Exercise: Dice roll sum

- Write a method `diceSum` similar to `diceRoll`, but it also accepts a desired sum and prints only arrangements that add up to exactly that sum.

```plaintext
diceSum(2, 7);
[1, 6]
[2, 5]
[3, 4]
[4, 3]
[5, 2]
[6, 1]
diceSum(3, 7);
[1, 1, 5]
[1, 2, 4]
[1, 3, 3]
[1, 4, 2]
[1, 5, 1]
[2, 1, 4]
[2, 2, 3]
[2, 3, 2]
[2, 4, 1]
[3, 1, 3]
[3, 2, 2]
[3, 3, 1]
[4, 1, 2]
[4, 2, 1]
[5, 1, 1]
```
Consider all paths?

<table>
<thead>
<tr>
<th>chosen</th>
<th>available</th>
<th>desired sum</th>
</tr>
</thead>
<tbody>
<tr>
<td>-</td>
<td>3 dice</td>
<td>5</td>
</tr>
</tbody>
</table>

```
1 2 dice   2 2 dice   3 2 dice   4 2 dice   5 2 dice   6 2 dice
1 1 die    1 2 1 die   1 3 1 die   1 4 1 die   1 5 1 die   1 6 1 die
1 1 1      1 1 2      1 1 3      1 1 4      1 1 5      1 1 6
1 6 1      1 6 2      ...
```
Optimizations

- We need not visit every branch of the decision tree.
  - Some branches are clearly not going to lead to success.
  - We can preemptively stop, or prune, these branches.

- Inefficiencies in our dice sum algorithm:
  - Sometimes the current sum is already too high.
    - (Even rolling 1 for all remaining dice would exceed the sum.)
  - Sometimes the current sum is already too low.
    - (Even rolling 6 for all remaining dice would not reach the sum.)
  - When finished, the code must compute the sum every time.
    - (1+1+1 = ..., 1+1+2 = ..., 1+1+3 = ..., 1+1+4 = ..., ...)
New decision tree

<table>
<thead>
<tr>
<th>chosen</th>
<th>available</th>
<th>desired sum</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>3 dice</td>
<td>5</td>
</tr>
</tbody>
</table>

1 2 dice

2 2 dice

3 2 dice

4 2 dice

5 2 dice

6 2 dice

1, 1 1 die

1, 1, 1

1, 1, 2

1, 1, 3

1, 1, 4

1, 1, 5

1, 1, 6

1, 1, 3

1, 1, 4

1, 1, 5

1, 1, 6

1, 6, 1

1, 6, 2

...
The "8 Queens" problem

- Consider the problem of trying to place 8 queens on a chess board such that no queen can attack another queen.

  - What are the "choices"?
  
  - How do we "make" or "un-make" a choice?
  
  - How do we know when to stop?
Naive algorithm

- for (each square on board):
  - Place a queen there.
  - Try to place the rest of the queens.
  - Un-place the queen.

- How large is the solution space for this algorithm?
  - $64 \times 63 \times 62 \times \ldots$
Better algorithm idea

- Observation: In a working solution, exactly 1 queen must appear in each row and in each column.

  - Redefine a "choice" to be valid placement of a queen in a particular column.

  - How large is the solution space now?
    - $8 \times 8 \times 8 \times \ldots$
Recall: Backtracking

A general pseudo-code algorithm for backtracking problems:

Explore(\texttt{choices}):
- if there are no more \texttt{choices} to make: stop.
- else, for each available choice \texttt{C}:
  - Choose \texttt{C}.
  - Explore the remaining \texttt{choices}.
  - Un-choose \texttt{C}, if necessary. (backtrack!)
Exercise

• Suppose we have a Board class with these methods:

<table>
<thead>
<tr>
<th>Method/Constructor</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>public Board(int size)</td>
<td>construct empty board</td>
</tr>
<tr>
<td>public boolean isSafe(int row, int column)</td>
<td>true if queen can be safely placed here</td>
</tr>
<tr>
<td>public void place(int row, int column)</td>
<td>place queen here</td>
</tr>
<tr>
<td>public void remove(int row, int column)</td>
<td>remove queen from here</td>
</tr>
<tr>
<td>public String toString()</td>
<td>text display of board</td>
</tr>
</tbody>
</table>

• Write a method solveQueens that accepts a Board as a parameter and tries to place 8 queens on it safely.
• Your method should stop exploring if it finds a solution.
Extra: Graphical User Interfaces

- Involve large numbers of interacting objects and classes
  - Highly framework-dependent

- Path of code execution unknown
  - Users can interact with widgets in any order
  - Event-driven

- In Java, AWT vs. Swing; GUI builders vs. writing by hand
Swing Framework

- Great case study in OO design
Composite Layout

Draw out desired result

Divide into regions

Figure out appropriate layout managers and components