LLM Training

Time limit: 3 seconds
Memory limit: 1024 megabytes

You are given a text dataset. Your task is to train LLM (Large Language Model) and find the minimal possible loss. No kidding.

A text dataset is an array of texts $t_1, t_2, \dots, t_n$. Each text t_i is a sequence of tokens. We define the set of tokens T as the set of all tokens that appear in at least one text t_i. Additionally, for each text t_i, there is a set of positions $L_i \subseteq \{1, 2, \dots, |t_i|\}$. The token $t_i[j]$ is generated by LLM if $j \in L_i$ and is written by the user if $j \notin L_i$.

Let us define LLM with context size k as a probabilistic model P_k, such that it defines the probability distribution of the next token of the sequence, depending on a context w — a sequence of length between 0 and k (inclusive) whose elements are from T. Thus the probabilistic model P_k is a large table of probabilities $P_k(\text{next}|w)$, defined for any context $w \in T^*$, $0 \le |w| \le k$ and any token next $\in T$. Conditions $0 \le P_k(\text{next}|w) \le 1$ and $\sum\limits_{\text{next} \in T} P_k(\text{next}|w) = 1$ should be satisfied.

The loss function of LLM with the context size k is the following function defined for P_k:

$$\mathcal{L}_k(P_k) \ = \ \sum_{i=1}^{n} \sum_{j \in L_i} -\log_2 P_k\left(\underbrace{t_i[j]}_{\text{next token}} \ \middle| \ \underbrace{t_i[\max(1, j-k) \mathinner{..} j-1]}_{\text{context}} \right)$$

Here $t_i[l \mathinner{..} r] = t_i[l]t_i[l+1] \dots t_i[r]$ is the substring from l-th to r-th token, $t_i[1 \mathinner{..} 0]$ is an empty string. So, for each text and for each token that is generated by LLM, we add to the loss the negative logarithm (base 2) of the probability that this token will be generated, depending on the substring of previous k tokens (or the whole prefix, if it has length less than k). If the probability is zero, we assume that the negative logarithm is $+\infty$. This loss function is known as the (base 2) Cross Entropy Loss over the LLM-generated positions. The smaller the loss function value $\mathcal{L}_k(P_k)$, the better LLM P_k is.

For each $0 \le k < \max\limits_{i=1..n} |t_i|$, calculate the minimum possible loss $\mathcal{L}_k(P_k)$ that could be obtained for some P_k — LLM with context size k. It can be proved that this minimum is reachable and is not infinite.

Input

The first line contains a single integer n ($1 \le n \le 10^5$) — the number of texts in the dataset. Text descriptions follow.

The first line of the i-th text description contains a single integer m_i ($1 \le m_i \le 3 \cdot 10^5$) — the length of t_i ($m_i = |t_i|$).

The next line contains m_i strings $t_i[1]$, $t_i[2]$, …, $t_i[m_i]$ ($1 \le |t_i[j]| \le 5$) — tokens of the text t_i. Each token consists of symbols with ASCII codes from 33 to 126 (printable characters).

The next line contains a string ℓ_i of m_i letters `U` and `L`, which encodes the set L_i. All positions with the letter `L` are generated by LLM, and all positions with the letter `U` are written by the user. So $L_i = \{j \mid \ell_i[j] = \texttt{L}\}$. It is guaranteed that the last token is generated by LLM, so $\ell_i[m_i] = \texttt{L}$.

It is guaranteed that the sum of m_i for all i ($1 \le i \le n$) does not exceed $3 \cdot 10^5$.

Output

Print $M = \max\limits_{i=1..n} m_i$ real numbers: for each $k = 0, 1, \dots, M-1$ print the minimum possible loss $\mathcal{L}_k(P_k)$ for all possible P_k — LLM with context size k.

Your answers will be accepted if their absolute or relative errors do not exceed 10^{-6}; formally, if p is your answer, and q is the jury's answer, this should hold: $\frac{|p-q|}{\max\{1,|q|\}} \le 10^{-6}$.

Examples

standard input	standard output
4 5 1 + 1 = 2 UUUUL 5 1 + 2 = 3 UUUUL 5 2 + 1 = 3 UUUUL 5 2 + 2 = 4 UUUUL	6.000000000000 6.000000000000 4.000000000000 4.000000000000 0.000000000000
4 4 N E F <EOS> LLLL 5 N E R C <EOS> LLLLL 6 N E E R C <EOS> LLLLLL 5 I C P C <EOS> LLLLL	55.683674395584 12.490224995673 8.000000000000 8.000000000000 8.000000000000 8.000000000000
1 16 a b a c a b a d b a b d a b a c ULLULLLLLLULLLLL	22.595941331507 12.464393446710 5.245112497837 2.000000000000 0.000000000000 0.000000000000 0.000000000000 0.000000000000 0.000000000000 0.000000000000 0.000000000000 0.000000000000 0.000000000000 0.000000000000 0.000000000000 0.000000000000
2 4 WA WA WA AC LULL 4 AC AC WA AC LLUL	5.509775004327 4.754887502163 4.000000000000 2.000000000000