# B - Programming

## Please read all the sections carefully:

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**III.** Important Information
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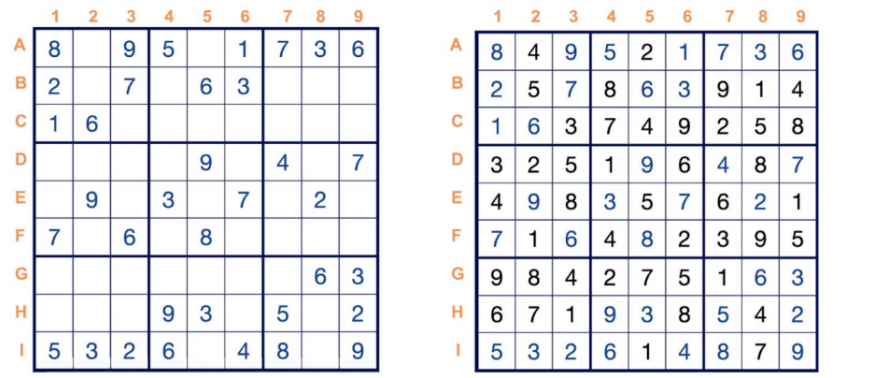
## I. Introduction



| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
|---|---|---|---|---|---|---|---|---|---|
| A | 8 | | 9 | 5 | | 1 | 7 | 3 | 6 |
| B | 2 | | 7 | | 6 | 3 | | | |
| C | 1 | 6 | | | | | | | |
| D | | | | | 9 | | 4 | | 7 |
| E | | 9 | | 3 | | 7 | | 2 | |
| F | 7 | | 6 | | 8 | | | | |
| G | | | | | | | | 6 | 3 |
| H | | | | 9 | 3 | | 5 | | 2 |
| I | 5 | 3 | 2 | 6 | | 4 | 8 | | 9 |

| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
|---|---|---|---|---|---|---|---|---|---|
| A | 8 | 4 | 9 | 5 | 2 | 1 | 7 | 3 | 6 |
| B | 2 | 5 | 7 | 8 | 6 | 3 | 9 | 1 | 4 |
| C | 1 | 6 | 3 | 7 | 4 | 9 | 2 | 5 | 8 |
| D | 3 | 2 | 5 | 1 | 9 | 6 | 4 | 8 | 7 |
| E | 4 | 9 | 8 | 3 | 5 | 7 | 6 | 2 | 1 |
| F | 7 | 1 | 6 | 4 | 8 | 2 | 3 | 9 | 5 |
| G | 9 | 8 | 4 | 2 | 7 | 5 | 1 | 6 | 3 |
| H | 6 | 7 | 1 | 9 | 3 | 8 | 5 | 4 | 2 |
| I | 5 | 3 | 2 | 6 | 1 | 4 | 8 | 7 | 9 |

The objective of Sudoku is to fill a 9x9 grid with the numbers 1-9 so that each column, row, and 3x3 sub-grid (or box) contains one of each digit. You may try out the game here: **sudoku.com**. Sudoku has 81 **variables**, i.e. 81 tiles. The variables are named by **row** and **column**, and are **valued** from 1 to 9 subject to the constraints that no two cells in the same row, column, or box may be the same.

Frame your problem in terms of **variables**, **domains**, and **constraints**. We suggest representing a Sudoku board with a Python dictionary, where each key is a variable name based on location, and value of the tile placed there. Using variable names **A1**... **A9**... **I1**... **I9**, the board above has:

- sudoku_dict["B1"] = **2**, and
- sudoku_dict["E2"] = **9**.

We give value **zero** to a tile that has not yet been filled.

## Executing your program

Your program will be executed as follows:

```
$ python3 sudoku.py <input_string>
```

In the starter zip, `sudokus_start.txt`, contains hundreds of sample unsolved Sudoku boards, and `sudokus_finish.txt` the corresponding solutions. Each board is represented as a single line of text, starting from the top-left corner of the board, and listed left-to-right, top-to-bottom.

The first board in `sudokus_start.txt` is represented as the string:

003020600900305001001806400008102900700000008006708200002609500800203009005010300

Which is equivalent to:

0 0 3 0 2 0 6 0 0
9 0 0 3 0 5 0 0 1
0 0 1 8 0 6 4 0 0
0 0 8 1 0 2 9 0 0
7 0 0 0 0 0 0 0 8
0 0 6 7 0 8 2 0 0
0 0 2 6 0 9 5 0 0
8 0 0 2 0 3 0 0 9
0 0 5 0 1 0 3 0 0

Your program will generate `output.txt`, containing a single line of text representing the finished Sudoku board. E.g.:

483921657967345821251876493548132976729564138136798245372689514814253769695417382

Test your program using `sudokus_finish.txt`, which contains the solved versions of all of the same puzzles.

## III. Backtracking Algorithm

Implement **backtracking** search using the minimum remaining value heuristic. Pick your own order of values to try for each variable, and apply forward checking to reduce variables domains.

- Test your program on `sudokus_start.txt`.
- Report the number of puzzles you can solve and the mean, standard deviation, min, and max of the runtime over all puzzles in `sudokus_start.txt`.

## IV. Important Information

### 1. Test-Run Your Code

Test, test, test. Make sure you produce an output file with the **exact format** of the example given.

### 2. Grading Submissions

We test your final program on **20 boards**. Each board is worth **5 points** if solved, and zero otherwise. These boards are similar to those in your starter zip, so if you solve all those, you'll get full credit.

### 3. Time Limit

No brute-force! Your program should solve puzzles in **well under a minute** per board. Programs with much longer running times will be killed.

### 4. Just for fun

Try your code on the world's hardest Sudokus! There's nothing to submit here, just for fun. For example:

**Sudoku:**
800000000003600000070090200050007000000045700000100030001000068008500010090000400

**Solution:**
812753649943682175675491283154237896369845721287169534521974368438526917796318452

## IV. What You Need To Submit

1. Your `sudoku.py` file (and any other python code dependency)
2. A `README.txt` with your results, including the:
   - number of boards you could solve from `sudokus_start.txt`,
   - running time statistics: min, max, mean, and standard deviation.

## V. Before You Submit

- Ensure that your file is named `sudoku.py`
- Ensure that your file compiles and runs.