Warm-up: Greedy or Not?

Sometimes it can be tricky to tell when a greedy algorithm applies. For each problem, say whether or not
the greedy solution would work for the problem. If it wouldn’t work, give a counter example.

1. You have unlimited objects of different sizes, and you want to completely fill a box with as few objects
   as possible. (Greedy: Keep putting the largest object possible in for the space you have left)

2. You have unlimited objects, all of which are size $3^k$ for some integer k, and you want to completely fill
   a box with as few objects as possible. (Greedy: same approach as the previous problem)

3. You have lines that can fit a fixed number of characters. You want to print out a fixed series of words
   while using as few lines as possible. (Greedy: Fit as many words as you can on a given line)

Cutting Ropes

Suppose we are given n ropes of different lengths, and we want to tie these ropes into a single rope. The cost
to connect two ropes is equal to sum of their lengths. We want to connect all the ropes with the minimum
cost.

For example, suppose we have 4 ropes of lengths 7, 3, 5, and 1. One (not optimal!) solution would be to
combine the 7 and 3 rope for a rope of size 10, then combine this new size 10 rope with the size 5 rope for a
rope of size 15, then combine the rope of size 15 with the rope of size 1 for a final rope of size 16. The total
cost would be $10 + 15 + 16 = 41$. (Note: the optimal cost for this problem is 29. How might you combine
the ropes for that cost?)

Find a greedy algorithm for the minimum cost and prove the correctness of your algorithm.

Mice to Holes

There are n mice and n holes along a line. Each hole can accommodate only 1 mouse. A mouse can stay at
his position, move one step right from $x$ to $x + 1$, or move one step left from $x$ to $x - 1$. Any of these moves
consumes 1 minute. Mice can move simultaneously. Assign mice to holes such that the time it takes for the
last mouse to get to a hole is minimized, and return the amount of time it takes for that last mouse to get
to its hole.

Example:

Mice positions: 4 -4 2
Hole positions: 4 0 5

Best case: the last mouse gets to its hole in 4 minutes \{4 \to 4, -4 \to 0, 2 \to 5\} and \{4 \to 5, -4 \to 0, 2 \to 4\}
are both possible solutions
Roads and Airports

Given a set of $n$ cities, we would like to build a transportation system such that there is some path from any city $i$ to any other city $j$. There are two ways to travel: by driving or by flying. Initially all of the cities are disconnected. It costs $r_{ij}$ to build a road between city $i$ and city $j$. It costs $a_i$ to build an airport in city $i$. For any two cities $i$ and $j$, we can fly directly from $i$ to $j$ if there is an airport in both cities. Give an efficient algorithm for determining which roads and airports to build to minimize the cost of connecting the cities.