PROBLEM OF THE MONTH

January 2013

MATHEMATICS

Alice wrote a secret letter on a piece of paper and put it in one of the 8 numbered envelopes. Bob has to find out, which envelope contains the letter by asking Alice questions to which she can answer only "Yes" or "No". Bob knows that Alice's answers are not necessarily truthful, but he also knows that she would not lie more than once.

1. What do you think is the minimum amount of questions Bob has to ask to find the envelope with the letter?
2. What would be the smallest amount of questions Bob has to ask if there would be not 8 but 250 envelopes?

You do not need to PROVE that Bob's strategy utilizes the smallest number of questions, but you should prove that the strategy WORKS (i.e. Bob should know for certain where Alice put her letter after asking his series of questions).

PHYSICS

Joe the trucker is delivering 48000 lbs of cargo in his rig equipped with a 550 hp engine. Joe is trying his best to keep the truck's speed at the 55 mph limit. On an uphill climb Joe noticed that he could only maintain this speed up to a 3% grade[1], and (at this grade and 55 mph) the truck fuel efficiency gauge was measuring 2.2 mpg (miles per gallon). Estimate the fuel efficiency Joe was getting on a flat portion of his route, if the mass of his truck without cargo is 32000 lbs.

[1] % grade is a common measure of road slope in the US. This is what's displayed in street signs, driver's navigation aids, etc. It is defined as $100 * vertical_{elevation}/horizontal_{run}$, so, for instance, a 45-degree slope is 100% grade.

CHEMISTRY

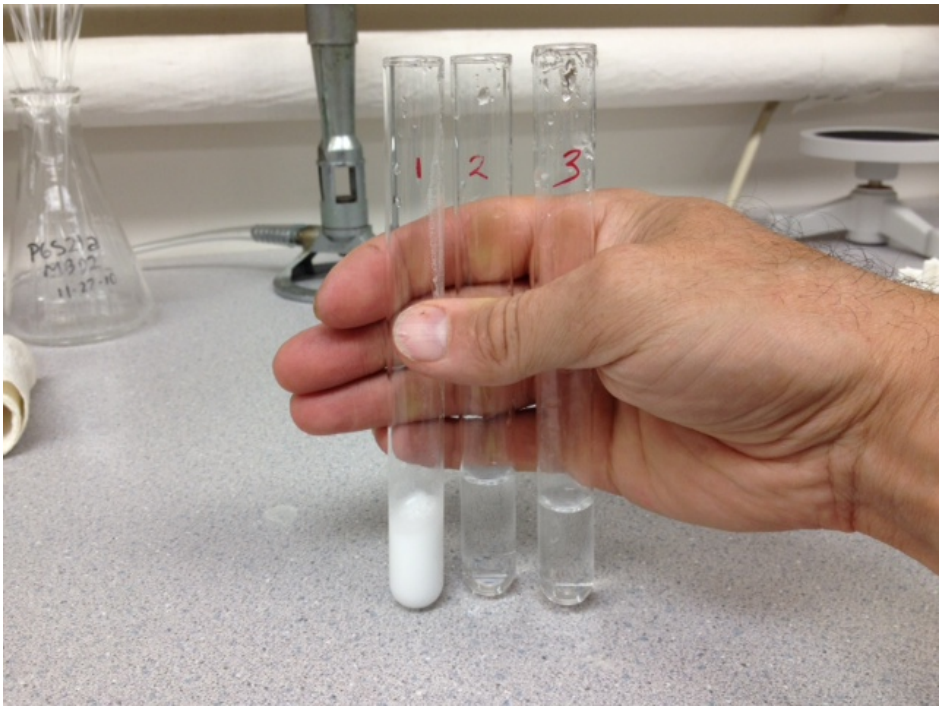
In my lab, I prepared three water solutions, sodium sulfate, calcium hydroxide (lime water), and calcium chloride, and labeled them (fig 1).

When I came to the lab next morning, I found someone had wiped out all the labels (by accident). According to the rules, I had to dispose all those solutions. However, before doing that, I decided to experiment a little bit. I decided to check if I am able to restore the labels. Firstly, I marked these bottles as “1”, “2”, and “3” (because I didn’t know the actual content of each of them, fig 2),

and poured small amount of each solution into the test tubes marked accordingly (“1”, “2”, and “3”). Then I added few drops of phenolphtalein solution to each tube (fig 3), and that is what I observed:

Then I washed all three test tubes, and poured fresh solutions “1”, “2”, or “3” to each of them. As previously, the number on the bottle corresponded to the test tube number. After that, I added a solution “1” to the solutions “2” and “3”, and I observed formation of precipitates in the tube “2”, and “3”:

Then I washed test tubes again, and added the solution “3” to the solutions “1” and “2”. Only a solution “1” gave a precipitate with a solution “3”; no precipitation was observed in the test tube “2”:



After that, I concluded I am able to restore all three labels. Am I right? Is it really possible to restore the labels, and if yes, which labels ($Ca(OH)_2$, Na_2SO_4, or $CaCl_2$) correspond to the solutions “1”, “2”, and “3”?
Please, draw the equations of each reaction if you can. As usually, all information you need to solve this problem is available at our SchoolNova web site (http://schoolnova.org/nova/classinfo?class_id=chemistry101&sem_id=f2013 or http://schoolnova.org/nova/classinfo?class_id=chemistry101&sem_id=s2014).

BIOLOGY

The father of modern genetics, Gregor Mendel studied the inheritance of traits in pea plants. Please write a concise scientific report of his groundbreaking work answering the following questions: a) what was Mendel's main hypothesis? b) Why did he choose pea as an object? c) Did he consider anything else and would it be possible to use another species for his work? d) How did he perform his experiments? e) What did he observe? F) How did he interpret his results?

In his work Mendel described 7 monogenic traits. It is often said that he got extremely lucky because pea plants have exactly 7 pairs of chromosomes thus all these traits were not linked. Yet, later experiments revealed that 7 traits studied by Mendel are located on 5 chromosomes. Why do you think these traits are not linked?

COMPUTER SCIENCE

Write a Java method that calculates the number of times a string of length 2 is the same and at the same position in 2 given strings.

For example:
Same("xyz","xyz") --> 2
Same("aaqppmm", "aayppm") → 3
Same("123","198") --> 0

Take 2 strings from stdin and use your method inside the 'main' method to calculate the number of matches.
http://www.tutorialspoint.com/java/java_strings.htm
http://www.tutorialspoint.com/java/java_string_substring.htm