dean of the Graduate Division at Stanford put it this way[4]. ". . . the program does not replace the teacher but can hopefully free the teacher from routine exposition, and give time for doing the things that only the teacher can do," teaching students to think for themselves.

Programmed instruction can help you give your students a better education; I hope the information I have presented here will encourage you to try programs in your classroom.

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ChE book reviews

Engineering Thermodynamics
M. W. Zemansky and H. C. Van Ness,
McGraw-Hill (1966).

Professors Zemansky and Van Ness have written a text on thermodynamics with the "common core" course in mind. As such, the text represents a combination of and selection from the material offered in the conventional beginning courses in thermodynamics in the chemical and mechanical engineering curricula. In following this path, the authors had to judge that certain topics included in these portions of the typical chemical engineering program would either be deleted, or discussed in other courses. A similar statement, but with different topics in mind, applies equally well to the typical mechanical engineering program.

Viewed against the background of the typical chemical engineering program, there are certain features which make this book different. First, there are a number of applications discussed in the text which are not presently included in this part, if indeed in any part, of the chemical engineering program. In this category are such topics as "bars in tension and compression" (chap. 2), "work in straining a bar" (chap. 3), "work in changing the polarization of a dielectric in a parallel plate capacitor" (chap. 3) "work in changing the magnetization of a magnetic solid" (chap. 3) and some of those discussed in "applications" (chap. 14).

Secondly, a number of the classical experiments are discussed. This includes the determination of "J" factor mechanical equivalent of heat (chap. 4), determination of $(\partial U/\partial P)_T$ of a gas (chap. 5), reversible change of volume of a gas (chap. 7), and the measurement of latent heat of vaporization (chap. 11) to cite a few. By the discussion of experimental methods and the inclusion of experimental data in some figures, I believe the authors are attempting to impress on the student the physical significance of the quantities which are later used in the solution of problems. This is a part of education which is apparently being phased out in the fundamental sciences and mathematics.

Looking at the other side of the coin, the missing material, the chemical engineer will note that "fugacity" is not mentioned. The theorem of correspondence states is introduced and used only in one problem—11.1. Also, only mixtures of ideal gases are considered. Nothing is included on heats of solution, or properties of real mixtures, and very little on thermochemistry. Also, the development and use of the humidity chart and calculation of dewpoints and bubble-points using Raoult's law—topics common to practically all initial chemical engineering courses—are not considered.

Undoubtedly, many mechanical engineers reviewing this book would find that some of their favorite topics have been omitted or treated with brevity and, conversely, some topics have been covered more extensively than is usually the case.

The book is well written and the level of mathematics—some partial differential equations are used—such that the second year, or certainly the first semester third year, student should have no trouble. If a student cannot learn the the principles of thermodynamics from this book, it should certainly not be due to the mathematics used. Each chapter is concluded with a number of problems which appear to offer the user a reasonable choice; i.e. some difficult ones and some not so difficult. Apparently, the problems were selected so a slide rule is the only type of computer necessary.

The usage of this book by chemical engineers depends upon how our programs develop over the next few years. If we move to more common core courses—and thermodynamics is one of the prime areas where such movement is possible—this book "Engineering Thermodynamics," should be seriously considered for use.

James H. Weber
University of Nebraska

ChE problems for teachers

The following solutions to thermodynamics problems published in CEE Spring quarter, pp. 95-96, 1968, were prepared by Professors R. K. Irey and J. H. Pohl at the University of Florida. We continue to solicit questions on subjects of general engineering or scientific interest to be presented in this department.

1\. (a) Consider u as $u(s,x_i)$,

$$du = \left(\frac{\partial u}{\partial s}\right)_{\vec{x}_i} ds + \sum_{j=1}^{N}\left(\frac{\partial u}{\partial \vec{x}_j}\right)_{s,\vec{x}_i}\cdot d\vec{x}_j$$

By analogy with

$$du = Tds - \sum_{j=1}^{N} \vec{F}_j \cdot d\vec{x}_j$$

$$\left(\frac{\partial u}{\partial s}\right)_{\vec{x}_i} = T \quad \text{and} \quad \left(\frac{\partial u}{\partial \vec{x}_j}\right)_{s,\vec{x}_i} = -F_j \text{ , (N+1 eqs.)}$$

(b) The Maxwell relations are

$$\left(\frac{\partial T}{\partial \vec{x}_j}\right)_{s,\vec{x}_i} = -\left(\frac{\partial \vec{F}_j}{\partial s}\right)_{\vec{x}_j \vec{x}_i}$$

$$\left(\frac{\partial \vec{F}_i}{\partial \vec{x}_j}\right)_{s,\vec{x}_i} = \left(\frac{\partial \vec{F}_j}{\partial x_i}\right)_{s,\vec{x}_j}$$

(c) i) N+1, for a total of 4(N+1) eqs.

ii) $\frac{3N(N+1)}{2}$, for a total of 2N(N+1) eqs.

iii) Take the derivative of ψq and substitute du into the equation

$$d\psi q = -sdT - \sum_{j=1}^{N} \vec{F}_j \cdot d\vec{x}_j \ .$$

Consider the total derivative of $\psi q = \psi q(T, x_i)$, $i = 1, \cdots, N$.

$$d\psi q = \left(\frac{\partial \psi_q}{\partial T}\right)_{\vec{x}_i} dT + \sum_{j=1}^{N}\left(\frac{\partial \psi_q}{\partial \vec{x}_j}\right)_{T,\vec{x}_i}\cdot d\vec{x}_j \ .$$

thus, $\left(\frac{\partial \psi_q}{\partial T}\right)_{\vec{x}_i} = -s$ and $\left(\frac{\partial \psi_q}{\partial \vec{x}_j}\right)_{T,\vec{x}_i} = -\vec{F}_j$.

Since

$$\frac{\partial^2 \psi_q}{\partial T \partial \vec{x}_j} = \frac{\partial^2 \psi_q}{\partial \vec{x}_j \partial T}$$

we have

$$\left(\frac{\partial \vec{F}_j}{\partial T}\right)_{\vec{x}_j,\vec{x}_i} = \left(\frac{\partial s}{\partial \vec{x}_j}\right)_{T,\vec{x}_i}$$

2\. (a) Consider $s = s(T, \vec{x}_i)$ and $s = s(T, \vec{F}_i)$.
Then

$$ds = \left(\frac{\partial s}{\partial T}\right)_{\vec{x}_i} dT + \sum_{j=1}^{N}\left(\frac{\partial s}{\partial \vec{x}_j}\right)_{T,\vec{x}_i}\cdot d\vec{x}_j \qquad \text{(i)}$$

and

$$ds = \left(\frac{\partial s}{\partial T}\right)_{\vec{F}_i} dT + \sum_{j=1}^{N}\left(\frac{\partial s}{\partial \vec{F}_j}\right)_{T,\vec{F}_i}\cdot d\vec{F}_j \qquad \text{(ii)}$$

$$C_{\vec{F}_i} = \left(\frac{\partial \psi_u}{\partial T}\right)_{\vec{F}_i} = T\left(\frac{\partial s}{\partial T}\right)_{\vec{F}_i} \quad \text{and}$$

$$C_{\vec{x}_i} = \left(\frac{\partial u}{\partial T}\right)_{\vec{x}_i} = T\left(\frac{\partial s}{\partial T}\right)_{\vec{x}_i} \qquad \text{(iii)}$$

Use the Maxwell relations,

$$\left(\frac{\partial s}{\partial \vec{x}_j}\right) = \left(\frac{\partial \vec{F}_j}{\partial T}\right)_{\vec{x}_i,\vec{x}_j} \quad \text{AND} \quad \left(\frac{\partial s}{\partial \vec{F}_j}\right)_{T,\vec{F}_i} = -\left(\frac{\partial \vec{x}_j}{\partial T}\right)_{\vec{F}_i,\vec{F}_j}$$

and the relations (iii) in (i) and (ii). Then set the right of (ii) equal to the right of (i).

$$C_{\vec{F}_i} - C_{\vec{x}_i} = T\left\{\sum_{j=1}^{N}\left(\frac{\partial \vec{F}_j}{\partial T}\right)_{\vec{x}_i,\vec{x}_j}\cdot\frac{d\vec{x}_j}{dT} + \sum_{j=1}^{N}\left(\frac{\partial \vec{x}_j}{\partial T}\right)_{\vec{F}_i,\vec{F}_j}\cdot\frac{d\vec{F}_j}{dT}\right\}$$

If $\vec{F}_j$ is constant,

$$C_{\vec{F}_i} - C_{\vec{x}_i} = T\sum_{j=1}^{N}\left(\frac{\partial \vec{F}_j}{\partial T}\right)_{\vec{x}_i,\vec{x}_j}\cdot\left(\frac{\partial \vec{x}_j}{\partial T}\right)_{\vec{F}_i,\vec{F}_j}$$

If $\vec{x}_j$ is constant, the result is the same.

(b) From (i) above

$$ds = \left(\frac{C_{\vec{x}_i}}{T}\right) dT + \sum_{j=1}^{N}\left(\frac{\partial \vec{F}_j}{\partial T}\right)_{\vec{x}_i,\vec{x}_j}\cdot d\vec{x}_j$$

From the exactness of this equation

$$\left(\frac{\partial C_{\vec{x}_i}}{\partial \vec{x}_j}\right)_{T,\vec{x}_i} = T\left(\frac{\partial^2 \vec{F}_j}{\partial T^2}\right)_{\vec{x}_i,\vec{x}_j}$$

Hold T constant in this equation and integrate with respect to all $\vec{x}_j$. The lower limit is a reference value, $C_{\vec{x}_j^*}$. The upper limit is variable.

$$C_{\vec{x}_j} - C_{\vec{x}_j}^{*} = T\sum_{j=1}^{N}\int_{\vec{x}_j^*}^{\vec{x}_j}\left(\frac{\partial^2 \vec{F}_j}{\partial T^2}\right)_{\vec{x}_i,\vec{x}_j}\cdot d\vec{x}_j$$