Question 1:

$$\mathsf{prefix}_k^0[\psi] \quad \vee \quad \bigvee_{\ell=0}^{k} \lambda_\ell \wedge \mathsf{lasso}_{(k,\ell)}^0[\psi]$$

Provide a propositional encoding of (k,l) loops for solving the existential model checking problem formulas **EGFp**. To this end, define $prefix_k^0[\psi]$ and $lasso_{(k,l)}^0[\psi]$ for ψ ≡ GFp

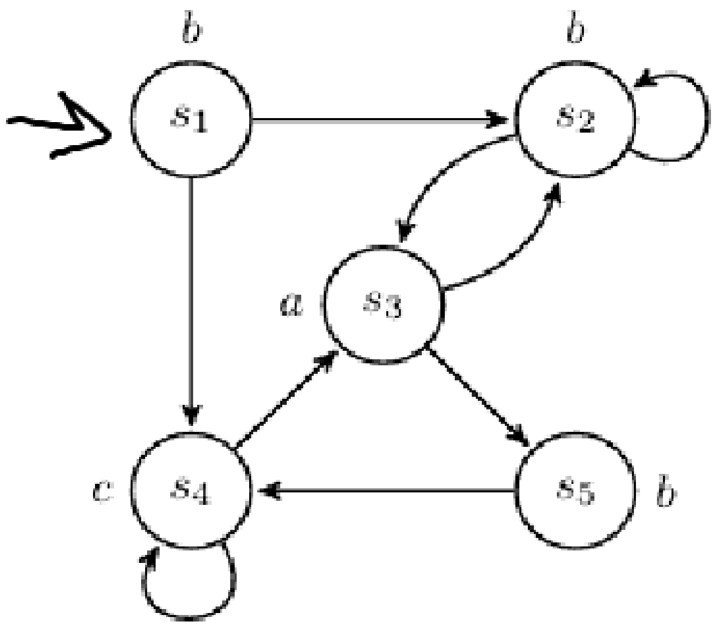
Note: Define the encoding of **GFp** as a self-contained formula. That is, your encoding should not contain atoms of the form prefix or lasso for any ψ (in particular not for G ϕ or F ϕ)

Question 2:

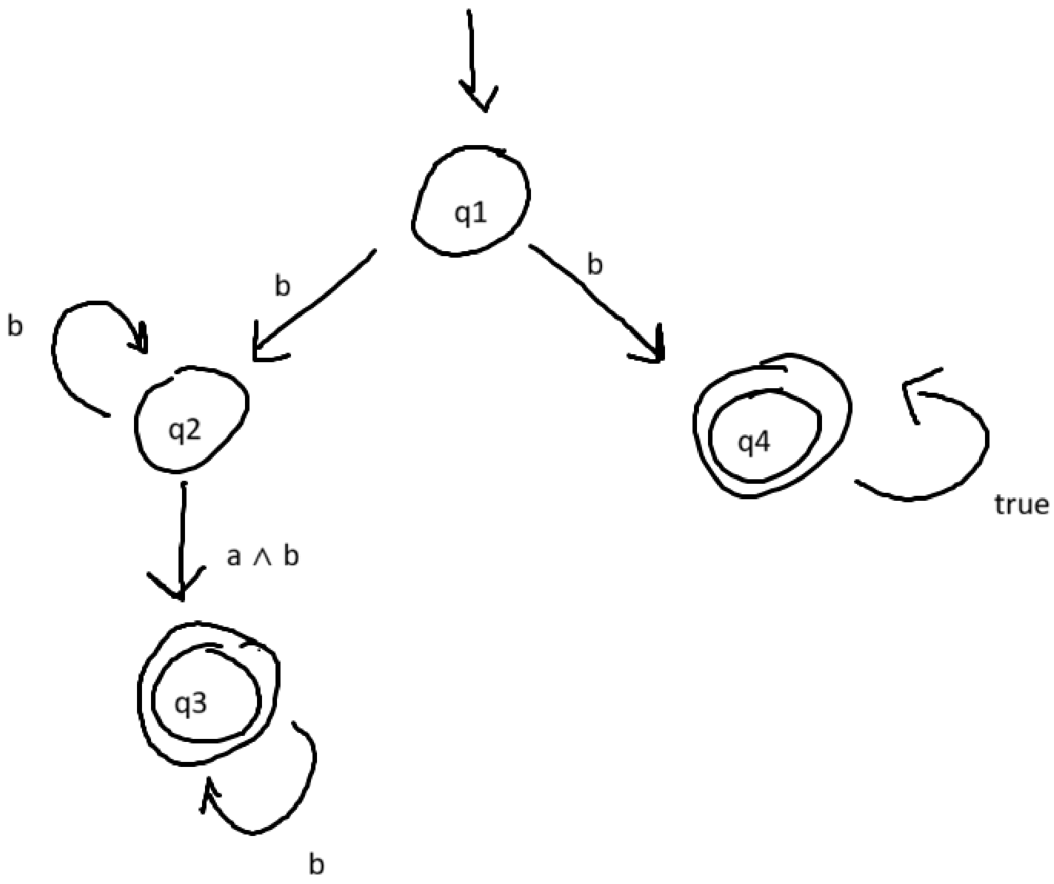
Perform automata based LTL model checking on the Kripke structure and Büchi automaton for ϕ

Is there an execution violating ¬ϕ? If yes provide the counterexample.

Kripke structure:



Büchi automaton:



Question 3:

Let K =(S,s0,R,AP,L) be a finite Kripke structure with AP = {clk,init,reset}, and let s0 be the only state labeled with "init". Express the following specifications about K in terms of CTL⋆. Where possible, provide an LTL or CTL formula.

a) clk is always immediately followed by ¬clk and vice versa

b) For every execution, every positive edge of clk (ie transition from ¬clk to clk) is eventually followed by a negative edge of clk (ie transitions from clk to ¬clk)

c) From every state in K, it is possible to return to the initial state (which is labeled init) via a state labeled reset.

d) All paths starting at the initial state lead to a cycle that does not contain a state labeled init, unless the cycle includes a state labeled reset.

e) Whenever a state labeled with reset is reached, the initial state labeled with init will be reached at a strictly later point.

Question 4:

Are the following statements true/false? Mark the corresponding column in the table below.

(a) Fairness conditions cannot be directly expressed in CTL∗.

(b) Every CTL formula has an equivalent CTL formula containing only AF, AX, and EU.

(c) For the boolean formula $(x_1 \oplus y_1) \vee \cdots \vee (x_n \oplus y_n)$, with $\oplus$ being xor, one can find an order on the variables $x_1,\ldots,x_n,y_1,\ldots,y_n$, so that the ROBDD that encodes the formula is linear in the size of n.

(d) Let A ∧ B be unsatisfiable, and let I1 and I2 be interpolants for A and B. Then I1 **∨** I2 is also an interpolant for A and B

(e) Every trace that is a counterexample to a LTL property is lasso-shaped (i.e., has the form $s0, \ldots, s_{\ell-1}, (s_\ell, \ldots, sk)^\omega$).

(f) A Kripke structure M with n states has a reachability diameter of at most n.

(g) There is a non-empty Kripke structure M that satisfies (**AGEFp**) ∧ (**AGFp**).

(h) for any propositional logic formulas ϕ there exists an equisatisfiable formula ψ in conjunctive normal form (CNF) in which each clause has at most 3 literals.

(i) If a given transition system is safe (i.e., property P holds), then the IC3 model checking algorithm always computes the logically strongest inductive invariant that proves that P holds.

(j) Given n Büchi automata B1,...Bn, the number of states of the asynchronous product B1 ∥ · · · ∥ Bn is polynomial in n.

Question	True	False
(a)		
(b)		
(c)		
(d)		
(e)		
(f)		
(g)		
(h)		
(i)		
(j)		