Phys 115: Inquiry Into Physics	**Tenth Assignment, due Monday, Nov. 19th**
Section 0201: Ayush Gupta	Please also email to ayush.courses@gmail.com

Question 1: Temperature curves, Energy and Molecules

A. Say you take a water from the water heater in one of those Styrofoam cups we are using in class and put in one of the temperature probes in it and pressed collect. You note that at the beginning the water was at a temperature of 70 degrees Celsius. Now you just keep collecting data with the probe in the water for a fairly long time (say 3 hours or so). What do you think the temperature versus time graph would look like? Draw a sketch.

   Say you do the same thing but with really cold water from the cooler now (here you note the initial temperature to be 6 degrees Celsius). What do you think the temperature versus time graph will look like in this case? (Draw a sketch)

   Keep in mind that in this question you are not mixing the two waters.

B. So we have been talking about energy and how that is related to temperature. What happens to the energy of the hot water during this time – does it gain energy, lose energy or neither? What about the energy of the cold water? Is your explanation for energy consistent with the temperature curve that you have sketched?

   Now if you say that the energy of the hot and cold water changed – then where did the energy go (in case one of the two lost energy) or where did the energy come from (in case one of the two gained energy)

C. Molecular picture: One assumption the physicists make is that what we see in our normal world is based on how things happen at a deeper molecular level. The whole magic school bus metaphor is basically to get you to think about what might be going on at a molecular level and figuring out if that is in tune with our understanding of the world as we see it (in the sense that we "see" water, thermometers, bulbs, wires, batteries but not really atoms and electrons).

   So in part C I want you to think about what might be going on at a molecular level with our hot water molecules in the hot-water-cup in part A during the time that you sketched the graph for? What goes on with the cold water molecules during the time that you sketched the graph for? Try and see if your molecular picture is consistent with your explanation in parts A and B.

Question 2: Mixing hot and cold water

This is basically a question on what we ended class on Wednesday with. We were talking about what happens at a molecular level when we mix equal amounts of hot and cold water. Describe what you were thinking in details. This should be easy, since you have had group and class discussion with white board on this. Be as specific as you can and see if you can tie in your molecular picture to the observation we made.

Also if there are parts of your molecular picture that concern you are you are not sure about tell me about those.

As usual, this portion is one that really needs a picture to illustrate what you are thinking.

Small note on pictures and metaphors: scientists often use metaphors and pictures (like the ones we are using in class, say like the highway or chain ideas we used for circuits) to explain their ideas to other scientists. So this is also a part of scientific communication, not just a pedagogic activity.

Question 3: Making sense of a BBC article

Read the following article from BBC website: here is the link for that:
http://news.bbc.co.uk/1/hi/sci/tech/7084099.stm
Below is also a text version of the document.

For this question, I want you to bring a printout of the article. On the printout, highlight portions of the article that make sense to you. In the margin next to the highlighted portion, or on a separate sheet or somewhere, write down what you make of that portion – i.e. what did you think the author is trying to say in that portion.

Also highlight portions that did not make sense to you. Write notes on what specifically about that portion did not make sense to you.

(Article follows on next page)

BBC NEWS

Getting the measure of a kilogram

By Jonathan Fildes
Science and technology reporter, BBC News

In a heavily-guarded, subterranean vault on the outskirts of Paris is a lump of metal about the size of a plum.

To the eye it's an unremarkable object but "Le Grand K" or the international prototype, as it is known, has global significance.

The cylinder of platinum and iridium is the only object known to scientists that has a mass of exactly 1kg. It is the reference object from which the unit of mass is derived. Hence, all objects measured in kilograms, whether a bag of sugar or an aircraft carrier, are defined by Le Grand K's mass.

The object, along with a clutch of copycat cylinders, was forged in London in the 1880s. Le Grand K was kept at the International Bureau of Weights and Measures (BIPM) in Sevres in France and the others were distributed around the metric world - Britain holds Kilogram 18 for example - to act as the arbiters of mass. Every few years the siblings were taken to Paris to be measured against Le Grand K to make sure that everyone was singing from the same song sheet.

Tiny drift

But around 30 years ago scientists discovered a problem. The international prototype was no longer the same mass as the other cylinders. And, since then, the drift has continued. "Relative to the average of all the sister copies made over the last 100 years you could say it is losing [mass], but by definition it can't," explained Dr Richard Steiner of the National Institute of Standards and technology (NIST) in the US. "So the others are really gaining mass."

The fluctuation is about 50 parts in a billion, less than a single grain in a bag of sugar. But whilst it is tiny, the change can have important consequences, particularly for scientists who require precise definitions of the kilogram for other measurements such as voltage. However, as they are all measured against each other, knowing which are losing mass or gaining it is an open question. "We just don't know," admitted Dr Steiner.

If they have shed mass, one suggestion is that it is because atmospheric pollutants, incorporated into the cylinders when they were forged, have escaped. If they have gained mass it could be because the platinum based ingots have absorbed mercury from the atmosphere or hydrogen from the solvents used to clean the ingots. The drift of Le Grand K relative to the others could be explained by the fact that it is taken out of its vault and handled less often than the other objects.

The bottom line is that the cylinders have now passed their useful shelf life as the ultimate reference for the kilogram and as a result, scientists around the world have been working on new ways to define the kilogram.

Balancing force

Next week the custodians of measurement, the General Conference on Weights and Measures (CGPM), will meet in Paris and one of the things on their agenda will be to assess progress in the field. Two methods are currently being considered to do away with Le Grand K. Both try to characterise mass in terms of a constant of nature, the way all other basic scientific units are now defined.

For example, the metre was originally measured against a brass bar but is now defined as the distance travelled by light in a vacuum in a precise fraction of a second.

One approach is to try to define the kilogram using a piece of apparatus known as the watt balance, which amongst other things can be used to determine the quantum mechanical constant known as the Planck constant. "The Planck constant is the constant that relates energy to frequency in a photon," said Dr Seton Bennett, Deputy Director at the National Physical Laboratory (NPL) in the UK. "It is related to a lot of other constants so it crops up all over the place in physics and in particular in the equations that describe the operations of the watt balance."

This complex piece of machinery, invented at NPL, consists of a vacuum-enclosed balance arm, an ultra powerful magnet and a replica kilogram. "What you are doing in the watt balance is balancing a current passing through a [wire] coil in a magnetic field against the force of gravity on the kilogram." This is achieved by lowering the coil into the magnetic field, creating a downward electromagnetic force. By adjusting the current running through the coil the force can be made to exactly balance gravity's pull on the kilogram.

A second experiment is then conducted to measure the strength of the magnetic field. "When you combine those experiments, the equations give you a result that includes the Planck constant," said Dr Bennett. The constant is therefore intimately linked to the mass of a kilogram. By rearranging equations the constant can be used to determine the mass of the kilogram. "We are looking for experimental results that are 50 parts per billion or better," said Dr Bennett. This accuracy is equivalent to the drift measured between the standard kilograms used today. "If we can do better than that we can come up with a value that we know is right and will stand for all time."

Dr Steiner at NIST has so far managed to measure the Planck constant with uncertainties of 36 parts in a billion. But their value is different from that measured at NPL, leaving scientists on both sides of the Atlantic scratching their heads.

Golden globe

However, there is another, perhaps more intuitive, approach.

"We want to redefine the kilogram on the basis of the mass of an atom," said Professor Peter Becker of the national metrology institute (PTB) in Germany. "We want to try to count the atoms in one kilogram of a crystal." The project is named after the Avogadro Constant - the total number of carbon-12 atoms in 12 grams (0.012 kg). But instead of carbon-12, Professor Becker's crystal of choice is a sphere of silicon, about the size of a grapefruit. "We measure the volume of the sphere and we measure the volume of an atom of the silicon. "So when you divide the silicon sphere by the volume of the atoms you get the number of the atoms - this is very simple."

Except that it is not simple. There may be 50 septillion (trillion trillion) atoms in the sphere and early work showed that they could only be measured with accuracies of a few parts in 10 million - not down to the crucial parts per billion.

The problem is that silicon occurs as isotopes - different forms of the same element with different masses. To get round this, Professor Becker has commissioned Russian scientists to grow ultrapure 1kg spheres of silicon made up of 99.99% of one particular type of atom, known as silicon 28. The material for these spheres costs 1 million Euros (£0.7m). "This gives us the chance to derive a result with an acceptable level of uncertainty," he said.

History repeats

At the moment it looks like the watt balance method has the edge over atom counting and may therefore become the method used to redefine the kilogram, Professor Becker admitted. But he does not think his work is in vain. "If the decision is in favour of the watt balance we can check the work independently," said Professor Becker. Dr Bennett is of the same opinion. "The two experiments are related so we have to get them to agree," said Dr Bennett. But that will be just the start of the redefinition. In the world of measurement and standards everything must be precise and replicable.

"There will also have to be some standard instrument, whether a watt balance or something else, which will be used to monitor the kilogram or we're just back in the same situation," said Dr Bennett. "I think the reality will be that there will still be the kilogram in Paris for years to come."

Story from BBC NEWS:
http://news.bbc.co.uk/go/pr/fr/-/1/hi/sci/tech/7084099.stm

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