1.) Which of the properties specified below are safety properties (see Bérard et al: Chapter 7, p. 83–89)? Remember to motivate your answer.

(a) If a request arrives in the initial state of the system, it will be answered.
(b) In all states of the system, an acknowledgement arrives only after a request has been sent before.
(c) Whenever a request input becomes high it stays high until an acknowledgement input becomes high.
(d) In all states of the system, a request stays high if the acknowledgement never becomes high.
(e) In all states of the system, a request is followed by an acknowledgement in five time units.

2) In the book (Bérard et al: Chapter 7.4, p. 87–89) the history variables method is described. The basic idea is to introduce a new Boolean variable \( h_i \) for each (past) temporal subformula, and initialize all them to false in the initial state. The model is instrumented to record changes in the truth of the past temporal subformulas following the semantics of past temporal operators.

Let \( h'_i \) denote the value of the temporal subformula variable \( h_i \) in the previous time step, \( f_1, f_2 \) the values of variables corresponding to subformulas at the current time step, and finally \( f'_1, f'_2 \) the values of variables corresponding to subformulas at the previous time step.

With this notation the update rule for the formula \( h = X^{-1} f_1 \) becomes:
\[ h_i := f'_1. \]
Give the update rules for all the other formula types:

(a) \( h_i = p \) for \( p \in AP \),
(b) \( h_i = \neg f_1 \),
(c) \( h_i = f_1 \lor f_2 \),
(d) \( h_i = G^{-1} f_1 \), and
(e) \( f_1 S f_2 \).
3.) Consider the automaton of Figure 7.1 of the book (Bérard et al., p. 87). Add history variables to the model to model check a temporal formula containing past time temporal operators by using a standard CTL model checker. Also give the CTL formulas to model check in the following two cases.

(a) $AG(X^{-1} \text{alarm} \Rightarrow F^{-1} \text{crash})$

(b) $AG(F^{-1} \text{alarm} \Rightarrow ((\text{crash} \lor \text{alarm}) S (X^{-1} \text{ok})))$

Give the models with history variables added in the expressions in similar style to Figure 7.2, or notation similar to that of the exercise above.