Quiz 1
CS 341: Foundations of Computer Science II — **Fall 2026, Section H01**
Prof. Marvin K. Nakayama

Print family (or last) name: _____

Print given (or first) name: _____

I have read and understand all of the instructions below, and I will obey the University Policy on Academic Integrity.

_____
Signature and Date

- This quiz has 4 pages in total, numbered 1 to 4. Make sure your quiz has all the pages.
- Note the number written on the upper right-hand corner of the first page. On the sign-up sheet being passed around, print your name next to this number.
- This quiz will be 25 minutes in length.
- This is a closed-book, closed-note quiz. Unauthorized materials, including notes and electronic devices (e.g., cellphone, smart watch, smart glasses, calculator, headphones), are not allowed.
- For all problems, follow these instructions:
  1. Give only your answers in the spaces provided. **Be sure to clearly indicate your answers.** Only what is written in the answer space will be graded, and points will be deducted for any scratch work in the answer space. Use the backs of the exam sheets to work out your answers before filling in an answer space.
  2. DFA stands for deterministic finite automaton; NFA stands for nondeterministic finite automaton; PDA stands for push-down automaton; CFG stands for context-free grammar; TM stands for Turing machine.
  3. For any state diagrams that you draw, you must **include all states and transitions**.

Problem	1	2	3	Total
Points				

1. **[20 points, Multiple Choice]** For each of the following questions, circle the letter of the correct answer.

1.1. If a language A is recognized by a nodeterministic TM, then
   (a) there must exist an NFA that recognizes A.
   (b) there must exist a deterministic TM that recognizes A.
   (c) A must be finite.
   (d) A must be infinite.
   (e) none of the above.

1.2. The language
$$E_{\text{DFA}} = \{ \langle D \rangle \mid D \text{ is a DFA with } L(D) = \emptyset \}$$
is
   (a) decidable.
   (b) Turing-recognizable but not decidable.
   (c) finite.
   (d) none of the above.

1.3. If languages A and B are unequal, then
   (a) $\overline{A \cup B} = \emptyset$.
   (b) $\overline{A} \cup B = \emptyset$.
   (c) $\overline{A \cap B} = \emptyset$.
   (d) $\overline{A} \cap B = \emptyset$ and $A \cap \overline{B} = \emptyset$.
   (e) $\overline{A} \cap B = \emptyset$ or $A \cap \overline{B} = \emptyset$.
   (f) $\overline{A} \cap B \neq \emptyset$ and $A \cap \overline{B} \neq \emptyset$.
   (g) $\overline{A} \cap B \neq \emptyset$ or $A \cap \overline{B} \neq \emptyset$.
   (h) none of the above.

1.4. If a language A is recognized by a 5-tape TM, then
   (a) there does not exist a single-tape TM that recognizes A.
   (b) there does not exist a nondeterministic TM that recognizes A.
   (c) A has an enumerator.
   (d) none of the above.

1.5. Suppose that a language A is recognized by a TM $M = (Q, \Sigma, \Gamma, \delta, q_0, q_{\text{accept}}, q_{\text{reject}})$. Then for a string $w \in \Sigma^*$ with $w \notin A$,
   (a) M must accept w.
   (b) M must reject w.
   (c) M must loop on w.
   (d) M must reject or loop on w.
   (e) none of the above.

Each of the following problems requires you to prove a result. Be sure to provide a step-by-step argument, with justifications for every step. If you are asked to prove a result X and your proof relies on another result Y, then you do not need to prove Y if Y is a result that we either went over in class or is in the homework. In this case, you need to make clear what result Y you are citing in your proof of X (e.g., say something like, "By the result that $S^{**} = S^*$ for any set S of strings, we can show that …"). But if your proof of X uses a result Y not covered in class or in the homework, then you also have to prove Y.

2. [**15 points**] Show that the class of Turing-recognizable languages is closed under union. Explain your answer.

3. [**15 points**] Consider the problem of determining **whether an NFA and regular expression are equivalent**. Express this problem as a language and show that it is decidable.