Data Structures and Algorithms -II (Sample Lab Problems for Prectice)
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Previous problems from lab evaluations

1. You are developing a system for a company where each employee has a unique Employee ID, Name, and Salary. The company wants to sort the employee records by Employee ID using Merge Sort, and later use Binary Search to quickly find an employee based on their Employee ID. Write C++ program to implement this problem.
2. The Rural Electrification Board (REB) plans to connect 7 villages in a sub-district (upazila) of Tangail with electric power lines. The estimated cost (in lakh taka) of setting up electric poles and wires between the villages is given below:

Village 1	**Village 2**	**Cost (lakh taka)**
Delduar	Elasin	5
Delduar	Pathrail	2
Elasin	Pathrail	3
Elasin	Lauhati	6
Pathrail	Atia	4
Lauhati	Atia	7
Lauhati	Deuliya	1
Atia	Deuliya	2
Deuliya	Gharinda	3
Atia	Gharinda	6

Determine which connections should be built to ensure all villages are connected with the minimum cost. Provide the total cost and the selected connections

3. You are developing a system for a hospital where multiple patients book appointments, and each appointment has patient name and serial number. The hospital wants to sort all patient appointments chronologically using Merge Sort, so they can manage the daily schedule. Write a C++ program to accept a list of patients with their names and serial, sort the list in ascending order of serial number using Merge Sort.

4. A university is setting up LAN connections between 7 academic departments: CS, EEE, ME, CE, Arch, BBA, and English. The IT team wants to minimize wiring costs. The cost between departments (in units) is:

Dept 1	**Dept 2**	**Wiring Cost**
CS	EEE	2
CS	ME	3
EEE	ME	1
ME	CE	4
CE	Arch	2
Arch	BBA	5
BBA	English	2
ME	BBA	6
CE	English	7

Starting from CS, to create the least-cost network that connects all departments.

5. A message delivery robot moves between computers in a network. The network is represented as a graph where:
   Nodes = computers (numbered from 0 to N-1)
   Edges = communication links between them with:
   a positive transmission delay (weight)
   a message word (a string)
   You are given: A start computer and an end computer and A target keyword (string)
   The robot must deliver a message from start to end, choosing the shortest path in terms of total delay. In the shortest paths, the robot finds the concatenated message words along the path sharing the maximum LCS with the target keyword.

   Example:
   4 4
   0 1 2 "abc"
   1 2 2 "de"
   0 2 4 "abd"
   2 3 1 "c"

0 "aplbmcdpe" 3

Output:
Minimum Delay: 5
LCS with 'abcde': 5
Path: 0 -> 1 -> 2 -> 3

6. You are an adventurer traveling through a map of cities connected by roads. Each road has a **travel time**. Some cities contain **treasure items**. Each item has: A **weight** (e.g., how hard it is to carry) and a **value** (e.g., gold coins)
   Your goal is: **Reach the destination city in minimum time**, and **Collect treasure items along the path**, keeping total **weight ≤ your backpack limit**, and maximizing the **total value** of collected items.
   - N: number of cities (0-indexed)
   - M: number of roads
   - Each road connects two cities u and v with travel time t
   - K: number of cities that contain treasure items
   - Each treasure is located in a city, with weight and value
   - start and destination: source and target cities
   - capacity: the maximum weight you can carry

Example:
5 6 //n, m
0 1 2
0 2 4
1 2 1
1 3 7
2 3 2
3 4 3
3 //k
1 2 10 //city_id weight value
2 3 20
3 4 25
0 5 4 //start capacity destination

Output:
Minimum Travel Time: 9
Max Treasure Value: 45
Path: 0 -> 1 -> 2 -> 3 -> 4
Items Picked: [city 2 (20), city 3 (25)]

New Problems

7. You're working as a systems engineer at a cybersecurity firm. The firm has a multi-layer encryption pipeline used to process highly confidential government data. The data passes through a series of n encryption modules. Each module transforms the data and can be represented as a matrix operation (due to underlying linear transformations in the encryption algorithms).

   The matrices must be multiplied in a specific order to maintain data integrity and compliance, but the computational cost of these operations varies significantly depending on the multiplication sequence.

   The goal is to securely optimize the system by determining the best order of operations that:

   Preserves the output (i.e., doesn't change the final matrix product),

   Minimizes the number of scalar multiplications (reducing computational load and encryption latency).

   If the wrong multiplication order is chosen, not only does the system slow down, but the encryption hardware could overheat and shut down, causing a security breach.

   Input Format:

   Integer n — number of matrices (encryption modules)

   Array p[0..n] — where matrix Ai has dimensions p[i-1] x p[i]

   (Hint: Use MCM to solve it)

   Output Format:

   A single integer: minimum number of scalar multiplications

   A string showing the parenthesization of multiplication order

8. You're working with an international relief organization that deploys autonomous drones in the aftermath of natural disasters (e.g., earthquakes, floods). A disaster has struck a region with N villages that need urgent supply drops.

   Your mission is two fold:

   - Build a communication/control network between the central base and the villages using the least possible cabling cost.
   - Load the drones with optimal supplies to maximize utility (i.e., how much essential value they deliver), subject to their maximum weight capacity — this is a 0/1 Knapsack problem.
   - Input will be a graph with N nodes (villages), connected by M potential cable routes. There will be maximum weight W that a drone can carry. Each route has a cost. A set of K supply items, each with:
     - Item name
     - weight

- utility score

(Hint: apply MST algorithm, knapsack with use of structure to solve this)

9. You are a systems engineer at Q-Net Corp, which manages a futuristic quantum data teleportation network between research stations spread across a planetary grid. Each station can process quantum packets using a sequence of matrix transformations. Additionally, quantum packets must travel from the main data source (node S) to a destination station (node D) through the shortest possible route, considering transmission costs.

   However, due to quantum stability constraints, the order of matrix operations applied at the destination station affects both accuracy and performance. Hence, you need to determine the most efficient sequence of matrix multiplications at the destination after finding the shortest transmission path.

   Your Objective:

   a. Find the shortest path (minimum cost) to transmit a quantum packet from the source node S to destination node D in a weighted, directed graph.
   b. At the destination node, a chain of n matrix operations must be applied to the packet. Find the minimum cost to multiply these matrices.

   To solve this you will need : V = number of nodes (stations), E = number of directed edges (quantum links), Each edge goes from node ui to vi with cost wi; S = source node; D = destination node; n = number of matrices at station D; p[] = array of dimensions such that matrix i is of size p[i-1] x p[i]

   Example Input: 5 6

   1 2 4

   2 3 3

   1 4 2

   4 5 1

   5 3 1

   3 5 2

   1 3

   4

   10 20 30 5 60

(Hint: requires shortest path and mcm to solve)

<u>Advice: Practice combinations of multiple algorithms to solve a single problem for lab test.</u>