MATHEMATICS

5 points: Four circles of the same size are inscribed in a bigger circle, as shown in the Figure. One of the small circles is shaded black. Find the fraction of the area of the large circle which is shaded.
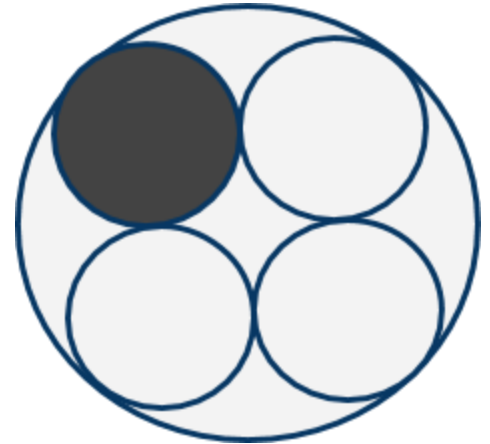
10 points: Four circles of the same size are inscribed in a bigger circle, as shown in the Figure. One of the small circles is shaded black. Four smaller equal circles are now inscribed into another one. Out of them, one is shaded, and another is again replaced by a smaller version of the whole figure… Find the fraction of the area of the large circle which is shaded as a result of this never-ending sequence of inscription and shading.
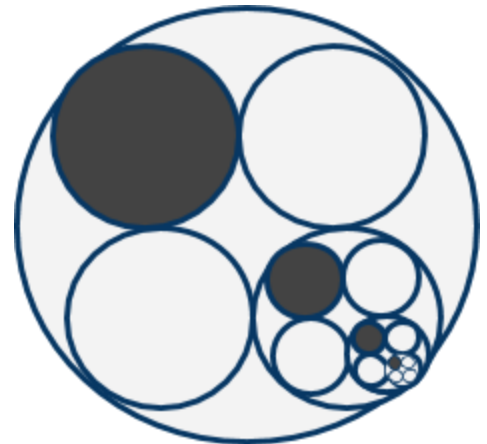
PHYSICS

This month Physics problems are on the mechanical equilibrium and simple machines. You might find the following links useful.

http://hyperphysics.phy-astr.gsu.edu/hbase/Mechanics/lever.html
http://hyperphysics.phy-astr.gsu.edu/hbase/Mechanics/simmac.html#c1
http://hyperphysics.phy-astr.gsu.edu/hbase/torq.html#equi
http://hyperphysics.phy-astr.gsu.edu/hbase/fequ.html#equ
http://hyperphysics.phy-astr.gsu.edu/hbase/toreq.html

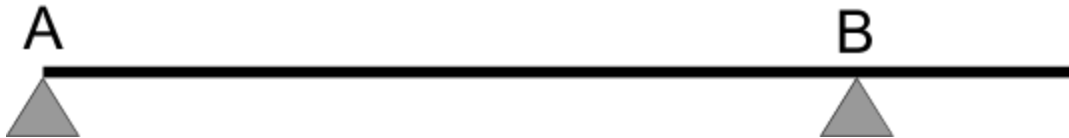**5 points:** Two people are carrying a plank of the length L, supporting it at points A and B as schematically shown in the Figure. What should be the distance between points A and B for the person A to carry exactly one third of the weight of the plank. The plank is uniform and horizontal.

10 points: Two masses $m_1 = 2$ kg and m_2=3 kg are suspended motionlessly with the help of a pulley, ropes and a plank as presented on the diagram. At what distance from the left end of the plank should you place a pivot point O to keep the system in equilibrium if the length of the plank is 0.6 m and the mass of the plank is $M = 5$ kg. The masses of the pulley and ropes are negligible.
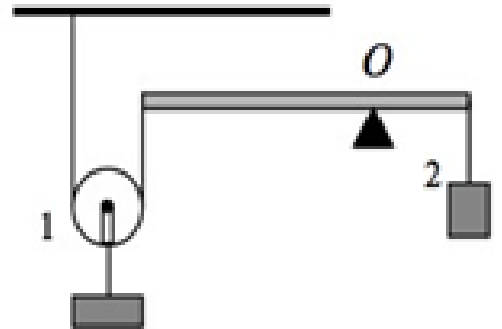
CHEMISTRY

5 points:

An elastic balloon made of a semipermeable membrane (a membrane that is permeable for water molecules, but not for inorganic ions and larger molecules or ions) was filled with 5.9% aqueous solution of sodium chloride and sealed. Then the balloon was placed into a beaker filled with 11.7% solution of potassium sulfate. Both solutions are at equilibrium, which means the balloon is not shrinking or expanding. The solution in the beaker was diluted with an equal volume of 7.4% aqueous calcium chloride. How will the balloon's volume change?

10 points:

Mercury and its salts are very toxic substances. The maximum allowed concentration of mercury salts in drinking water is 2 ppb (2 ng/L). Unfortunately, in some areas, drinking water may be contaminated by mercury, for example, due to the proximity of mercury deposits. Imagine you came to a small town where the only well that serves as source of drinking water contains inorganic mercury salts at concentration of 30 ppb, which is considerably higher than the maximum allowed concentration. There is an unlimited amount of the following reagents in this town:

> *Sodium sulfide, potassium iodide, sodium sulfate, lithium bromide, calcium chloride, ammonium nitrate.*

Which chemicals from this list would you advise to add to the drinking water to neutralize a toxic effect of mercury (at least, as a temporary solution), and in what concentration should these chemicals be used?

BIOLOGY

5 points:

The 4th season of the *Black Mirror* TV show starts with the story of some virtual world where digital clones of real humans had been placed. To make these clones, the main hero obtained biological samples from them (for example, by picking up traces of their saliva). Then, he placed these samples into some machine that performed some "scanning" (the details of this procedure are not explained in the film), and, after the scanning is complete, a digital clone of this individual appears in the virtual world. These clones completely retained the personality of their real world prototypes. To them, the process of transfer looked like if they have been suddenly transferred from the real world into the virtual world.

Can such a technology be developed (at least in a remote future), and what are major technical challenges for its implementation? If the answer is negative (it is impossible in principle), explain why?

10 points:

As a rule, when some animal or bird species is characterized by a significant sexual dimorphism, males look more "beautiful", bright, and aesthetically attractive than females. Accordingly, during the mating period, a male demonstrates some specific behaviour to attract female's attention, whereas a female take no special efforts to attract attention of males, and just selects the male who look more attractive than others.

In contrast, humans demonstrate totally opposite behaviour: usually, a woman tries to look aesthetically attractive, and woman's role traditionally consists in accepting or rejecting a man, whereas the initiative comes from the men's side.

Is that difference a result of some social stereotypes, or it has some evolutionary origin? Explain your answer.

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.
- 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!

5 points:

Given an 1-D array of integers, your program needs to find which two cells of non-equal value have the greatest number of cells separating them. Your program should enter the array on input. Please indicate the farthest cells in the output of your program in some way.

Example:
Input:
1, 1, 2, 2, 0, 1
Output:
(1,1,2,2,0),1

10 points:

Same as the above, but with an additional condition that the values of the determined "outside" cells cannot repeat between them.

For example, if we take the same input as in the 5 pts problem:
1, 1, 2, 2, 0, 1
the same solution will not stand as then value 1 will repeat within the sub-array between the outside cells. Correct solution in this case is
1,(1,2,2,0),1

To make the problem even more interesting (and to make your program more efficient), try to avoid nested loops in your program (that is a loop within a loop).