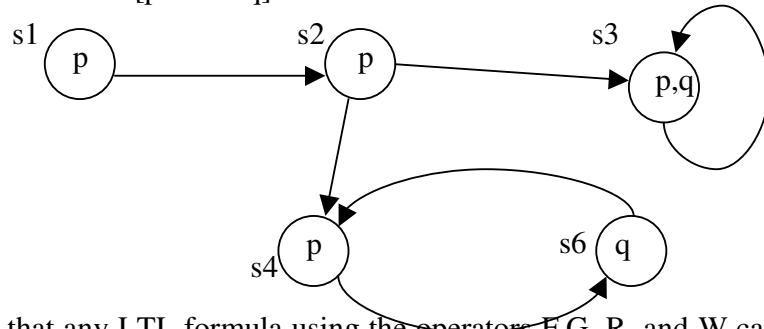


1. [1 point] Give a simple CTL model with a state satisfying the CTL formula $\neg EG p$ but not satisfying $AG\neg p$
2. [2 points] Use the *fixpoint method* to find the states of the following transition system that satisfy the CTL formula $A[p U AF q]$:



3. [1 point] Show that any LTL formula using the operators F, G, R, and W can be transformed into a semantically equivalent one which uses only the Boolean operators, X, and U.
4. [1 point] Describe a finite method for checking if the language of a Büchi automaton is empty.
5. [2 points] Let $a[1..k]$ be an array of integer, and consider the following two commands swapping two elements of the array, one with the help of a temporary variable and another without it:

<pre> SWAP1 = tmp := a[j]; a[j] := a[i]; a[i] := tmp </pre>	<pre> SWAP2 = a[i] := a[i]+a[j]; a[j] := a[i]-a[j]; a[i] := a[i]-a[j] </pre>
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- a) Prove $\{a[i]=x \wedge a[j]=y\} \text{ SWAP1 } \{a[i]=y \wedge a[j]=x\}$.
 - b) Try to prove $\{a[i]=x \wedge a[j]=y\} \text{ SWAP2 } \{a[i]=y \wedge a[j]=x\}$. Where is the error? Modify the precondition so that you can obtain a correct proof.
6. [3 points] Consider the following following Hoare triple of a command computing the sum of the first m integers (recall that $1+2+\dots+m = m*(m+1) \text{ div } 2$):

```

{m ≥ 0}
x := 0;
y := 1;
while (y ≤ m) do
  x := x + y;
  y := y + 1
od
{x = m*(m+1) div 2}
  
```

- a) Find an invariant and give a proof outline for *partial* correctness.
- b) Find a variant and give a proof outline for *total* correctness.

The final score is given by the sum of the points obtained.