1. Let $\mathcal{M} = (S, R, v)$, where

$$S = \{a, b, c, d, e, f\}$$
$$R = \{(a, b), \langle a, c \rangle, \langle b, d \rangle, \langle b, e \rangle, \langle c, d \rangle, \langle d, d \rangle, \langle e, e \rangle, \langle e, f \rangle, \langle f, a \rangle, \langle f, b \rangle, \langle f, c \rangle, \langle f, d \rangle, \langle f, e \rangle\}$$

- $\{s \in S \mid v(s, P) = \text{true} \} = \{a, b, c, d, e, f\}$
- $\{s \in S \mid v(s, Q) = \text{true} \} = \{e, f\}$
- $\{s \in S \mid v(s, R) = \text{true} \} = \{f\}$

Let $F = \{R\}$. Which of the following claims hold?

a) $\mathcal{M}, a \models A(P \lor Q)$
b) $\mathcal{M}, a \models A(P \land Q)$
c) $\mathcal{M}, a \models EGP$
d) $\mathcal{M}, a \models EGP$

2. Let $\mathcal{M} = (S, R, v)$, where

$$S = \{a, b, c, d, e\}$$
$$R = \{(a, b), \langle a, c \rangle, \langle b, d \rangle, \langle b, e \rangle, \langle c, d \rangle, \langle d, a \rangle, \langle d, d \rangle, \langle e, b \rangle, \langle e, c \rangle\}$$

- $\{s \in S \mid v(s, P) = \text{true} \} = \{a, b, c\}$
- $\{s \in S \mid v(s, Q) = \text{true} \} = \{c, e\}$

Give the states in which $\text{AG}(\langle P \rightarrow Q \rangle U(P \land Q))$ is true.

3. Let $\mathcal{M} = (S, R, v)$, where

$$S = \{a, b, c, d, e\}$$
$$R = \{(a, b), \langle a, c \rangle, \langle b, d \rangle, \langle d, a \rangle, \langle e, c \rangle, \langle d, e \rangle, \langle e, a \rangle\}$$

- $\{s \in S \mid v(s, P) = \text{true} \} = \{a, c\}$
- $\{s \in S \mid v(s, Q) = \text{true} \} = \{b, c\}$

Give the states in which $\text{AG}(Q \rightarrow A(EF(P \lor UF)))$ is true.

1. Let $\mathcal{M} = (S, R, v)$, where

$$S = \{a, b, c, d\}$$
$$R = \{(a, a), (a, b), (a, c), \langle a, d \rangle, \langle b, a \rangle, \langle b, a \rangle, \langle c, b \rangle, \langle c, b \rangle, \langle d, d \rangle, \langle d, d \rangle\}$$

- $\{s \in S \mid v(s, P) = \text{true} \} = \{b, d\}$
- $\{s \in S \mid v(s, Q) = \text{true} \} = \{b\}$

Using the tableau-based LTL model checking method, determine whether the following holds: $\mathcal{M}, a \models EX(\neg P \lor Q)$.

2. Let $\mathcal{M} = (S, R, v)$, where

$$S = \{a, b, c\}$$
$$R = \{(a, a), (a, b), \langle a, c \rangle, \langle b, b \rangle, \langle c, b \rangle, \langle a, c \rangle\}$$

- $\{s \in S \mid v(s, P) = \text{true} \} = \{b, c\}$

Using the tableau-based LTL model checking method, determine whether the following holds: $\mathcal{M}, a \models AFGP$.

1. Using tableaux, show that the following CTL formula is valid.

$$(Q \lor P \land P \lor AFA(P \lor Q)) \rightarrow A(P \lor Q)$$

2. Using tableaux, determine whether the following LTL formula is satisfiable.

$$GF P \rightarrow GF \neg P$$