University Application - Computer Science
Problem statements

Never trust a computer you can't throw out a window.

Steve Wozniak

Aim: to practice problem-solving statements – Interview, CSAT

Such problem statements are used as they distinguish candidates, as solving problem statements require strong analytical and computational thinking skills.

Problem 1

https://www.youtube.com/watch?v=ReFhu8KYbmU&ab_channel=GarrettFogerlie

You are lost in a jungle, walking along a narrow path. You come to a T-junction, and you are aware that one way leads out of the jungle to safety, the other to a snake-infested area and almost certain death. There are two tribesmen at the T junction, and you have been informed that one of these men will always answer a question truthfully, the other will always lie.

What question will you ask?

Problem 2 - Lily-pad lunacy. (Oxford University past interview question)

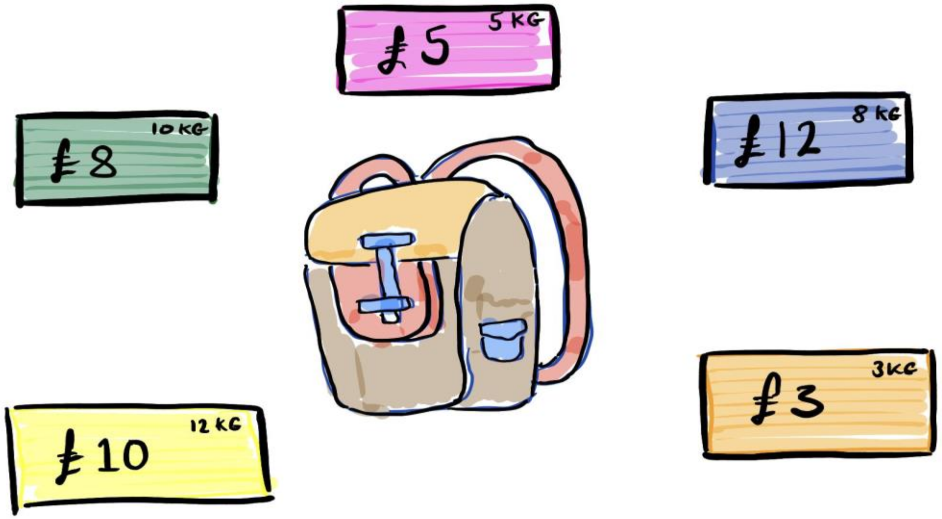
Difficulty: Easy

Eleven lily pads are numbered from 0 to 10. A frog starts on pad 0 and wants to get to pad 10. At each jump, the frog can move forward by one or two pads, so there are many ways it can get to pad 10. For example, it can make 10 jumps of one pad, 1111111111, or five jumps of two pads, 22222, or go 221212 or 221122, and so on. We'll call each of these ways different, even if the frog takes the same jumps in a different order.

How many different ways are there of getting from 0 to 10?

Problem 3 Knapsack problem

The problem is to fill the rucksack with no more than 20kg of weight, whilst giving the maximum value of the items possible.



`Now generalise and come up with an algorithm to solve this problem and any version of this problem.`

Problem 4 Four Ramblers

Four ramblers, A, B, C and D, with just one torch between them, arrive at a bridge across a deep ravine on a very dark night. The torch is essential for a successful crossing of the ravine. The bridge is only capable of taking two ramblers at a time, safely.

How should then ramblers proceed to cross the bridge?

Additional constraints

A needs one minute to cross the bridge

B needs two minutes to cross the bridge

C needs five minutes to cross the bridge

D needs ten minutes to cross the bridge

Since each rambler needs the torch to cross, whenever a pair cross the bridge together, it is the slower rambler who determines the total time required to make the crossing

The crossing must be done in less than 19 minutes because the bus on the other side leaves in 18 minutes.

Problem 5 Scouts

This is an example of the Decrease and Conquer strategy.

A group of 10 Scouts are stranded on a small island, a short distance from the mainland. Two small boys are playing on the shore in a very small rowing boat, which is only big enough to hold either the two boys or one Venture Scout.

How can all the Scouts reach the mainland and leave the boys and their boat together on the island?

How many trips does the boat make from one shore to the other?

What is the answer in the general case of n Venture Scouts?

Problem 6 WW2 Code Breakers

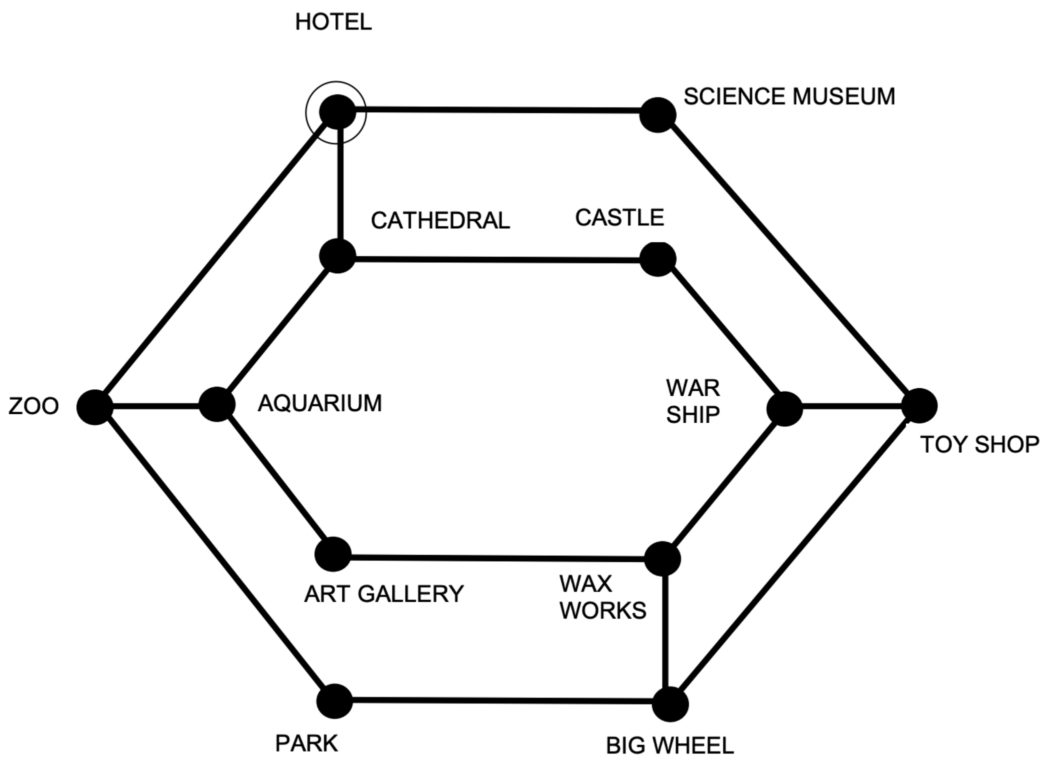
In the film “The Imitation Game”, the code breakers tried different approaches to cracking the German code, a transposition cipher in which each letter of the alphabet was replaced by another letter.

(a) Using a “brute force” method, how many different permutations of letters would they need to try, in the worst-case scenario? Leave your answer in the form of a factorial.

(b) Describe another strategy that could be tried rather than a brute force method to crack the code.

Problem 7
Focus: Graphs, Data Representation, Generalisation, Computational Thinking

Guided Tour
City Tube Map

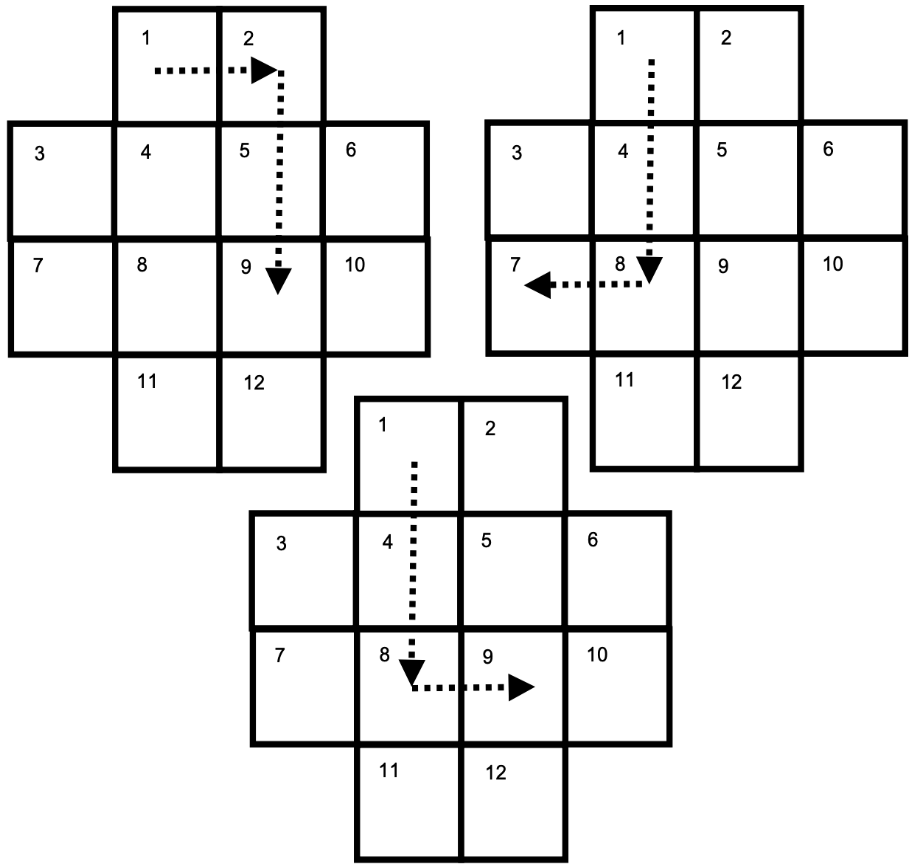


Starting at the hotel, plan a route so that tourists can visit every tourist attraction just once ending up back at the hotel.

The Knight's Tour Rules

Place the piece on square 1. By making only "knight" moves as in chess (see below), find a series of moves so that the knight visits every square exactly once, returning to where it started.

A knight moves in an L-shape: one square along and two squares up (in any direction. For example a piece on square 1 can move to square 6, 7 or 9.



Computational thinking

The diagram that we drew is what a computer scientist calls a **graph.**
A **graph** is a series of spots (we call those the nodes of the graph) and lines that join them

For the Knight's puzzle we have a node for each square of the board. We then add an edge for each possible knight move. It is this change of representation of the data that makes the puzzle seem easier. To create the graph, we had to do an 'abstraction'. **Abstraction** is just the hiding of information, or to think of it another way you must change the representation of the puzzle – change the way that it is presented, change what the board looks like and how the moves are done – to make clearer the things that matter in the puzzle. The positions of the board and how you can move between them are the only things that matter, so that is the abstraction we use - we hide all other information like the shape, size and position of the 'squares 'of the board.

We also saw two examples of **generalization**. We saw that we could generalize both problem statements and see that they are really the same kind of problem of finding a series of moves that visit every point exactly once and return to the start. A graph is a general representation – lots of apparently different problems can be represented by graphs. We also saw that in this case we could generalize the solutions – the solutions to both problems turn into exactly the same series of steps of the graph up to the words/numbers we have used to label the nodes. That of course isn't always the case, the graphs and solutions of two problems could be very different.

Another aspect of computational thinking that we have used here is **pattern matching** – when you see a problem or puzzle that involves moving from place to place, whatever the places are, consider representing it as a graph. Another way of saying that is if you can match a problem to the pattern of moving from place to place then use a graph to represent it. In this case we could go a step further.

Once we see that the two graphs are the same (i.e., we have pattern matched the solutions) we realise that we already have the answer. All we have to do is transform the graphs to be the same thing by swapping the labels over and we can transform the answer of one into the answer of the other. We then just read off an answer to both problems from the **general solution.**

As an aside, the way we explored all the possible moves to draw the graph is a variation of what is called **depth first search**: we explored paths to their end, following the trail 1 – 9 – 3 – 11 to the end, before backing up and trying different paths. An alternative (**breadth first search**) would involve drawing all the edges from a node before moving on to a new node, i.e., drawing all the edges from node 1, then drawing all the edges from node 9, then all the edges from node 6. These are two different algorithms for exploring graphs exhaustively: two different **graph traversal algorithms.**

Problem 8

I have forgotten my 5-character computer password, but I know that it consists of the letters `a`, `b`, `c`, `d`, `e` in some order. When I enter a potential password into the computer, it tells me exactly how many of the letters are in the correct position.

When I enter `abcde`, it tells me that none of the letters are in the correct position. The same happens when I enter `cdbea` and `eadbc`.

Using the best strategy, how many **further** attempts must I make in order to **guarantee** that I can **deduce** the correct password?

A None: I can deduce it immediately

B One

C Two

D Three

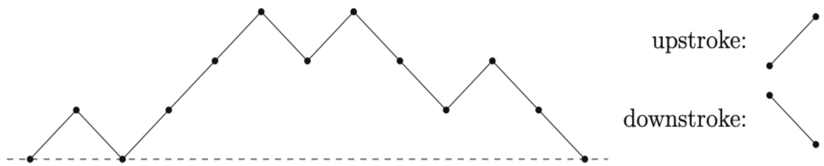
E More than three

Problem 9

You must remove the k smallest elements from a list of length n. Strategy (1) sorts the list in ascending order, which takes time n^2, then removes the first k elements. Strategy (2) repeatedly finds the smallest element by scanning the list and removing it until k elements are removed. The time taken to compare two elements is 1 and the time taken to remove an element is 1. All other operations take zero time. Prove that strategy (2) is faster.

Problem 10

The diagram shows an example of a *mountain profile.*



This consists of *upstrokes* which go upwards from left to right, and *downstrokes* which go downwards from left to right. The example shown has six upstrokes and six downstrokes. The horizontal line at the bottom is known as *sea level.*

A *mountain profile of order n* consists of n upstrokes and n downstrokes, with the condition that the profile begins and ends at sea level and **never** goes **below** sea level (although it might reach sea level at any point). So the example shown is a mountain profile of order 6.

Mountain profiles can be coded by using U to indicate an upstroke and D to indicate a downstroke. The example shown has the code UDUUUDUDDUDD. A sequence of U's and D's obtained from a mountain profile in this way is known as a *valid code.*

Which of the following statements is/are true?

I If a valid code is written in reverse order, the result is always a valid code.

II If each U in a valid code is replaced by D and each D by U, the result is always a valid code.

III If U is added at the beginning of a valid code and D is added at the end of the code, the result is always a valid code.

A none of them

B I only

C II only

D III only

E I and II only

F I and III only

G II and III only

H I, II and III