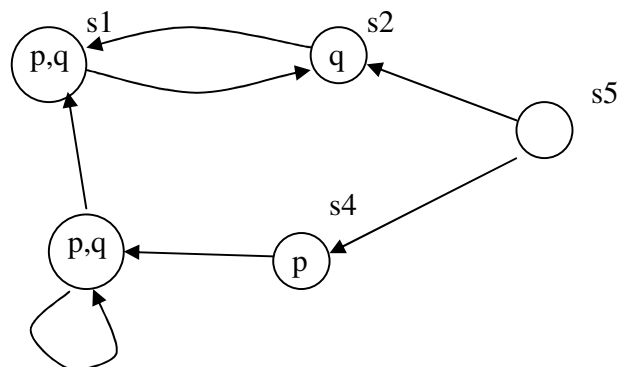


1. a) Draw the transition system obtained by synchronising the following two



- with respect to the set  $\text{Sync} = \{ \langle a_1, b_1 \rangle, \langle a_2, b_2 \rangle, \langle a_3, b_3 \rangle \}$ . [10 points]  
 b) Write a CTL formula specifying that a system is non-blocking. [10 points]  
 c) Are the states  $s_0$  and  $t_0$  of above two transition systems satisfying this formula? [10 points]

2. Let  $p$  and  $q$  be two atomic propositions. Using the fixed-point method give the set of all states of the following transition system satisfying the CTL formula  $\text{EX} (p \vee \text{EG } q)$ . [10 points]



3. Give a simple CTL model  $\langle S, \rightarrow, \ell \rangle$ , such that every  $s \in S$  has some  $s' \in S$  such that  $s \rightarrow s'$ , and a state  $s_0 \in S$  satisfying the CTL formula  $\text{AG } p$  but not satisfying  $\text{AF } p$ . [10 points]
4. Give the proof rule for the total correctness of the statement **while**  $b \{ S \}$ . [10 points]

5. Prove the total correctness of following Hoare triples:

a)  $(\mid x=2 \mid) x := x+1 (\mid x^2=9 \mid)$

[ 5 points]

b)  $(\mid \text{true} \mid) \text{if } x < 0 \text{ then } \{ x := -x \} \text{else } \{ x := x \} (\mid x \geq 0 \mid)$

[10 points]

c)  $(\mid x=10 \mid) \text{while } x > 0 \{ x := x-2 \} (\mid x=0 \mid)$

[15 points]

6. Give a proof outline for the partial correctness of the following Hoare triple:

$(\mid x \geq 0 \wedge y \geq 0 \mid)$

```

while x ≠ y {
  if x < y then {
    y := y - x
  } else {
    x := x - y
  }
}
 $(\mid x = y \mid)$ 

```

[20 points]

The final score is given by the sum of the points obtained divided by 10 (with a maximum of 10).

**Proof system for partial correctness** (while-rule omitted, see question 4.):

1.  $(\mid \phi \mid) \text{skip } (\mid \phi \mid)$

2.  $(\mid \phi[e/x] \mid) x := e (\mid \phi \mid)$

3. 
$$\frac{(\mid \phi \mid) c1 (\mid \phi \mid) (\mid \phi \mid) c2 (\mid \psi \mid)}{(\mid \phi \mid) c1 ; c2 (\mid \psi \mid)}$$

4. 
$$\frac{(\mid \phi \wedge b \mid) c1 (\mid \psi \mid) (\mid \phi \wedge \neg b \mid) c2 (\mid \psi \mid)}{(\mid \phi \mid) \text{if } b \text{ then } \{ c1 \} \text{else } \{ c2 \} (\mid \psi \mid)}$$

5. 
$$\frac{(\mid ?? \mid) c (\mid ?? \mid)}{(\mid ?? \mid) \text{while } b \text{ do } \{ c \} (\mid ?? \mid)}$$

6. 
$$\frac{\phi \Rightarrow \phi1 (\mid \phi1 \mid) c (\mid \psi1 \mid) \psi1 \Rightarrow \psi}{(\mid \phi \mid) c (\mid \psi \mid)}$$