Exercise 33
Given the Kripke structure $K$ shown below.

![Kripke structure diagram]

Given trace $\pi$ and LTL formula $f$, decide if $f$ holds in $\pi$, i.e., $\pi \models f$.

<table>
<thead>
<tr>
<th>Trace $\pi$</th>
<th>Formula $f$</th>
<th>yes</th>
<th>no</th>
</tr>
</thead>
<tbody>
<tr>
<td>$5, (3, 4, 1)^o$</td>
<td>$\text{FG}r$</td>
<td></td>
<td></td>
</tr>
<tr>
<td>$5, 4, 1, (3)^o$</td>
<td>$\text{GF}s$</td>
<td></td>
<td></td>
</tr>
<tr>
<td>$0, (2)^o$</td>
<td>$\text{FF}(\neg s)$</td>
<td></td>
<td></td>
</tr>
<tr>
<td>$(0, 2, 1)^o$</td>
<td>$\text{G}(\neg r \rightarrow \text{X} s)$</td>
<td></td>
<td></td>
</tr>
<tr>
<td>$(0, 2, 1, 2, 4, 1)^o$</td>
<td>$\text{F}(p \ \text{U} \ s)$</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Exercise 34
For each of the following temporal formulae, check whether there is an equivalent formula in $LTL^{\text{det}}$. If so, then specify such an equivalent formula meeting the syntactic criteria for $LTL^{\text{det}}$ as given on lecture slide 69. Note that subformulae $p$ and $q$ are atomic propositions, i.e. $p, q \in \mathcal{A}$.

a) $\text{EF } p \rightarrow \text{AX } q$

b) $(\text{AF } p) \land \text{AX } \neg p$

c) $\neg((\text{EX } \neg q) \lor (\text{EF } \neg p))$

Exercise 35

\begin{center}
\begin{tikzcd}
0 \ar[d] \arrow[r, shift left=1] & 1 \\
\{p\} \arrow[r, shift left=1] & \{q\}
\end{tikzcd}
\end{center}

Given Kripke structure $K$ as shown above. Justify your answers to the following questions.

a) Does $K \models f$ hold for ACTL formula $f := \text{AX } p \lor \text{AX } q$?

b) Let $g := f \setminus A$. Does $K \models g$ hold?

c) Based on the results of a) und b): are $f$ and $g$ equivalent?

d) Based on the results of a), b) and c): is there an LTL formula which is equivalent to $f$?

Exercise 36
Given CTL formula $f := \text{AF } (r \rightarrow \text{AG } a)$, where $r$ and $a$ are atomic propositions, i.e. $r, a \in \mathcal{A}$. Draw a Kripke structure $K$ with exactly one initial state such that $K \not\models f$ but $K \models f \setminus A$ (Hint: there is such $K$ with no more than 3 states). Is there an LTL formula which is equivalent to $f$? Justify your answers.