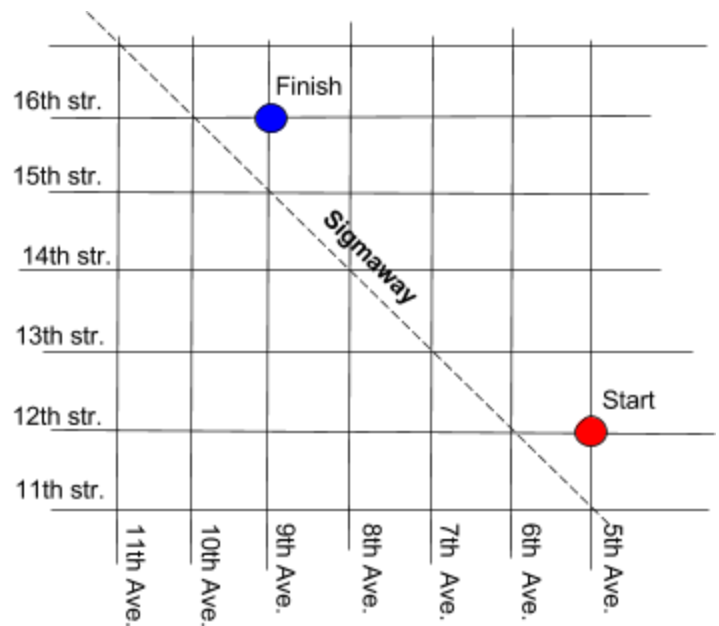




**MATHEMATICS**

**5 points:** A tourist arrives in SigmaCity. The city is somewhat similar to Manhattan: Streets follow East-West direction, and their numbers are increasing from South to North. Avenues are perpendicular to the Streets and their numbers are increasing from East to West (see the Figure. Please ignore the Sigmaway - it is needed for 10pt problem only). The tourist starts his journey near the train station located at the corner of 12th Str. and 5th Ave. He knows that there is a Sigma Museum somewhere northwest of him, so at each intersection, depending on the traffic light, he would go North or West, with equal probability. What is the probability that the tourist will eventually reach the Museum located at the intersection of 16th Str. and 9th Ave.?



**10 points:** A tourist arrives in SigmaCity. The city is somewhat similar to Manhattan: Streets follow East-West direction, and their numbers are increasing from South to North. Avenues are perpendicular to the Streets and their numbers are increasing from East to West (see the Figure). The tourist starts his journey near the train station located at the corner of 12th Str. and 5th Ave. He knows that there is a Sigma Museum somewhere northwest of him, so at each intersection, depending on the traffic light, he would go North or West, with equal probability.

However, there is one more street in the city called Sigmaway that runs diagonally as shown in the Figure. The tourist never crosses it, knowing that the museum is located at the same side of the Sigmaway as the train station. At the intersection with the Sigmaway he always turns North. What is the probability that the tourist will eventually reach the Museum located at the intersection of 16th Str. and 9th Ave.?

## PHYSICS

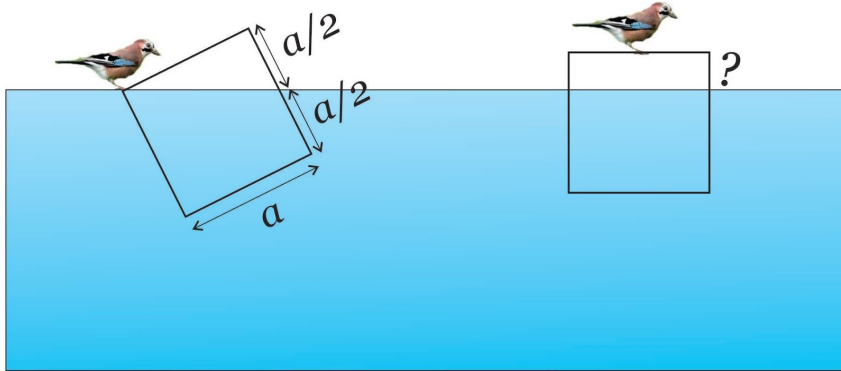
This month problems are on the Archimedes' principle and on the law of the lever. You might find the following links useful.

Buoyancy: <http://hyperphysics.phy-astr.gsu.edu/hbase/pbuoy.html#arch3>  
[https://en.wikipedia.org/wiki/Archimedes%27\\_principle](https://en.wikipedia.org/wiki/Archimedes%27_principle)

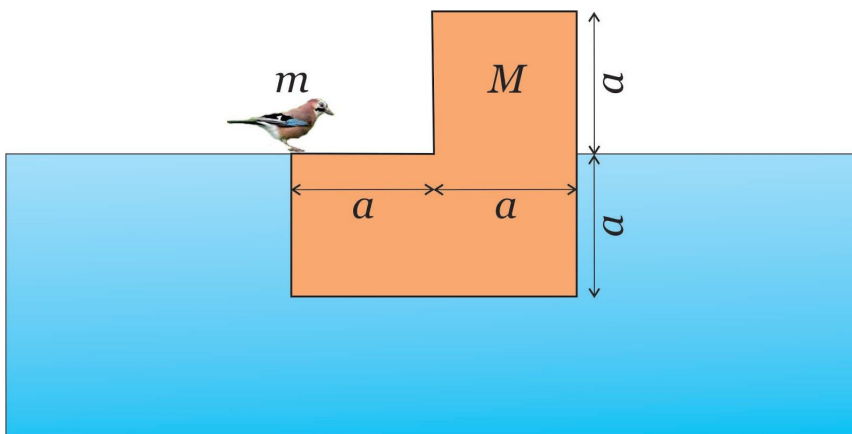
Center of mass: <http://hyperphysics.phy-astr.gsu.edu/hbase/cm.html>

Torque and equilibrium: <http://hyperphysics.phy-astr.gsu.edu/hbase/torq.html>

**5 points:** A bird of mass  $m$  stands at the corner of the wooden log of square cross-section and mass  $M$  floating in the water, such that the corner at which the bird stands is level with water, while the level of water on the opposite side of the square log is at the middle of that side (see picture below). Find the level of water (how far the log will be immersed in water) when bird moves to the center of the log.



**10 points:** A bird of mass  $m$  stands at the corner of the wooden log with an L-shaped cross-section with dimensions shown in the Figure. The log is floating in the water, so that the corner at which the bird stands is level with water and the bottom of the log is horizontal. Find the mass of the log  $M$ .



## CHEMISTRY

### 5 points:

You are organizing the Escape-the-Lab game. In this game, players have to obtain a four digit number to open the last lock. To solve this puzzle, players use the following set of objects: two sets of bottles with some colorless liquids inside (the bottles are labeled as 1, 2, 3, 4, and A, B, C, D, accordingly), and a 4x4 rack with empty test tubes. The test tubes are labeled as shown on the scheme below:

1a 2a 3a 4a  
1b 2b 3b 4b  
1c 2c 3c 4c  
1d 2d 3d 4d

These labels are a clue: players are supposed to mix a solution from the bottle 1 and a solution from the bottle 'a' in the test tube 1a, a solution from the bottle 2 and the bottle 'a' in the test tube 2a, etc. When the solutions are added to all test tubes, precipitation occurs in some of them, so they will look like this:

o o x o  
o o o o  
o o o x  
o x x x

where 'o' means a clear solution, and 'x' means a precipitation.

That corresponds to the binary numbers 0010 (2), 0000 (0), 0001 (1), and 0111 (7), which is the code (2017) that opens the lock.

**Question:** which chemicals should you use to prepare solutions 1, 2, 3, 4, A, B, C, and D?

### 10 points:

You are organizing the Escape-the-Lab game. In this game, players have to obtain a four digit number to open the last lock. To solve this puzzle, players use the following set of objects: two sets of bottles with some colorless liquids inside (the bottles are labeled as 1, 2, 3, 4, and A, B, C, D, accordingly), and a 4x4 rack with empty test tubes. The test tubes are labeled as shown on the scheme below:

1a 2a 3a 4a

1b 2b 3b 4b

1c 2c 3c 4c

1d 2d 3d 4d

These labels are a clue: players are supposed to mix a solution from the bottle 1 and a solution from the bottle 'a' in the test tube 1a, a solution from the bottle 2 and the bottle 'a' in the test tube 2a, etc. When the solutions are added to all test tubes, precipitation occurs in some of them, so when the secret number is, for example, 2018, the array of test tubes will look like this:

o o x o (i.e. 0010)

o o o o (i.e. 0000)

o o o x (i.e. 0001)

x o o o (i.e. 1000)

where 'o' means a clear solution, and 'x' means a precipitation; in that case it corresponds to the binary numbers 0010 (2), 0000 (0), 0001 (1), and 1000 (8).

**Question:** which chemicals should you use for solutions 1, 2, 3, 4, A, B, C, and D if you need to encode the number 2018?

## BIOLOGY

### 5 points:

- *How did they happen to be so little? – asked Dorothy. – I never saw such small pigs before.*
- *They are from the Island of Teenty-Weent, - said the Wizard, - where everything is small, because it's a small island.*

This is the explanation that the Wizard of Oz gave Dorothy in L. Frank Baum's book. Is this explanation for the smaller pig size valid only in the author's made-up universe, or could an animal's size be different depending on whether or not that animal inhabits an island in the real world? If so, do you think that the Wizard's smaller island = smaller animals statement would always be true? Why or why not? Give examples.

### 10 points:

One night Dr. Z, the Chief Physician of the Crystal City Memorial Hospital came home very disappointed.

- *Today I spent all day collecting data from the archives of our hospital about patients who were diagnosed with cancer in the last 50 years. - he told his wife, Mrs.Z and showed her a table:*

Years	Oncology cases
1950s	88
1960s	87
1970s	101
1980s	479
1990s	2658
2000s	3012

- *As you know, up until mid 80's our Crystal City was a small town of hunters, surrounded by forests. But then they found minerals and built factories right next to the city. I am sure that pollution of the environment with industrial wastes is the reason for the growth in the number of cancer patients. I will demand the closure of factories, in order to save lives! - said Dr. Z*

Mrs. Z, who had also graduated from medical school, wasn't that certain of her husband's interpretation of these oncology data, and she gently offered him to discuss it the next day, so that she could do some research of her own beforehand.

What explanation(s) of the oncology data other than environmental pollution could she have in mind?

What additional data do you think Mrs. Z wanted to find on her own before discussing the topic with her husband?

## COMPUTER SCIENCE

- You can write and compile your code here:  
<http://www.tutorialspoint.com/codingground.htm>
- Your program should be written in Java or Python
- No GUI should be used in your program: eg., `easygui` in Python. All problems in POM require only text input and output. GUI usage complicates solution validation, for which we are also using *codingground* site. Solutions with GUI will have points deducted or won't receive any points at all.
- Please make sure that the code compiles and runs on <http://www.tutorialspoint.com/codingground.htm> before submitting it. We use this site when we grade the solutions. Failure to run on this site will lead to automatic point reduction.
- Any input data specified in the problem should be supplied as user input, not hard-coded into the text of the program.
- Submit the problem in a plain text file, such as `.txt`, `.dat`, etc.  
**No .pdf, .doc, .docx, etc!** Again, failure to follow these instructions will lead to point reduction.

### 5 points:

Write a program that given two substrings and a longer string determines whether the longer string contains both substrings in a non-overlapping way. For example, if "abc" and "bce" are the substrings, then "abce" fails, but "abcabce" works. Substrings and the string should be entered from input. You can use substring search function in your selected programming language (such as `find()` in Python and `indexOf()` in Java).

### 10 points:

You are given a dictionary (a set of strings, which your program should obtain from input), and then given a "test" string (also entered from input), which is likely a mistype of one of the dictionary strings. Your program should decide which of the dictionary strings was most likely mistyped. In addition to your code, please explain your approach; doing so in program comments is the best way. Points will be assigned for the code as well as for the the explanation.