ChE laboratory

THE UNSTRUCTURED STUDENT-DESIGNED RESEARCH TYPE OF LABORATORY EXPERIMENT

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THE STANDARD LABORATORY experiment in chemical engineering centers around a fixed piece of equipment, so the whole exercise is pretty much unchanged from year to year. But in these times when use of the personal computer is widespread, student reports of these experiments can easily be saved, merged, and passed on year after year, in ever-improved form—sometimes with little thought on the part of the preparer.

We would like to encourage the increased use of a different kind of exercise: the research type of laboratory experiment. Here, instead of showing the students the equipment to be used, and telling them what to do and how to write it up (eight sections in the report, starting with introduction, theory, *etc.*), tell them what you want to discover and let them choose their own way of doing it.

In this paper, this type of experiment is discussed and illustrated with one example. The main idea is as follows:

1. *Tell the team of students the question you want answered. Choose a question which can be answered in more than one way–something which is not in their textbooks and which will require that they develop their own analysis; something which was not asked last year or the year before.*
2. *The students should consider the alternatives and decide among themselves, after discussion, how to go about answering the question.*
3. *Once a decision is made, the students should present their plan to the instructor in order to see if equipment is available. At this point, they might be asked (gently, of course) if they would like to reconsider part of their plan.*
4. *The students are then to proceed with the experiment, to compare their results with the literature, and to write up their findings–not a big report, but one which is to the point.*

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EXAMPLE OF THE MINI-RESEARCH EXPERIMENT

The Question

Tell the student team that you want them to find ***h*** for melting ice, maybe because you have been asked to look into the feasibility of capturing antarctic icebergs for towing to parched lands for fresh water (make up a good story). More precisely, tell them to

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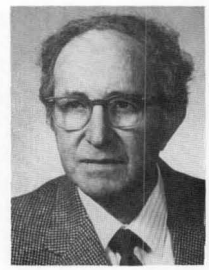

Octave Levenspiel is professor of chemical engineering at Oregon State University and is particularly interested in chemical reactors. He has written a number of books and was one of the earliest recipients of ASEE's Lectureship Award. He recently received an honorary doctorate from France for his "internationally outstanding scientific reputation."

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develop an expression for ***h*** for downfacing ice surfaces in quiescent water at different temperatures, to compare this with what's available in literature, and to recommend an expression for use.

Tell them that there is no experimental set-up for this purpose. However, say that the laboratory has vats, thermometers, scales, and calipers available, and that Professor X has a refrigerator with a freezer section in his office which he may allow them to use if asked nicely.

Tell the team to report back to you when they are ready and to tell you what they plan to do, what equipment they've assembled, and what they found in the literature. We suggest reserving about one-third of the marks for this presentation, to see if they really have thought the problem through. The whole experiment should take two laboratory periods.

One Way to Answer the Question

1. *Take half of a fast-food hamburger styrofoam container, fill it with water, and freeze it.*

2. *Place it face down in a vat of water, remove any air bubbles that are present, and then measure the thickness of the slab of ice with calipers at various times. That is all there is to the experiment itself.*

3. *The analysis needed to find **h** should not be difficult, but since it will not be found in any book they will have to develop it themselves. They should be able to do it. Don't help them. They should find that the slope of the thickness-time curve is all they need. Figure 1 shows the procedure, and Figure 2 shows what we found when we did this experiment.*

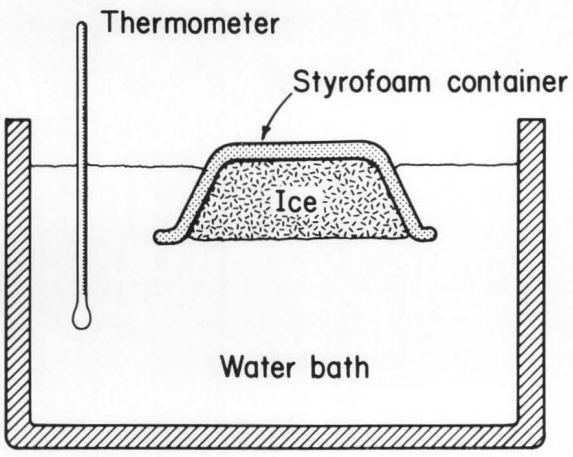

FIGURE 1. Experimental set-up.

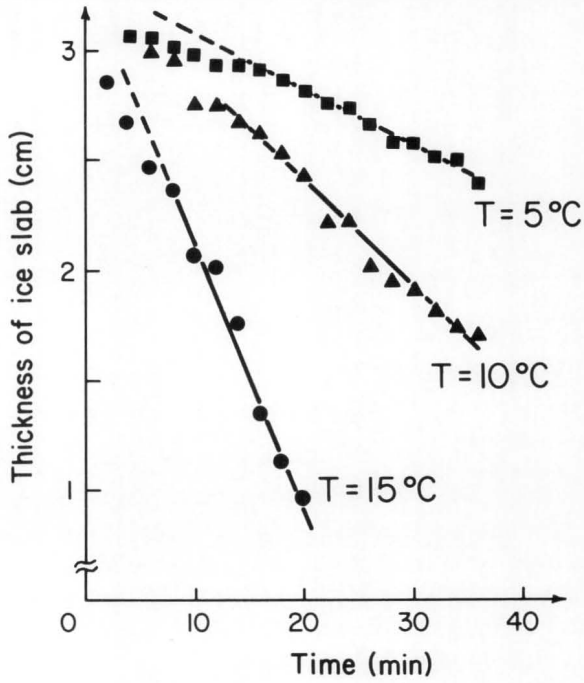

FIGURE 2. Typical findings for the thickness of ice layer vs. time for horizontal downfacing slabs of ice in water at various temperatures.

4. *In the analysis and discussion of their results, you may want to look for the following points:*

   - *Were the students able to find a literature correlation for **h** for cold downfacing plates in water? Did they check Perry?*
   - *Did it occur to them that **h** for melting ice may differ from **h** for ordinary flat surfaces, and did they search for this **h** value in the literature? Did they even consider this whole matter? (Extra points!)*
   - *Did they compare their values with the literature values and discuss the differences?*
   - *If they found a lower initial slope in Figure 2, as we did, did they try to explain why this was so? Or did they just least-square the whole set of data? (Poor.)*
   - *Did they at least plot the data and look at it? Or did they just generate a computer program which calculated **h** without human intervention or judgement? (Terrible!)*

5. *As for the experimental procedure:*

   - *Did they try to insulate the top and sides of their block of ice, somewhat as we did, or did they plunge the whole*

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*block under water, calculate **h** for the top and sides, and subtract to find **h** for the bottom. (Hopeless!)*

• Did they measure the thickness at more than one point, and did they plot all their points? Or did they just average all their readings?

*• Did they state that they tried to make their measurements with as little disturbance as possible (agitation will greatly increase **h**)? Did they discuss this and verify this with calculations?*

• Did they choose a large enough reservoir of water so that the water temperature did not change significantly during the experiment?

• Did they choose to weigh the ice? (Not such a good method because the edges of the slab melt faster than the center.)

*• In the weighing approach, if that was used, did they remove the slab for weighing? (Poor, because the extra agitation increases **h** drastically.) Or did they figure out how to weigh the slab in place? (Better.)*

Variations and Extensions

Many variations and extensions of this simple experiment can be used by the teacher throughout the years. For example:

- *Find **h** for vertical surfaces in water at different water temperatures.*
- *Find **h** for horizontal upfacing surfaces in water. (This is more difficult experimentally and is not recommended.)*
- *Repeat all the above for ice in air.*
- *Find the effect of fluid motion relative to the ice surface. For air, all one needs is a regular household fan and a pitot tube to study this.*

For the teacher, there is the inescapable temptation to ask the student to study a number of these factors, all in one experiment: upfacing, downfacing, vertical, effect of velocity and of ΔT, *etc.* Try to resist this as the lesson of this experiment can be learned just as well by studying one factor alone.

FINAL COMMENTS

What do students learn from this type of experiment?

- *They have to use their ingenuity and come up with their own way to answer the question.*
- *The best way of approaching the problem will not come to them right away, but only after they have thought up a number of schemes. This sort of exercise may give them an appreciation of the value of group discussion.*
- *They had to develop their own analysis and equations–no copying from books. This should give them a taste for doing original work.*
- *The laboratory course can be challenging, surprising, and interesting.*

We feel that there is a place for this type of laboratory experiment in the undergraduate program. □

AWARD LECTURE

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complished without the effort of several dedicated people. Professors R. L. Laurence and B. E. Ydstie helped with the initial proposal. Dr. Graham Sterling, Alan Ryan, Michael Hajjar, and the whole educational support committee from Analog Devices supported and assisted in our development of this laboratory. Their faith and vision were crucial to this project. Paul Grabin and Frank Pulaski were central to the setting up of the laboratory. We also acknowledge our undergraduate classes of 1985 and 1986. With their patience, assistance, and feedback, this major transformation was completed with a minimum of problems and an enhancement of the results. □