WATERLOO PROGRAM FOR HIGH SCHOOLS

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"WHAT'S THE DIFFERENCE between Chemistry and Chemical Engineering?" That's a question often asked by high school students (and teachers and guidance counselors) when they are seeking out a career with a chemistry bias. We have even been asked the question by students who have already chosen to study chemical engineering. The question is no doubt symptomatic of the lack of communication between schools and chemical engineering departments which, to my mind, has arisen because traditionally we could attract all the students we wished to enroll and we were definitely blasé about recruiting. Times have changed however, and now departments are worried about falling enrolments and the solid decline in the overall number of students wishing to study engineering in general and chemical engineering in particular. We must communicate with the schools and somehow we must get across to students and teachers the attractiveness of chemical engineering as a study discipline and career opportunity. In return we need to be educated in the changing patterns of high school curricula so that we are flexible and agile enough to adjust our courses to accommodate the needs and abilities of the new Freshmen. How can we open up this line of communication. No doubt there are many ways tried by many departments across North America and the world.

The Waterloo programme was inspired by my sabbatical experience at the University of Queensland, Australia, where I was called upon to take part in the Chemical Engineering High School Day Programme. This kind of educational programme is aimed at challenging small numbers of interested students to seriously learn about chemical engineering and consider the profession as a career opportunity. In our High School Programme we do not invite busload after busload of uninterested students to the campus and deliver a pep talk, a movie, and a donut in the hope of catching a few. Instead, we send out a limited number of invitations to those students who have a curiosity (be it mild or strong) about chemical engineering.

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On a typical High School Day we can entertain about 33 students from outside the university. To these we add 11 of our own volunteer first-year undergraduates, several professors and some graduate student demonstrators. Small groups consisting of three high school students and one undergraduate, tackle four experiments selected from a total offering of eleven. Each experiment takes about one hour to complete and the students have to do the work themselves, although Professors are close at hand to introduce the basic principles of the experiments and answer questions. The experiments have been developed by the Professors of the department and strongly reflect their own interests, thus illustrating the breadth of the Waterloo degree programme and the scope of Chemical Engineering.

EXPERIMENTS TO CHALLENGE HIGH SCHOOL STUDENTS

1. Expansion of the Kitchener waste treatment plant (P.L. Silveston).

The object of the experiment is to illustrate what goes into process design and how one sets about it. The experiment gives the student a brief introduction to pollution control, computers and computer-aided design. In the explanation of the experiment (we have a High School Programme Manual) the concept of a process system is explained by reference to the present Kitchener (Ontario) Sewage Treatment Plant. It is then shown how the plant can be simulated by use of a digital computer programme. At this stage the existing programme is handed over to the students and they are requested to find out:

- If the present plant is capable of handling 95% of the Biological Oxygen Demand and Suspended Solids expected in 1985;
- What will be the effect of adding cylindrical tanks in the settlers or rows of square tanks to the aerators;
- What will be the cost to expand the city of Kitchener Plant to meet the 95% target.

2. Enzyme Catalysis (J.M. Scharer)*.

Intended to illustrate the involvement of biochemical applications of chemical engineering, the student is asked to determine the Michaelis—Menten constant for a particular enzyme reaction and the maximum reaction rate for a given enzyme concentration. The reaction studied is

$$H_2O_2 + E \underset{k_2}{\overset{k_1}{\rightleftharpoons}} X \xrightarrow{k_3} H_2O + 1/2\ O_2 + E$$

in which E represents catalase, and X an enzyme—H_2O_2 complex. The catalase is synthesized by use of bacteria such as E. coli, B. subtilis, S. Faecalis and S. Aureus, while the evolution of oxygen indicates the presence of the enzyme. Having determined the two constants from the system the students are asked:

- To explain why most aerobic organisms can synthesize catalase;
- How a change in enzyme concentration would affect the experimental results.

3. Analog Computation in Chemical Engineering (K.S. Chang).

A short presentation is given to the students in which the general purpose analog computer is described as an orderly collection of amplifiers, potentiometers, resistors, capacities etc. The patch board is introduced and the students are asked to patch up the circuit to be used for generating the $4 \sin t$ and $4 \cos t$ functions. The signals are displayed on an oscilloscope and an X-Y recorder. Among other questions, the students are asked:

- Why the signals produced by the circuit are $4 \sin t$ and $4 \cos t$.
- To develop a circuit diagram which would generate $4 \sin(10t)$ and $4 \cos(10t)$.

*Gorber, D.M. and Scharer, J., CEE 5 (2), 141 (1971).

4. An Advanced Analog Computation Problem (T.Z. Fahidy).

Following on from experiment (3) the students investigate the oscillatory behaviour of the Van der Pol Equation. Having done this the students then go on to:

- Sketch the shape of the limit cycle at various potentiometer settings and describe the findings.
- Discuss the practical use (if any) of such an electronic circuit.

5. Elastomers—A Fourth State of Matter? (B.M.E. Van der Hoff).

After a general introduction to the concept of viscoelasticity and the chemistry of rubber, the students use an Instron tester to investigate the properties of natural rubber and polyvinylchloride softened by the addition of oil. For example an elastic band is elongated in the machine and the force acting on the band is measured against time at constant elongation. The sample is then heated and the experiment repeated. Hysteresis is measured in the form of a force-elongation curve. Typical questions asked of the students are:

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- What is the value of the initial modulus at small elongation and the modulus just before break?
- Why is the area of the hysteresis loop larger for the polyvinylchloride than for the natural rubber?
- Why does a sample not return to its original length?

6. Experiments Demonstrating some Industrial Electro-Chemical Processes (K. Enns).

The objects of this experiment are to demonstrate a) the electrowinning of copper, b) electroetching and c) brass electroplating. It is explained that all electrochemical processes found in extractive metallurgical, metals refining and finishing industries involve cells containing anodes and cathodes. The students find out by experimentation the amount of copper won per kilowatt hour and calculate the energy cost per ton of copper. Then by building a cell using graphite for the anode and a partially covered copper sheet for the cathode, electroetching is discovered, and the amount of copper removed during the etching process is calculated. Finally another cell using a sheet steel cathode and a brass anode is built to enable the plating of the steel. Cu-Zn-cyanide solution is used in this experiment. Typical of the questions posed to the students at the end of this session are:

- Why is brass plated from a Cu-Zn cyanide solution?
- Why not plate brass from a much less poisonous $CuSO_4$-$ZnSO_4$ solution?

7. Waste Water Renovation by Ion Exchange and Adsorption (K. Enns).

This experiment is designed to demonstrate the demineralization of water by cation/anion exchange and colour removal by adsorption. A "waste water" sample is renovated firstly by exchanging all positively charged ions in the waste by H^+ using a cation exchanger. After testing for metals by atomic absorption, the solution is treated with an anion exchanger and then activated charcoal. By now the original murky solution is quite clean. The students are asked typically:

- Is it economically feasible to use ion exchangers to treat concentrated solutions?
- Can you suggest a reason why ion exchangers generally prefer (are selective for) bivalent and trivalent species over univalent species?

8. Determination of Lead in Gasoline by Polarographic Analysis (K. Enns).

Here the students find out what is meant by the polarographic method of analysis and determine the concentration of lead in a typical sample of gasoline. The significance of the typical 'S' shaped polarogram is explained and the students firstly calibrate a machine by making up a known sample containing lead nitrate, and secondly, investigate the unknown gasoline sample previously extracted into an aqueous solution. Typical questions to round off the session are:

- In what form is lead usually present in gasoline?
- Why can't we carry out polarographic analysis directly on the gasoline sample?

9. Determination of a Chemical Reaction Rate Constant By Thermal Analysis (K. Enns).

By a simple thermal analysis method the reaction rate constant of the catalyzed reaction between n-butanol and phenyl isocyanate is determined. The principles of heat of reaction and reaction kinetics are explained, and the students after being presented with an adiabatic reactor (thermos flask), magnetic stirrer, thermometer and automatic delivery syringe are put to work. The students are asked typically:

- Is it reasonable to assume that the thermos flask approximates an adiabatic reaction?
- Is the rate constant data obtained in this way useful? Or is it just an academic exercise?

10. Measurement of Liquid Flow (J. D. Ford).

It is explained that an important problem frequently encountered by engineers is that of measuring the rate of flow of a liquid. Whether it is the flow of a river or the flow of water into a kitchen sink, a few simple principles enable such measurements to be accurately made. The students are asked to investigate the use of an orifice for measuring the flow from a large variable head tank. The students discover the relationship between mean velocity in the orifice and head of fluid and are finally asked the following:

- A one pound ball falls to the ground from a height of 2 ft. At what velocity does it hit the ground?
- Considering the above question is related to our graph of log (velocity) versus log (head), what is the theoretical value of the exponent n in the relationship (velocity) α (head)^n.

One student presented the enzyme experiment in the form of a series of cartoons of whale-like bugs gobbling up molecules and burping up the new ones all over the place.

11. Flow Through Porous Media (F.A.L. Dullien).

In part one of the experiment the students are set the task of measuring the permeability of a porous material consisting of a packed bed of glass beads or sand by establishing the relationship between pressure drop and flow rate across the sample. In the second part of the experiment the students observe the phenomenon of dispersion by use of a dye tracer injected into the flow of a packed bed. Typical questions are:

- What is the permeability of a non-porous substance?
- What factors may influence dispersion in porous media?

BULL SESSION

When each group has completed four experiments it must prepare a two minute verbal report on the final experiment. This report is presented at the closing session of the day. Half an hour is allotted for report preparation and the usual visual aid materials are provided for the assistance of the students. The reports have been remarkable for several reasons. For example, the students have been seen to respond amazingly well to the challenge and have quickly learned the principles on which the experiments are based. Secondly, it has been worth noting how interesting and often amusing the students have made their two-minute presentations. One student presented the enzyme experiment in the form of a series of cartoons of whale-like bugs gobbling up molecules and burping out new ones all over the place.

Each group having made one report, the whole programme of eleven experiments is covered and the final half hour is devoted to informal open discussion. It has been our experience that at this stage, most of the barrier of shyness has been broken down and everyone is anxious to get a word in. Our own undergraduates make a big contribution to the discussion. Marilyn was a very glamorous first-year chemical engineer in 1971 and she came to all our High School Days in flaming hot pants. When one High School threw out the question "What was it really like to be a chemical engineering student?", it was answered by Marilyn with a very eye-catching gesture and one word "Fabulous." Despite the fact that from then on, the Professors thought Marilyn was our best advertisement, she left us at the end of the year for academic reasons, a very sad departure for one and all.

EFFECTIVENESS OF THE PROGRAMME

So far the only method of measuring the effectiveness of the programme has been to ask the students for their opinions at the end of the day and to observe the reactions of both students and professors in the laboratory and in the culminating group discussion.

Nearly all the students responding to a questionnarie say the programme is suitable for Grades 12 and 13 High School Students but *not* for Grade 11. Most of the experiments were judged to be correct level of difficulty, although most problems were caused by the analog computer experiments and least difficulty was experienced in the waste water treatment and fluid flow experiments. Many students would have liked an extra day to do *all* the experiments and most felt they had learned a lot. Several students indicated that the opportunity for discussion was a very important factor contributing to the success of the programme. One fellow suggested we insert a *steak* dinner into the programme and another felt that it would be very beneficial for his school teachers. This last comment prompted us to invite the local School Teachers' Federation to include an evening of working in our laboratories on their Professional Development Programme. One such evening has now been held with enormous success. The format was the same for the teachers as it was for the students and the closing discussion provided a real opportunity for the exchange of ideas on education.

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It has been mentioned that first year undergraduates were also used in the programme. Their reaction has also been very positive and we are considering offering the programme to all the Freshmen during registration week. Its purpose here will be to break down the barriers between Faculty and students almost before they have time to be erected, and to motivate the students by providing them with a broad view of the department at the very beginning of their university career.

Does our programme answer the question "What is the difference etc. . . . .". At least it illustrates the breadth of interest of chemical engineering, which we believe is one of its most attractive features. It also provides a forum where all kinds of people by working together, find communicating questions, answers and ideas to be very easy.

The High School Programme Manual can be obtained by writing to Professor E. Rhodes, Chemical Engineering, University of Waterloo, Waterloo, Ontario, Canada. Please enclose a cheque for $2.00 to cover the printing and postage costs. The cheque should be made payable to Chemical Engineering, University of Waterloo. □