1 Infinite strings (16=8+8 points)

1.1 $\omega$-regular expressions (8 points)
Exercise 4.7 on page 221 of Principles of Model checking.

1.2 Buchi automata (8 points)
Exercise 4.10 on page 222 of Principles of Model checking.

1.3 Linear temporal logic (15=5+3+7 points)

1.3.1 Problem 1 (5 points)
Exercise 5.4 on page 302 of Principles of Model checking.

1.3.2 Problem 2 (3 points)
Exercise 5.7 on page 303 of Principles of Model checking. Make sure you provide the full semantics of the operators.

1.3.3 Problem 3 (7 points)
Construct the GNBA corresponding to the formula $(\neg a) U (Xb)$ using EXACTLY the construction proposed in Theorem 5.37 on page 278 of Principles of Model checking.

2 CTL

2.1 Problem 1 (12 points)
Exercise 6.14 on page 436 of Principles of Model checking. For equivalences, provide arguments based on semantics of the formulas.
3  Bisimulation (6 points)

3.1 Problem 1 (6 points)
Exercise 7.7 (Part a) on page 585 of Principles of Model checking.

4  $\mu$-calculus (15=3+5+3 points)

4.1 Problem 1 (3 points)
The definition of the $\mu$-calculus requires that for each sub-formula $\mu x.f(x)$, all the occurrences of the variable $x$ appearing in $f(x)$ fall under an even number of negation in $f(x)$ under an even number of negations. This ensures monotonicity, that is: for all $S_1 \subseteq S_2$, we have that $f(S_1) \subseteq f(S_2)$. Given an example that violates our syntactic restriction, and show that is indeed non-monotone.

4.2 Problem 2 (5 points)
Write a $\mu$-calculus formula equivalent to the LTL formula $(a U G b)$. Feel free to use greatest and least fix-points operators. You don’t need to formally prove your construction, but please provide the intuition behind it.

4.3 Problem 3 (3 points)
Based on construction you provided in the previous problem what can you say about the complexity of translating LTL formulas into $\mu$-calculus formulas (i.e. given an LTL formula of size $n$, what is the size of the corresponding $\mu$-calculus formula with respect to $n$). Please explain your reasoning using examples.