

15-451/651 Algorithm Design & Analysis, Fall 2026

Programming Assignment #1

Programming Assignment #1, Due: Friday, September 18th at 11:59 pm

This is a programming assignment. You need to write code to solve the problem below, reading input from `stdin` and writing the answer to `stdout`. This problem must be completed solo, including the theoretical and conceptual ideas as well as the implementation. All the code you submit must be your own. All submissions will be screened for plagiarism. You may choose to solve the problem in **C++, C, Python, Rust, Java, or OCaml**.

Submission: Your solution to the problem should be submitted as a single code file using Gradescope. Submit only the code file with an appropriate file extension (`.c` for C, `.cpp` for C++, `.py` for Python, `.rs` for Rust, `.java` for Java, and `.ml` for OCaml). Do **not** put your file inside a tar or zip archive.

All submissions must be legitimate attempts to solve the problem. It will be considered an academic integrity violation to make submissions for any other purpose. For example, but not limited to: mass submitting submissions to DOS (denial-of-service attack) the autograder, submitting code that attempts to exfiltrate information from the autograder or tamper with the autograder or the machine it runs on, etc.

Assignment: Fingerprinting

Amazed by your stunning algorithms knowledge, a professor at CMU has contracted you to write plagiarism detection software for their course's final. In this test, n students will be writing an essay on a text-editing system. At any given point, the professor wants to be able to test if two students have the exact same essay. Every student starts with a blank essay. There are q operations of the form

1. Student k replaces the character at position i with the letter c (e k i c)
2. Student k adds a new letter c to the **end** of their essay (i k c)
3. Student k deletes a letter from the **front** of their essay (d k)
4. The detector wants to query whether student a and b have the exact same text. (q a b)

Input The first line of the input contains n and q separated by a space. You can assume that $1 \leq n \leq 10^6$ and that $1 \leq q \leq 3 \cdot 10^6$. The following q lines contain operations in the format specified above, i.e., they will start with a single character which is one of e, i, d, or q, followed by one-to-three space separated integers denoting the arguments to the operations as specified above. Students are indexed from 0 to $n - 1$. Every character in every essay is a valid printable non-whitespace ASCII character (ASCII code between 33 and 126).

Output Display an integer, the number of times the detector found equivalent submissions.

Program limits The base time limit is 2.5 seconds per run. Java gets 50% extra time, and Python gets 100% extra time. The memory limit is 512MB for all languages.

Complexity requirement Your solution must be able to process the entire set of operations in $O(n + q)$ expected time. To achieve this complexity you may want to implement an algorithm that can produce false positive results with very low probability. We reserve the right to manually deduct points from submissions that use an inefficient or brute-force algorithm.

Scoring The problem is worth 25 points. You will lose 3 points per failed test. There are 25 total secret test cases (not including the sample tests below which are only for debugging and are not scored). Your program will receive zero points if it does not pass the sample test cases.

Sample input/output:

Input	Output
2 10 i 0 a q 0 1 i 1 a q 0 1 i 0 b q 0 1 i 1 b q 0 1 e 0 0 b q 0 1	2

Input	Output
4 18 i 0 a i 1 b i 2 c i 3 d e 0 0 d e 1 0 c e 2 0 b e 3 0 a q 0 1 q 1 2 q 2 3 d 0 d 1 q 0 1 d 2 d 3 q 2 3 q 0 3	3

Input	Output
2 17 i 0 a i 1 a i 0 a i 1 a i 0 a i 1 a q 0 1 d 0 q 0 1 d 1 q 0 1 i 0 b i 1 b q 0 1 d 0 d 1 q 0 1	4