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An Interactive Multimedia Learning Environment for Chemical Engineering Education

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A Web-based interactive multimedia learning environment is presently under development for use in teaching basic chemical engineering concepts. When completed the system will allow students to learn at their own pace the theory and application of basic material and energy balances. The package will include interactive activities which will provide immediate feedback to the students on their progress. While the material is being primarily developed for use within the campus-based undergraduate environment, it has obvious applications to the continuing education of non-chemical engineers and technical staff. Because of the modular nature of the package, only a modest effort will be necessary to adapt the material to the specific needs of the non-traditional undergraduate student.

INTRODUCTION

Material and energy balance computations are typically the most frequent type of calculations all chemical engineers perform. These calculations may involve the estimation of a stream flow rate, a heating load or a process temperature. Material and energy balances are usually taught as the first chemical engineering subject in any undergraduate chemical engineering degree, as this subject provides the foundation upon which much of the later course content is built. Material and energy balances are also one of the key subjects which are taught to non-chemical engineers who seek to improve their knowledge and understanding of the profession.

With the widespread availability of information technology and multimedia the way in which the material is delivered may be completely reshaped to make best use of this technology. This paper describes a Web-based interactive multimedia learning environment which is presently being developed at The University of Melbourne. The developed system will allow the students to learn the material and to study the range of worked examples at their own pace. The environment being developed makes use of images and animations to allow the students to learn the basic concepts. The students will also have access to a very large library of problems with worked solutions from which to learn the problem-solving techniques. While the material is being primarily developed for use within the campus-based undergraduate environment, it has obvious applications to the continuing education of non-chemical engineers. Along with the course notes, this Web-based learning environment will facilitate distance learning.

CHEMICAL PROCESS ANALYSIS SYLLABUS

At The University of Melbourne, the study of material and energy balances is the first chemical engineering subject taken by the majority of chemical engineering undergraduate students. The content of this subject, which is known as Chemical Process Analysis (CPA), is summarised in Table 1.

The course begins with the students being introduced to the range of measurement units they may encounter in their professional careers. These include a selection of specialty units unique to particular industries. They also learn how to convert freely between different units. Since it is rare for any engineer to work only with pure materials, the students are taught how to describe the composition of mixtures. As composition may be described on a mass, molar or volume basis, they learn how to convert between these bases. Next the students are shown

Table 1: Content of the Chemical Process Analysis subject.

Units and Dimensions	Systems of units (eg SI, Imperial) Common units for quantities (eg temperature, pressure, energy) Unit conversions Equations and dimensional homogeneity
Characterisation of mixtures	Compositions and analysis of mixtures on molar, mass and volume bases Conversion between mass fractions and mole fractions
Block flow diagrams	Describing processes using block flow diagrams Types of unit operations and process flow streams
Material balances	General material balance equation for steady-state and unsteady-state processes Types of balances: total, component and elemental on mass and molar bases Balances around single and multiple unit operations Processes involving single and multiple simultaneous chemical reactions Solving processes incorporating recycle streams
Gases, liquids and vapours	The phase rule and PVT behaviour The critical point of pure substances and mixtures Characterising real gas behaviour by the compressibility factor Vapour pressure and its estimation Humidity systems and psychrometric charts Material balances involving real gases and humid systems
Heat capacity and enthalpy	The concepts of energy, specific heat and enthalpy Evaluating enthalpy changes and heats of reaction
Energy balances	General energy balance equation Solving energy balances in systems involving chemical reactions Balances involving heats of solution and dilution Simultaneous material and energy balances

how block flow diagrams may be used to represent processes. They are introduced to different unit operations, such as reactors, separators, distillation columns and mixers. They also learn about process flow streams, such as feed streams, bypasses, recycles, refluxes and purges.

With the above material in place, students are introduced to the concept of material balances. They learn how to set up and solve the balances around single unit operations and multiple operations. The complexity of the problems is increased by the presence of single and multiple simultaneous reactions. The students are shown how the appropriate use of recycle and purge streams can enhance the efficiency of some processes.

The next module, which may easily be omitted from the course if it is not required, considers the behaviour of gases, liquids and vapours. The phase rule is introduced and the Pressure-Volume-Temperature (PVT) behaviour of a typical material is discussed. Special emphasis is given to the significance of a substance's critical point. The non-ideal behaviour of real gases is discussed and a method using the compressibility factor to predict real gas behaviour is illustrated. Students are introduced to the joint concepts of vapour pressure and dew point and learn how to estimate the vapour pressure of any pure liquid. Material balance exercises involving real gas behaviour and humid (ie air-water vapour mixtures) systems are used to reinforce students' problem solving skills.

The concepts of energy, latent and sensible heats, specific heat capacity and enthalpy are introduced in the next unit. Students learn how to evaluate changes in enthalpy. Also developed is the ability to derive the heat of reaction for any reaction from standard heat of formation, or standard heat of combustion data. The students also learn how to use steam tables as well as tables of other physical property data.

Once these skills have been developed they are used to solve energy balances involving chemical reactions and/or changes in enthalpy arising from heats of solution. Finally the students are challenged by exercises requiring them to solve both material and energy balances simultaneously.

As well as teaching the students the material outlined above, every opportunity is taken to develop their problem-solving skills. No two problems encountered by the students are alike. They are required to think

Table 2: The ten modules of the Learning Environment.

1.	Dimensions and Units
2.	Compositions of Mixtures
3.	Block Flow Diagrams
4.	Material Balances
5.	Material Balances with Chemical Reactions
6.	Gases, Liquids and Vapours
7.	Heat Capacity and Enthalpy
8.	Energy Balances
9.	Energy Balances with Chemical Reactions
10.	Simultaneous Material and Energy Balances

Table 3: Physical property data available on-line.

1.	Saturated Water and Steam Properties
2.	Superheated Steam Properties
3.	Supercritical Steam Properties
4.	Water Density
5.	Properties of Refrigerants R12, R32, R123, R134a, R152a and R717 (ammonia)
6.	Methane, Ethane and Propane Gas Enthalpies
7.	Generalised Compressibility Factor Charts
8.	Vapour Pressure for Selected Compounds
9.	Psychrometric Charts for Selected Systems
10.	Properties of Dry Air at 101.325 kPa
11.	Enthalpy-Concentration Diagrams for Selected Aqueous Solutions
12.	Densities, Specific Heats, Thermal Conductivities and Viscosities of Selected Gases
13.	Periodic Table
14.	Critical point and Heat of Formation Data
15.	Antoine Vapour Pressure Equation Coefficient Data
16.	Unit Conversion

their way through a problem, developing a solution strategy which may not be unique. It is for this reason that students often find this subject particularly challenging. The exercises used in the subject have been developed over the last decade by the author so as to illustrate a range of unit operations, processes and industries.

While this subject has been developed as part of the undergraduate chemical engineering degree, its content is equally of use in the professional development of non-chemical engineer professionals. For example, this subject forms part of any bridging course designed to introduce chemists to chemical engineering. By tailoring the material appropriately, elements of this subject may also be used to enhance the training of non-professional technical staff. By selecting exercises appropriate to their particular industry, this training would be of benefit. As an example, the author is presently preparing material of relevance to the Australian dairy industry for a training programme to be sponsored by that industry.

DEVELOPMENT OF THE INTERACTIVE LEARNING ENVIRONMENT

Based upon the teaching material developed and experience gained over a decade of teaching the Chemical Process Analysis subject, the author is presently developing a Web-based interactive multimedia learning environment. The package will make use of the full potential of the Web environment and will include interactive activities, audio and video clips as well as animations. At this stage it is envisaged that the package will be implemented in two forms. The package will be loaded on a Web-server at The University of Melbourne. Access will be allowed to this resource over the Internet only to those students enrolled in a course. The second implementation involves distribution of the package on a CD-ROM. Both packages will be accessed using a Web-browser. The package presently under development is designed for use with Netscape Navigator Version 3 or equivalent software.

Upon entering the system's Home page, the students will be able to choose to study one of the ten modules or topics which are summarised in Table 2. Depending upon the student's individual requirements, certain material may be omitted or studied in a slightly different order.

The Home page for each module or topic will contain a list of educational outcomes expected to be achieved as a result of completing the topic. The Home pages will also contain lists of submodules or subtopics (see Figure 1). Each sub-module will contain written material, photos, diagrams and, where appropriate, animations and audio and video clips as well as interactive activities. As well as presenting the material the students must learn, each sub-module will also contain a series of examples along with their worked solutions.

Each module will also contain up to forty exercises which may be attempted by the student. Once students have completed an exercise, they will be able to access the numerical answer and also a thoroughly worked solution to the problem. Again, where appropriate, animations and audio clips will be used to assist in explaining the worked solution.

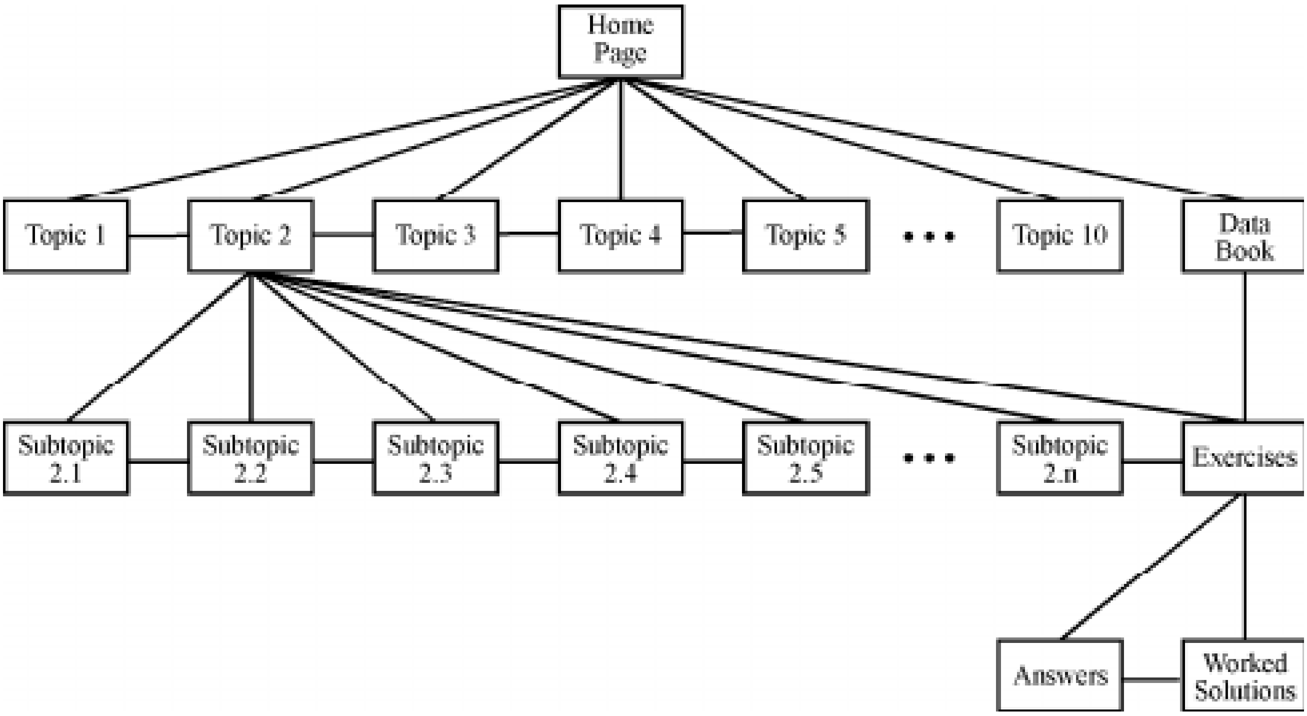

Figure 1: Structure of the Web pages.

As part of the package a handbook of the physical properties of a range of materials has been compiled by the author. This will be made available in printed form and as a series of Web pages. Table 3 summarises the data currently available in this data book. Note that additional data may be incorporated into this data book as required to support the study of problems relating to specific industries or locations.

INTERACTIVE ELEMENTS OF THE PACKAGE

One of the innovative features of the package is that each module will contain at least one interactive element that is designed to engage the student. The nature of the particular activity will depend upon the material. By way of example, consider two of the elements planned for the Gases, Liquids and Vapours module.

Many important concepts are introduced in this module by considering the PVT behaviour of a substance. When trying to explain this behaviour, reference is usually made to complicated diagrams of the type shown in Figure 2. The difficulty students encounter in understanding these diagrams arises because we are trying to represent complex three-dimensional behaviour using two-dimensional media. The interactive element will involve showing the students a three-dimensional representation of the PVT surface of a substance. Using a mouse, three screen

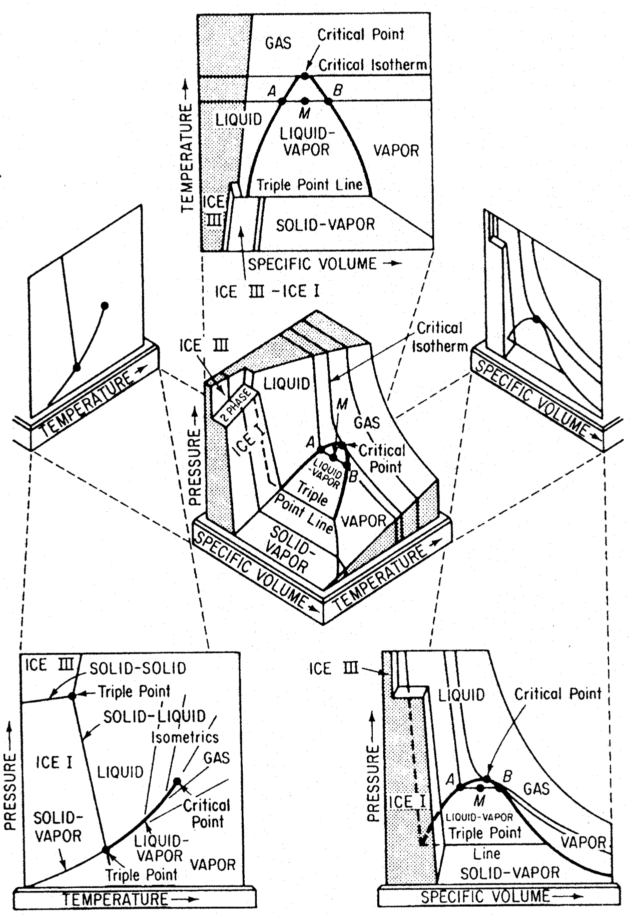

Figure 2: A series of diagrams used to represent the pressure-volume-temperature behaviour of the water substance (taken from Himmelblau [1]).

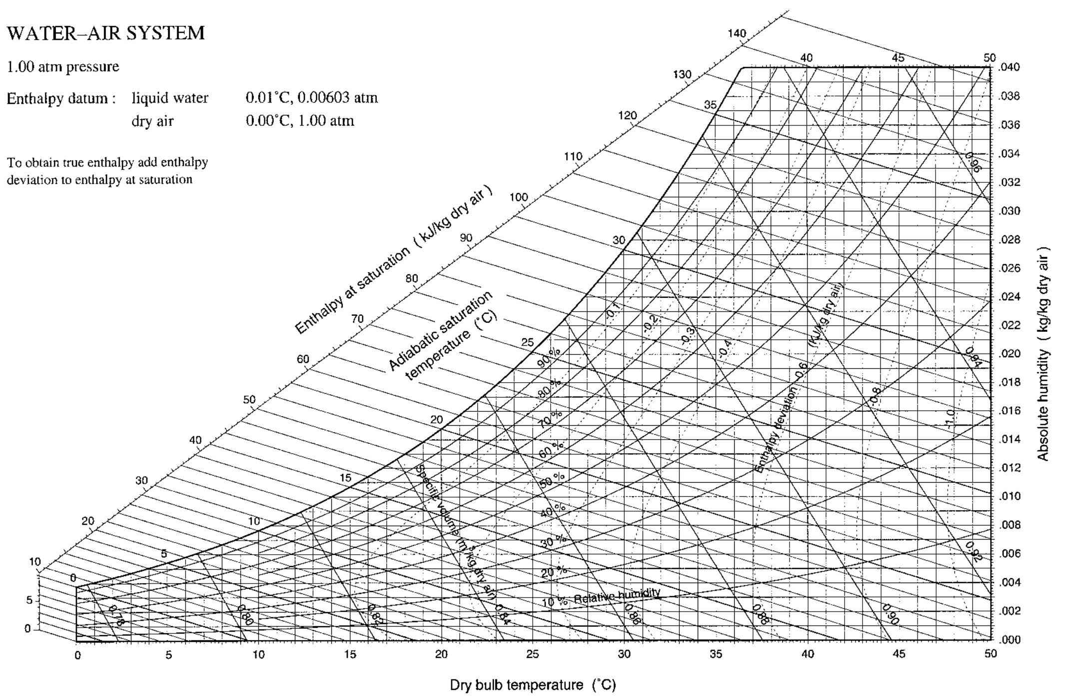

Figure 3: A typical psychrometric chart showing the properties of humid air (taken from Shallcross [2]).

controls for roll, pitch and yaw, and two controls for magnification, students will be able to investigate the surface by viewing it from any angle. For example, they will be able to see that when viewed correctly the gas-liquid two phase envelope collapses to a single curve, the vaporisation line. Similarly, they will learn to recognise the unique features of the critical point and the triple point.

The second interactive element of the module will assist in showing students how to use a psychrometric chart correctly. These complex-looking charts are used to present physical property data of mixtures of a condensing vapour with a non-condensing gas. The most important application is to humid air. A typical psychrometric chart is illustrated in Figure 3. In the first part of the activity the students will use the mouse to move a cursor around the chart on the screen. As the cursor moves, values for the various chart parameters will be continuously updated. Then, for a series of random points on a chart, students will be asked to use the charts to determine values for the chart parameters. Should a value the students enter be incorrect, an explanation of the correct value will be given.

CONCLUDING REMARKS

The package described above will not replace all lectures and tutorial classes in the Chemical Process Analysis subject, but will instead be used to complement the material delivered by the teaching staff. All students, whether campus-based undergraduates or not, will use the material together with specially-prepared course notes.

The package will be implemented in stages with the first two modules scheduled to be introduced in the teaching semester starting in late July 1999. Following feedback from students through surveys and focus group discussions, it is planned to implement the remaining modules over the following two years.

Because of the modular nature of the package, it will require only a modest effort to adapt most of the material to the specific needs of non-undergraduate students who are not based on campus. By the use of e-mail between the distant students and the academic, these students will be able to study and learn the course material with only limited attendance on campus. These students, many of whom will be engaged in full time employment, will be able to regulate their own pace of study, devoting as much or as little time to their studies week to week as their other commitments permit.

REFERENCES

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2. Shallcross D.C., *Handbook of Psychrometric Charts*. London: Chapman and Hall (1997).

BIOGRAPHY

Dr David C. Shallcross is a Senior Lecturer in the Department of Chemical Engineering at The University of Melbourne. After completing his PhD in Chemical Engineering at The University of Melbourne in 1986, he joined the Department of Chemical Engineering at the University of California, Davis as a post-doctoral fellow. He then spent two years with the Petroleum Engineering Department at Stanford University before joining The University of Melbourne in 1990.

His present research activities include ion exchange processes, enhanced oil recovery and psychrometry for non-conventional systems. His first book, *Handbook of Psychrometric Charts*, was published in 1997. He is currently Series Editor for a series of books being developed to introduce engineering problems into the secondary school class room.

Dr Shallcross is a member of the editorial board of the *Journal of Process Mechanical Engineering*. He was the Chairman of the Technical Programme Committee for the *1996 International Solvent Extraction Conference*, ISEC'96. Dr Shallcross is presently a member of the Organising Committee Executive of the *2001 World Chemical Engineering Congress,* as well as being Chair of the Congress Programme Committee. Dr Shallcross has won several awards for teaching excellence, the most recent being the *2000 Universitas Teaching Fellowship.*