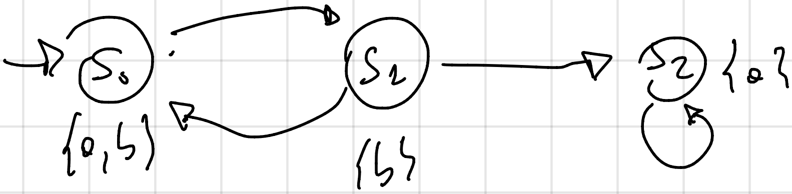
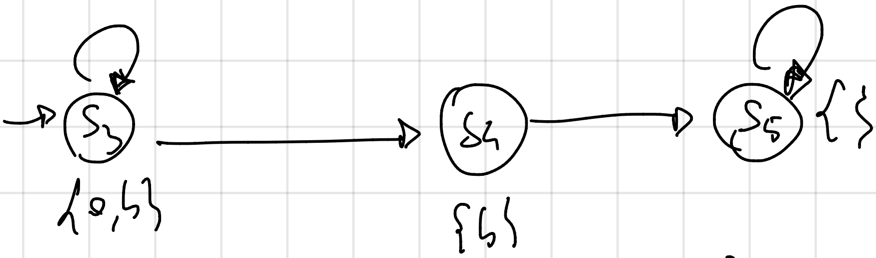
EX $\boxed{2.4}$





fair: $(\Box\Diamond(a\wedge b) \to \Box\Diamond\neg c) \wedge (\Box\Diamond(a\wedge b) \to \Box\Diamond\neg b)$

which are the fair paths?

unfair π_1 : $(s_0\, s_1)^\omega \rightsquigarrow (\{a,b\}\{b\})^\omega$

fair π_2 : $(s_0\, s_1)^+ s_2^\omega = \{(s_0\, s_1)^n s_2^\omega \mid n > 0\} \rightsquigarrow (\{a,b\}\{b\})^+ \cdot \{a,\}^\omega$

unfair π_3 : $(s_3)^\omega \rightsquigarrow \{a,b\}^\omega$

fair π_4 : $s_3^+\, s_4\, s_5^\omega \rightsquigarrow \{a,b\}^+\{b\}\{\}^\omega$

5.4 EX

a) $\Box(\text{Peter.use} \to \neg \text{Betsy.use} \wedge \text{Betsy.use} \to \neg\text{Peter.use})$

$\equiv \Box \; \neg(\text{Peter.use} \wedge \text{Betsy.use})$

b) $\Box(\text{B.use} \to \Diamond \text{B.release}) \wedge$

$\Box(\text{P.use} \to \Diamond \text{P.release})$

c) $\Box(\text{B.request} \to \Diamond \text{B.use}) \wedge$

$\Box(\text{P.request} \to \Diamond \text{P.use})$

d) $\Box\Diamond \text{P.request} \wedge \Box\Diamond \text{B.request}$

e) $\Box(\text{P.release} \to (\neg\text{P.use} \; \mathcal{U} \; \text{B.use})) \wedge$

$\Box(\text{B.release} \to (\neg \text{B.use} \; \mathcal{U} \; \text{P.use}))$

5.6 EX

$\Box a \to \Diamond b \stackrel{?}{\equiv} a \, \mathcal{U} \, (b \vee \neg a)$

$\Downarrow \equiv$

$\neg \Box a \vee \Diamond b$

$t_2' = \{a\}^n \{b\}$ ✓

$t_2 = \{\neg a\} \dots$ ✓

$\equiv$

$\Diamond \neg a \vee \Diamond b$

$\equiv$

$\Diamond(\neg a \vee b) \equiv true \, \mathcal{U} \, (b \vee \neg a)$

Two cases:

1) the trace starts with $\{a\}^n$ $\quad n>0$ { will wait for b or $\neg a$ / will wait for $b \vee \neg a$ }
2) the trace starts with $\{\neg a\}$ $\to$ both are satisfied

$\hookrightarrow$ this is exactly the same.

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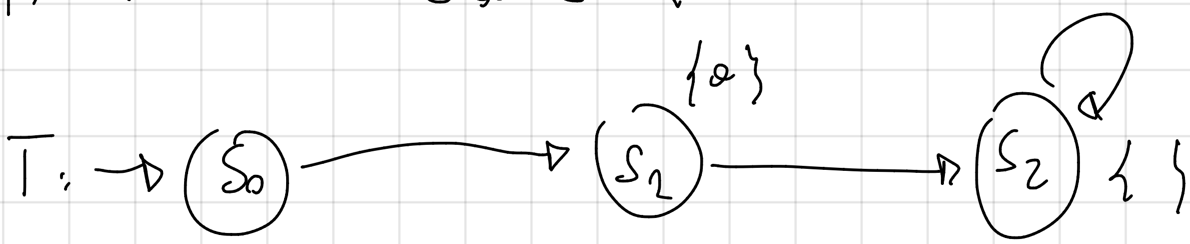
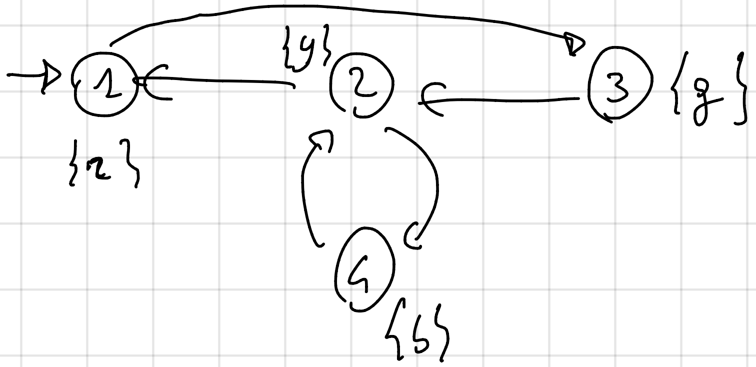
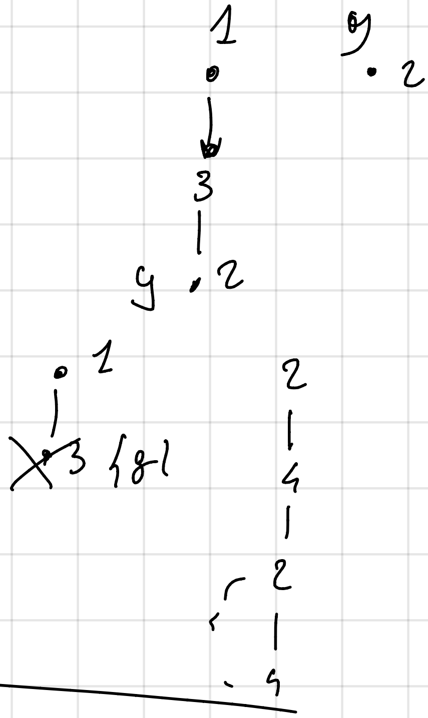
f) $\Diamond a \wedge \bigcirc \Box a \stackrel{?}{\equiv} \Diamond a$



$T \models \Diamond a$ and $T \not\models \Diamond a \wedge \bigcirc \Box a$

6.1 EX





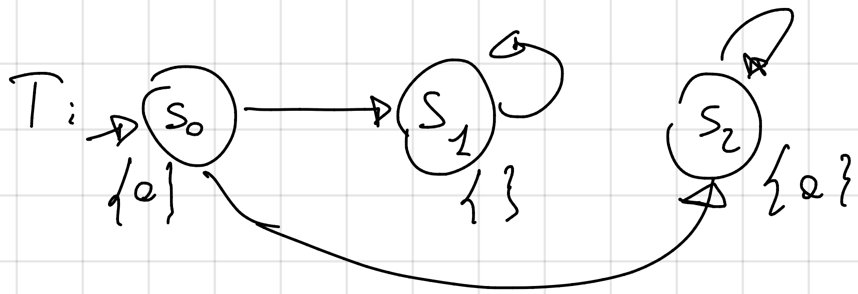
$Sat(\forall \Diamond g) = \{1, 2, 3, 4\}$

$Sat(\exists \Box \neg g) = \{2, 4\}$

$Sat(\forall (b \, U \, \neg b)) = \{1, 2, 3, 4\}$

6.3 EX $s \models \exists \Box a \Rightarrow s \models \forall \Box a$ NO

Counterexample T:

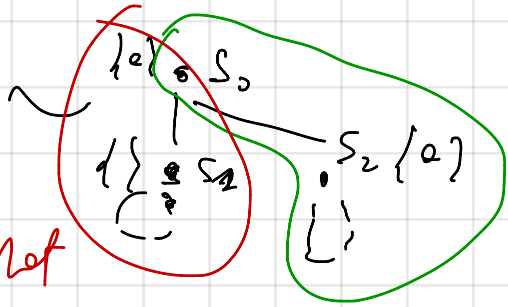


$\pi = s_0 s_2^{\omega} \Rightarrow s_0 \models \exists \Box a$

$\pi' = s_0 s_1^{\omega} \Rightarrow s_0 \not\models \forall \Box a$

$\Downarrow$

$\{a\}\{\}^{\omega}$



if $s \models \forall \Box a$

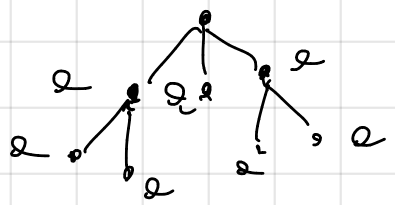
$\Rightarrow \forall \pi \in Path(s) : \forall j \in \mathbb{N} \ \pi_{(j)} \models a$

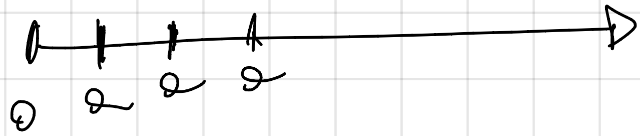
$\Rightarrow \exists \pi \in Path(s) :$

because we consider Transition Systems that are not blocked $\approx$ For each state s there is at least one outgoing transition

---

$\Phi_2 = \forall \Box \forall \Diamond a \overset{?}{\equiv} \Box \Diamond a$ Ex 6.14

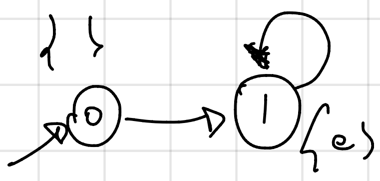


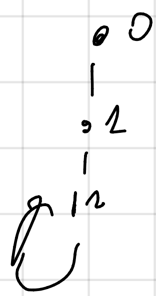


CTL LTL

$\Phi \equiv \varphi$ iff $\forall$ Transition Systems T : $T \models_{CTL} \Phi \Leftrightarrow T \models_{LTL} \varphi$

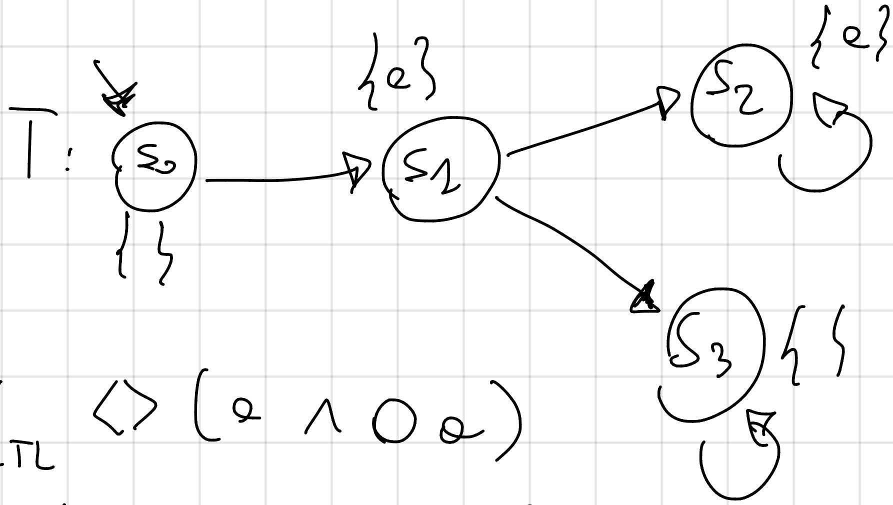
e.g. T:





c) $\forall\Diamond(a \wedge \exists\bigcirc a) \equiv \Diamond(a \wedge \bigcirc a)$?

NO

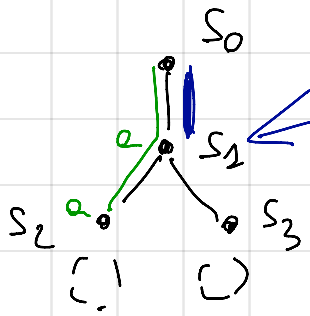


$T \not\models_{LTL} \Diamond(a \wedge \bigcirc a)$

because $s_0 s_1 s_3^{\omega} \rightsquigarrow \{\}\{a\}\{\}^{\omega}$

$T \models_{CTL} \forall\Diamond(a \wedge \exists\bigcirc a)$

yes



this state here satisfies $a \wedge \exists\bigcirc a$

EX $\boxed{6.7}$

$$\forall\bigcirc\left(\exists((\neg a)\,\mathcal{U}\,(b\wedge\neg c))\vee\exists\Box\forall\bigcirc a\right)$$

$\equiv \{\forall\bigcirc\psi \equiv \neg\exists\bigcirc\neg\psi\}$

$$\forall\bigcirc\left(\exists((\neg a)\,\mathcal{U}\,(b\wedge\neg c))\vee\exists\Box\neg\exists\bigcirc\neg a\right)$$

$\equiv \{\#\}$

$$\neg\exists\bigcirc\neg\left(\exists((\neg a)\,\mathcal{U}\,(b\wedge\neg c))\vee\exists\Box\neg\exists\bigcirc\neg a\right)$$

$\equiv$ {De Morgan}

$$\neg\exists\bigcirc\left(\neg\exists((\neg a)\,\mathcal{U}\,(b\wedge\neg c))\wedge\neg\exists\Box\neg\exists\bigcirc\neg a\right)$$

this is in existential normal form