

## **CPIMA CLASSROOM LESSON/ACTIVITY: “WHAT’S THAT FLAPPING IN THE BREEZE?” AND “WHAT I DID ON MY SUMMER VACTION”**

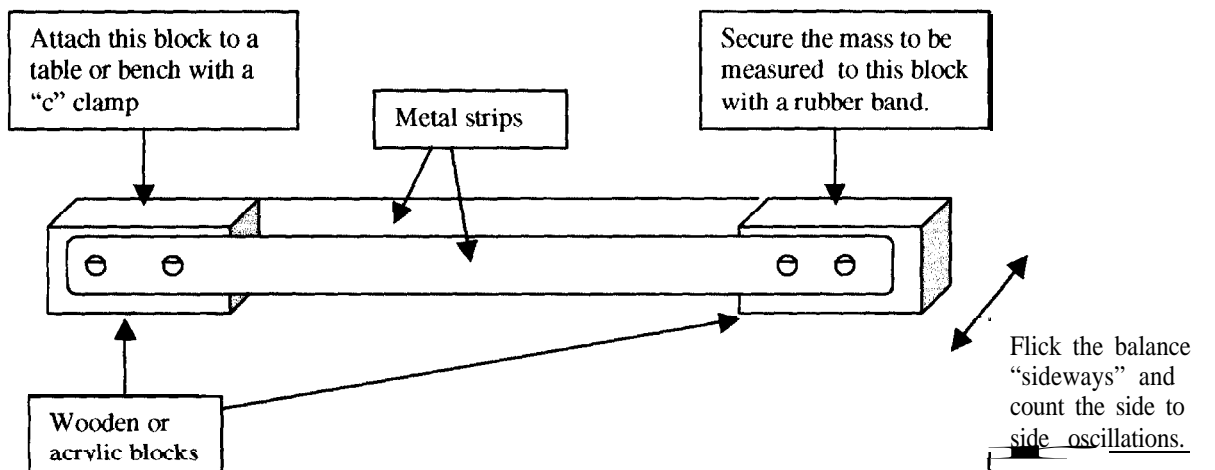
**BACKGROUND:** This summer at IBM Almaden Research Center I used a quartz crystal microbalance (QCM) to measure very small changes in mass due to fluid adsorption onto the surfaces of porous silicon-based polymer thin films. Porous dielectric films are currently being explored, because the inclusion of air greatly lowers the overall dielectric constant for the film and makes the film a more effective insulator for the ever-more dense circuitry in silicon chips. The intent of this study was to try and determine at what level of porosity this thin film material changed from a closed cell (isolated pores) structure to an open cell (interconnected pores) structure. This structural change has important implications for use of this material as a thin film dielectric in microelectronic circuits. The use of QCMs is widespread in chemistry and physics for measuring very small changes in mass. This Lesson has multiple parts, but probably only the first two parts (on the QCM) will be of interest to anyone but myself.

**PURPOSE:** The purpose of this lesson is: (1) To help students understand the operation of a QCM by way of analogy to an inertial balance (the actual principles of QCM operation are more complicated) and (2) To share with my chemistry students my summer research experience in materials science.

**INTRODUCTION:** I plan to introduce the lesson with the problem of how to weigh something which has a very small mass or very small changes in mass. The need to avoid friction will be pointed out. I will then demonstrate how the vibrational frequency of a system can be affected by changing the system’s mass. The bouncing of a spring with a mass attached to the can be used to illustrate this. I will then show an example of a home made inertial balance (see Figure 1). We will measure the frequency of the unladen balance and then the frequency with some kind of mass added to it. The determination of open or closed cell porosity of different foams may be demonstrated and done with the class as a whole or given as a laboratory activity in lab groups. At this point I favor the former rather than the latter for my own chemistry classes. The theory and use of an inertial balance would be a great activity by itself for a physics or physical science class, but you’ll have to build or buy a sufficient number of balances, unless you can talk a (really sweet) friend into doing it for you. [You (or that sweet friend of yours) can make an inertial balance out of just two 3” x 3” pieces of wood, one or two hack saw blades and four to eight small wood screws. See Figure 1.]

**THE INERTIAL BALANCE:** There is more than one way of making them. I have my favorite way illustrated below. For the last one I made, the metal strips (hack saw blades) were too stiff to use two (I had good vibrations, but frequencies were way too high to count), so I left one blade off. It seems to work pretty well for telling whether the foam samples I am using are open celled or closed cell. I would rather have two strips (one on each side of the blocks) because it gives the device better structural integrity-this is really important if students are using them. If the metal strips are stiff, the unladen frequency will be very high-perhaps too high to be able to count when comparing light masses. I have found it convenient to use 12” hacksaw blades, because they’re available

and because they're not easily mangled. Lighter, softer metal and longer metal strips will allow you to get lower (countable) frequencies for small masses. After flicking the free end of the balance, just count the number of cycles per convenient unit of time. I find that holding a piece of paper or other light object helps me to keep track of the cycles by giving me an auditory or tactile signal, to aid the visual signal.



**Figure 1**

### **ACTIVITY PART I (optional):** Calibrating the Inertial Balance

Objective: Do this if you want to use your inertial balances to determine mass or mass changes in terms of standard mass units.

Materials: 1 inertial balance per group

1 set of "weights" or other mass standards and means of securing them (like rubber band)

stop watch, clock w/second hand, watch

Procedure:

1. Measure the balance frequency with a range of known masses. The most appropriate units of frequency measurement will depend on the exact dimensions and characteristics of the materials used in the inertial balance. I have found that the number of cycles per ten seconds to be a fairly appropriate unit for the inertial balances I have used.
2. Having measured and recorded the frequencies for a an appropriate range of masses, have the students make a graph that will allow quick conversion of balance frequencies to standard mass units.

**ACTIVITY/DEMONSTRATION PART II:** Using the inertial balance to determine if foam samples are “open celled” or “closed cell”.

**Objective:** The objective here is to demonstrate, by way of an analogy, the main focus of my summer research project. It also demonstrates how, sometimes, information about material structure which may be difficult to obtain directly can be obtained by indirect means. The inertial balance is used to demonstrate how we can learn indirectly (without careful visual inspection or “hefting”) whether some different porous materials have open cell or closed cell structures.

**Materials:** inertial balance (1 per group)

2 samples of different kinds of foam material of the same size

plastic to cover wood of balance (if its made of wood), so it won't get wet

rubber band to hold foam blocks onto balance

**Procedure:**

1. Place one sample of each foam sample in a container of water about 1 hr ahead of time so the material has a chance to absorb the water, if it will.
2. Weigh the other sample (dry) sample of foam to get a dry mass of that foam.
3. One at a time, remove each different foam sample from the “soaking” container, let it drip excess water back into the container, then place it on the inertial balance and record the frequency.
4. Obviously, the open cell foams should show a significant increase in mass (lower frequency) after soaking, whereas the closed cell foams should have essentially the same frequency on the inertial balance as their dry counterparts.

**Discussion:** Students may feel that this is a very roundabout way to answer a very easy question, and they are right-there are any number of ways (all easier) of finding out if certain foams absorb water without using an inertial balance. However, with a foam film less than one micron in thickness, and with perhaps just a single layer of water molecules adsorbed on to the exposed surfaces, instead of completely filling the pores, none of these other methods would be very practical.

Foam samples are pretty easy to get. Many types can be obtained from packing material and some of these are open cell and some are closed cell. Its not always easy to predict which structure a foam has, though, until you try soaking it. Typically, polystyrene foams (like that used for coffee cups) are closed cell.