1. [20 marks] **Formatting concrete poetry.** In a concrete poem, the layout of the words on
the page forms a shape, for example a poem about a cat that forms a silhouette of a cat.

In this problem, you will implement a program that takes in a “poem” and a “shape” and
formats the poem to fit in the shape. The “poem” will be given as a list of words $w_1, \ldots, w_n$
(where a word is a string of non-whitespace characters). The “shape” will be given as a list
of line lengths $\ell_1, \ldots, \ell_m$. The task is to add line breaks and extra blank spaces to arrange
the words into lines of exactly the required lengths.

More specifically, the input is formatted as follows:

- Line 1 consists of the positive integers $m$ and $n$ separated by whitespace.
- Line 2 is a list of $m$ positive integers $\ell_1, \ldots, \ell_m$ separated by whitespace.
- Lines 3 and beyond contain a list of $n$ words $w_1, \ldots, w_n$ separated from each other by
  whitespace or newline characters.

The output of the program is a string that consists of the words $w_1, \ldots, w_n$ along with line
breaks and extra blank symbols that satisfy

1. The order of the words is not changed;
2. At least one blank symbol is placed between each pair of consecutive words on a line;
3. No line starts or ends on a blank symbol; and
4. The total length of the $t$th line (which is the length of the words placed on that line plus
   the number of blank symbols on that line) is exactly $\ell_t$.

Furthermore, let $G$ (the “gap”) denote the maximum number of blank spaces between any
two consecutive words in any row. The goal of the program is to return an arrangement of the
words that satisfies constraints (1)–(4) and minimizes $G$. (If it is impossible to arrange the
words in a way that satisfies conditions (1)–(4), then the program simply outputs No valid
solution.) Note that:

- Condition (3) implies that if a line has just one word then the length of the word must
  be equal to the length of the line.
- If words $w_i, w_{i+1}, \ldots, w_j$ go on line $t$ then the number of non-blank characters on
  the line is $\sum_{k=i}^{j} w_k$. Also, there are $j - i$ forced blanks. So the number of extra blanks that
  must be added is $\ell_t - (j - i) - \sum_{k=i}^{j} w_k$ and these blanks should be distributed as equally
  as possible in the $j - i$ spaces between the words.
Implement a dynamic programming algorithm that solves the word arrangement problem described above. You should aim for an algorithm with time complexity $O(n^2m)$, and the algorithm you implement must be the one you describe in your solution to Assignment 5. You can write your codes in C, C++ or Java.

Your program will be tested to see if your outputs satisfy constraints (1)–(4) and give the minimum value for $G$. (Note that the output may not be unique.)

See the next page for two example instances of the program and expected output.
Example 1. On input

7 17
17 11 10 9 8 7 6
Fury said to a mouse that he met in the house Let us both go to law

a valid output is as follows:\footnote{See Alice in Wonderland by Lewis Carroll for the full text of The tale of the mouse and its presentation in the form of the tail of the mouse.}

\begin{verbatim}
Fury said to a
mouse that
he met in
the house
Let us
both go
to law
\end{verbatim}

This solution has lines of exactly the right lengths, and the value of $G$ in this output is 3, as this is the number of blank spaces between the two words in line 5. There is no solution with smaller $G$.

Example 2. On input

11 71
50 50 26 26 47 47 26 26 51 51 51
The number e is of eminent importance in mathematics, alongside 0, 1, pi and i. All five of these numbers play important and recurring roles across mathematics, and are the five constants appearing in one formulation of Euler's identity. Like the constant pi, e is irrational: it is not a ratio of integers. Also like pi, e is transcendental: it is not a root of any non-zero polynomial with rational coefficients.

a valid output is

\begin{verbatim}
The number e is of eminent importance in mathematics, alongside 0, 1, pi and i. All five of these numbers play important and recurring roles across mathematics, and are the five constants appearing in one formulation of Euler's identity. Like the constant pi, e is irrational: it is not a ratio of integers. Also like pi, e is transcendental: it is not a root of any non-zero polynomial with rational coefficients.
\end{verbatim}

The value of $G$ in this example is 3, from the spaces in line 1. No solution has smaller $G$. 