1. **[1 point]** Give a simple CTL model with a state satisfying the CTL formula \( \neg \text{EG } p \) but not satisfying \( \text{AG } \neg p \).

2. **[2 points]** Use the *fixpoint method* to find the states of the following transition system that satisfy the CTL formula \( \text{A}[p \text{ U AF } q] \):

   ![Diagram]

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:

   \[
   \text{SWAP1 } = \text{ tmp := a[j]; } \quad \text{SWAP2 } = \text{ a[i]:= a[i]+a[j];}
   \]
   \[
   \quad a[j]:= a[i]; \quad a[j]:= a[i]-a[j];
   \]
   \[
   a[i]:= tmp \quad a[i]:= a[i]-a[j]
   \]

   a) Prove \( \{a[i]=x \land a[j]=y\} \text{ SWAP1 } \{a[i]=y \land a[j]=x\} \).
   b) Try to prove \( \{a[i]=x \land a[j]=y\} \text{ SWAP2 } \{a[i]=y \land a[j]=x\} \). 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 \( 1+2+\ldots+m = m^* \text{(m+1) div 2} \)):

   \[
   \begin{align*}
   &\{m \geq 0\} \\
   &x := 0; \\
   &y := 1; \\
   &\text{while } (y \leq m) \text{ do} \\
   &\quad x := x + y; \\
   &\quad y := y + 1 \\
   &\text{od} \\
   &\{x = m^* \text{(m+1) div 2}\}
   \end{align*}
   \]

   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.