Date: 17 - 01 - 2026
Assignment No.: 2

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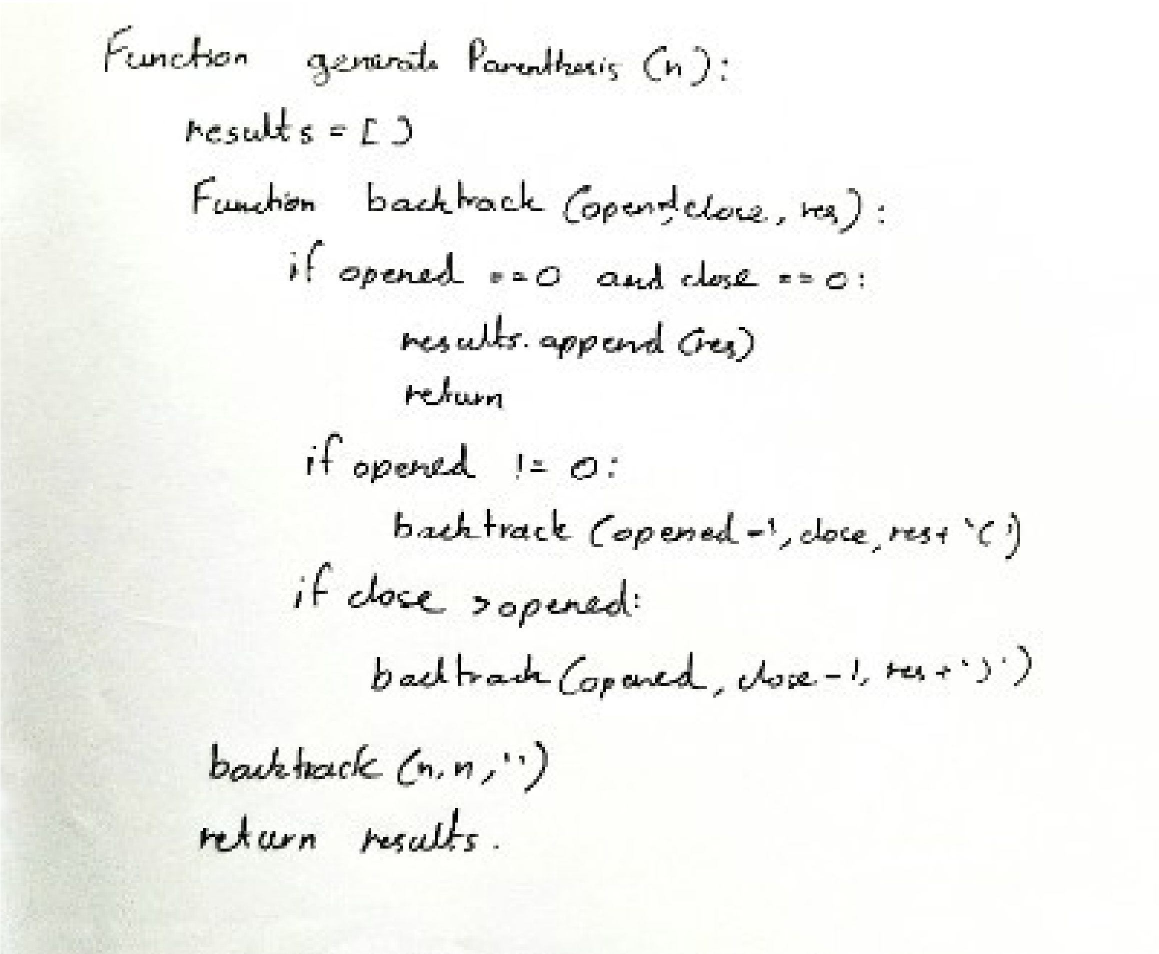
Assignment 2: Algorithms Using Backtracking

Question 1

Aim: Given n pairs of parentheses, write a function to generate all combinations of well-formed parenthesis.

Algorithm



```
Function generateParenthesis (n):
    results = [ ]
    Function backtrack (opened, close, res):
        if opened == 0 and close == 0:
            results.append (res)
            return
        if opened != 0:
            backtrack (opened -1, close, res + '(')
        if close > opened:
            backtrack (opened, close -1, res + ')')
    backtrack (n, n, '')
    return results.
```

Code

```
class Solution:
    def generateParenthesis(self, n: int) -> List[str]:

        def backtrack(opened: int, close:int, res='') -> None:
            if opened == 0 and close == 0:
                results.append(res)
                return
```

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```
            if opened != 0:
                backtrack(opened - 1, close, res + '(')

            if close > opened:
                backtrack(opened, close - 1, res + ')')

        results = []
        backtrack(n, n, '')
        return results
```

Time complexity

For this problem, the valid parenthesis combinations are given by the Catalan Number Series.

It's in the form:

$$C_n = \frac{1}{n+1}\binom{2n}{n}$$

Which can be approximated by the Stirlings equation.

$$C_n \sim \frac{4^n}{n^{3/2}\sqrt{\pi}}$$

In addition to this, we copy the string to the result with is of O(n) time complexity. Which makes it,

$$\text{Time} = O(n * C_n)$$

Substituting with above equation and taking higher order growths, the total time complexity is,

$$Time = O\left(\frac{4^n}{\sqrt{n}}\right)$$

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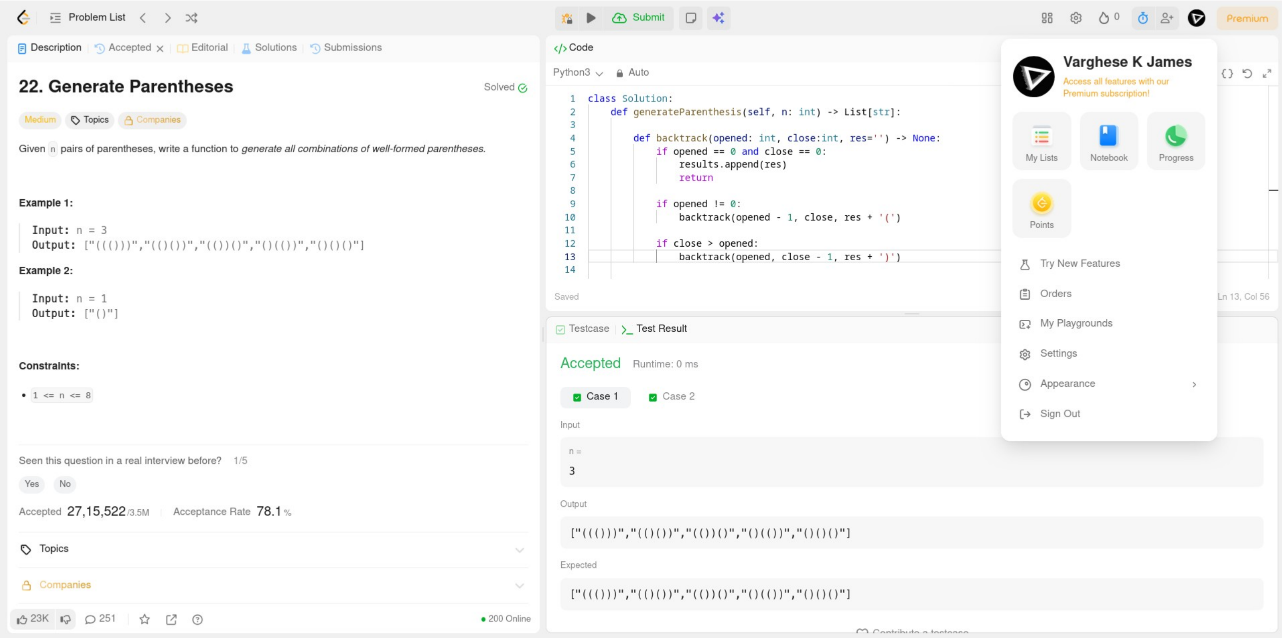
Screenshot of Output



Question 2

Aim: Given a directed acyclic graph (DAG) of n nodes labeled from 0 to n - 1, find all possible paths from node 0 to node n - 1 and return them in any order.

The graph is given as follows: graph[i] is a list of all nodes you can visit from node i (i.e., there is a directed edge from node i to node graph[i][j]).

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Algorithm

```
Function AllPathsSourceTarget(G)
    n = G.rows
    target = n-1
    results = [ ]
    path = [0]
    DFS-VISIT-PATHS(G, 0, target, path, results)
    return results

Function DFS-VISIT-PATHS(G, u, target, path, results)
    if u == target
        results.append(copy(path))
        return
    for each v in G.adj[u]
        path.append(v)
        DFS-VISIT-PATHS(G, v, target, path, results)
        path.pop()
```

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Code

```
class Solution:
    def allPathsSourceTarget(self, graph):
        target = len(graph) - 1
        results = []

        def dfs(node, path):
            if node == target:
                results.append(list(path))
                return

            for neighbor in graph[node]:
                path.append(neighbor)
                dfs(neighbor, path)
                path.pop()

        dfs(0, [0])
        return results
```

Time complexity

Let's take V as number of vertices, E as number of edges, and N_p as total paths from source to target.

In the worst case when path exists through every i < j, no of paths from node 0 to n - 1 is:

$$N_p = 2^{V-2}$$

Each path involved visiting V nodes, and copying current path into result list when target is reached, which takes O(V).

Hence the total time complexity is

$$T(V) = \sum_{p=1}^{N_p} (\text{nodes in path } p)$$

$$T(V) = O(V \cdot 2^V)$$

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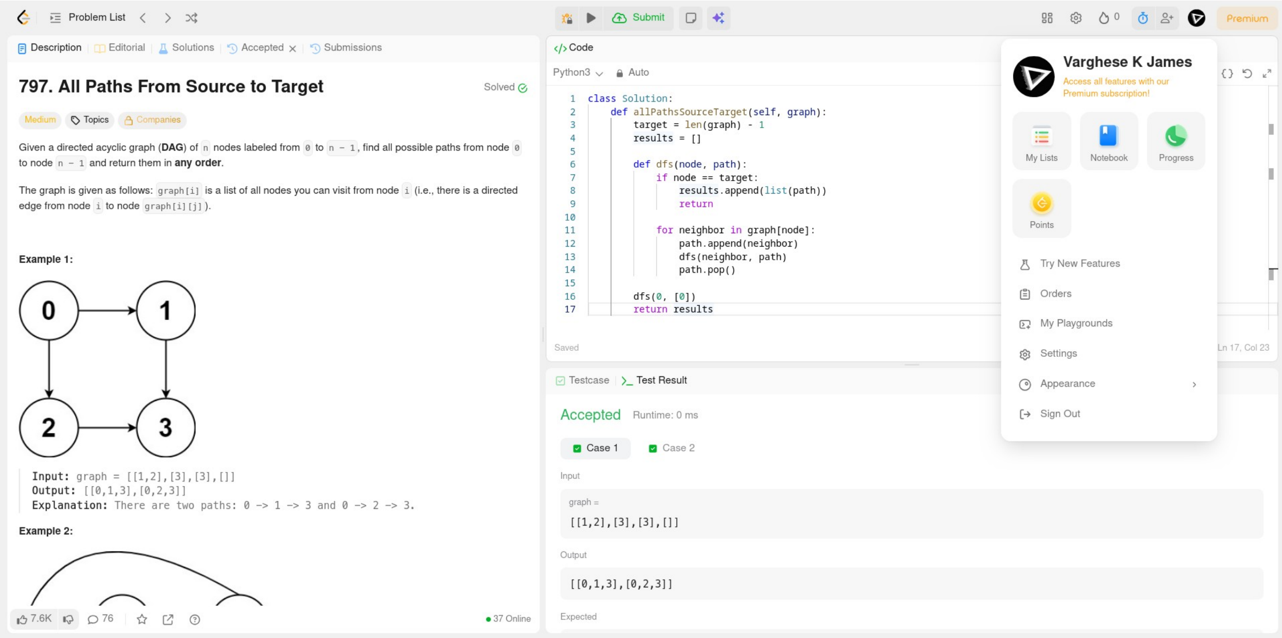
Screenshot of Output



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Learning Outcomes

- Learned about using backtracking algorithms to solve questions involving permutations and combination
- Learned about bespoke optimisations done to solve competitive programming questions.