The One-Page Thermodynamics Course

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ABSTRACT:

While the title may be a little misleading, for those who have experienced it, this one page may have saved their academic careers. This paper illustrates how to take a complex subject and make it less overwhelming.

Some years ago, several students who were overwhelmed with thermodynamics came in search of help in understanding this often difficult course. Understand that this was a one-semester course that covered the lion's share of a standard thermodynamics text. The breadth of the material included everything in a two-semester thermodynamics course except combustion, availability, and compressible flows. The shear volume of the material covered in just 40 lessons was enough to make the hearty faint, not to mention the majority of the students. Realizing that a problem existed and after some study into the use of mind-maps, an attempt to tie thermodynamics together on a single sheet of paper using this method seemed to be a worthy challenge.

The first attempt at mapping the course revealed a need to carefully choose the starting point; both in the course and on the paper. The purpose of mapping is to prepare a visual that grows logically to assist in understanding the material. Topics should be distinct, allowing for expansion for closer study. It is imperative that the process not be confusing and that the result accurately depict the course material presented.

The beauty of this system is that it is transferable to other courses. It also works when developing a curriculum for a discipline specific program such as mechanical or electrical engineering. The difficulty is that the developer must be acutely aware of the subject matter and its pitfalls.

This paper summarizes the method and demonstrates its applicability to Thermodynamics. General applicability follows as the method is developed and fine-tuned. Real-time demonstrations of mapping is more complex and requires the ability to erase.

INTRODUCTION:

Covering 80% of the average classical Thermodynamics course in 40 lessons requires students to assimilate a large quantity of material in a relatively short period. Considering that the book is over 950 pages in 16 chapters[1] with the appropriate appendices, just the size of the book is formidable. The fact that the material is difficult for most because it is considered esoteric, further complicates the learning process. In many cases, learning is accomplished by hours of *travail*, with no "real insight" provided by the teachers.

The success of learning by doing is not in question, rather, the concern is what can be done to assist the learner so that hard work leads to understanding in-depth. The goal is to replace drudgery with focused effort that results in comprehension and understanding in-lieu-of knowledge based learning as outlined in Bloom's Taxonomy. This higher order learning is the result that all teachers strive to achieve, for it is this level of mastery that satisfies the teachers desire to teach.

It is not obvious that a simple communication via the mind-map, outline, or any other similar method would be so exotic or so helpful. If this were the case, many would have used it in the past, especially in courses of similar complexity to thermodynamics. Several attempts to use this procedure met with varying degrees of success, but in general, students found that mapping satisfied their need to "visualize" the course.

HOW TO DO IT:

First, do not worry that this method will trivialize the course. The amount of detail is up to the person describing the material. It really depends on what is to be conveyed -- breadth or depth of the subject. Depth can be covered on subsequent maps designed for singular purposes. Linking of these maps allows for coverage without clutter or confusion. In their book, *Creative Problem Solving*[2], Edward and Monika Lumsdaine illustrate the use of the mind-map for writers in organizing material when overcoming writers block or when greater understanding of material is essential. Tied to Bloom's Taxonomy, this method of visualization assists in higher order learning. This is especially important in the engineering fields where knowledge based learning must be overcome; where synthesis becomes the mark of the true engineer.

Synthesis, the interrelation of material, is difficult for many students. The question often asked, but seldom answered is; "Why are we doing this?". The real questions being asked are; "How is everything related and how are solutions formulated?" Questions that can be answered quickly and visually since many learn visually.

Looking at life, a subject not easily trivialized, is a prime example of all of the above. A terribly complex thing to sort through, life can be mapped using three words.

BORN **LIVED** **DIED**

Not that complex, but with a great deal of information missing. We all realize that this example is extreme, but is it? To a small child experiencing the death of a grand-parent, this model might satisfy their quest for understanding of this terrible time in their life. It might show that death is a natural part of the process called life. Perhaps the "lived" portion needs to be bigger and with some illustration of the things accomplished in a lifetime. This would show the supremacy of that time and assuage the concerns of the child. Most adults tend toward expounding on their lives, since "born" was out of their control, as will be "died". So it is human nature to look at "lived" and focus on that.

The process can go on as "lived" expanded. Many new professors have spent much of their life in school, so even "lived" is easy for them. As we age, "lived" becomes more complex, with families, work, grand-children, death of parents, and so on. Thus, the level of explanation needs to be tailored to the situation -- breadth or depth.

DO IT:

The method is applicable to individual courses, programs, sequences, and comparison of courses with similar mathematical and/or physical basis. It can be expanded to show the place of engineering in the world. It can be applied to any system that needs to be portrayed in a manner that non-users can understand. It even applies to life and how we interact with people.

Figure 1 is an attempt to show Thermodynamics to a linear thinker. It is ordered and linear as we presented the course, but for that person, it was the key to understanding that the subject was not that complex, and that there was a reason we covered all that “stuff”. The original was written quickly and was less neat: in fact, it was also less linear. A friend who uses this method in programming tells his students to be messy: neatness means it was done after-the-fact, as this was.

Equilibrium (Quasi)?? Processes, States
Properties (u,h,s,p,T,v,C_p,C_v)

Ideal gases variable / constant specific heat

Open and Closed Systems

Conservation of Mass
Open and Closed Systems

The First Law of Thermodynamics
Open and Closed Systems

The Second Law
Open and Closed Systems
Irreversibility, Availability, Exergy
?Carnot?

Isentropic Relations

Properties of Steam and the Vapor Dome

Cycles

Air
- Brayton $r_p = P_2/P_1$; $r_{bw} = w_c/w_t$ (Turbojet = 1) (Propshaft < 1)
- Otto $r = v_1/v_2 = v_4/v_3$
- Diesel $r = v_1/v_2$ $r_c = v_3/v_2$

Rankine Steam, Mollier Charts or Steam tables
Reheat, Regeneration, Superheat
Vapor Compression Refrigeration Cycle (VCRC)
Heat Pumps, Refrigerators, Air Conditioning
SUVA, Freon Chart

Air Water Vapor Mixtures

Combustion -- Reaction Chemistry
Compressible Flows??

Figure 1. Linear Representation of the Thermodynamics Course

Figure 2 is non-linear and centers around several real devices. It presents thermodynamics in a manner normally taught in basic mind-mapping classes. Mastering the starting point(s) is critical and the most difficult part of the application. The starting points here are real devices because they are used as the starting point in the thermodynamics course where the mapping was used. The starting point can vary depending on how the information is to be used, the needs of the person(s) for whom the map is made, and the desired outcome. The multiple devices were selected because they represent the open and closed systems upon which the physical models are developed.

SUMMARY:

The one-page thermodynamics course is not meant to supplant the text or good teaching. It is a tool of some value to students who have trouble visualizing the application of the material. It has been used in other courses to summarize the way forward, develop course objectives, and summarize the course at the end of the term. The method is applicable any time the relationship between current course material and its application in the course or the profession is required. It works! Try it for yourself.

REFERENCES:

1. Cengel, Y. A. and Boles, M. A., *Thermodynamics: An Engineering Approach*, Second Edition, McGraw-Hill, Inc., 1994.

2. Lumsdaine, E. and Lumsdaine, M., *Creative Problem Solving: Thinking Skills for a Changing World*, McGraw-Hill, Inc., 1995.

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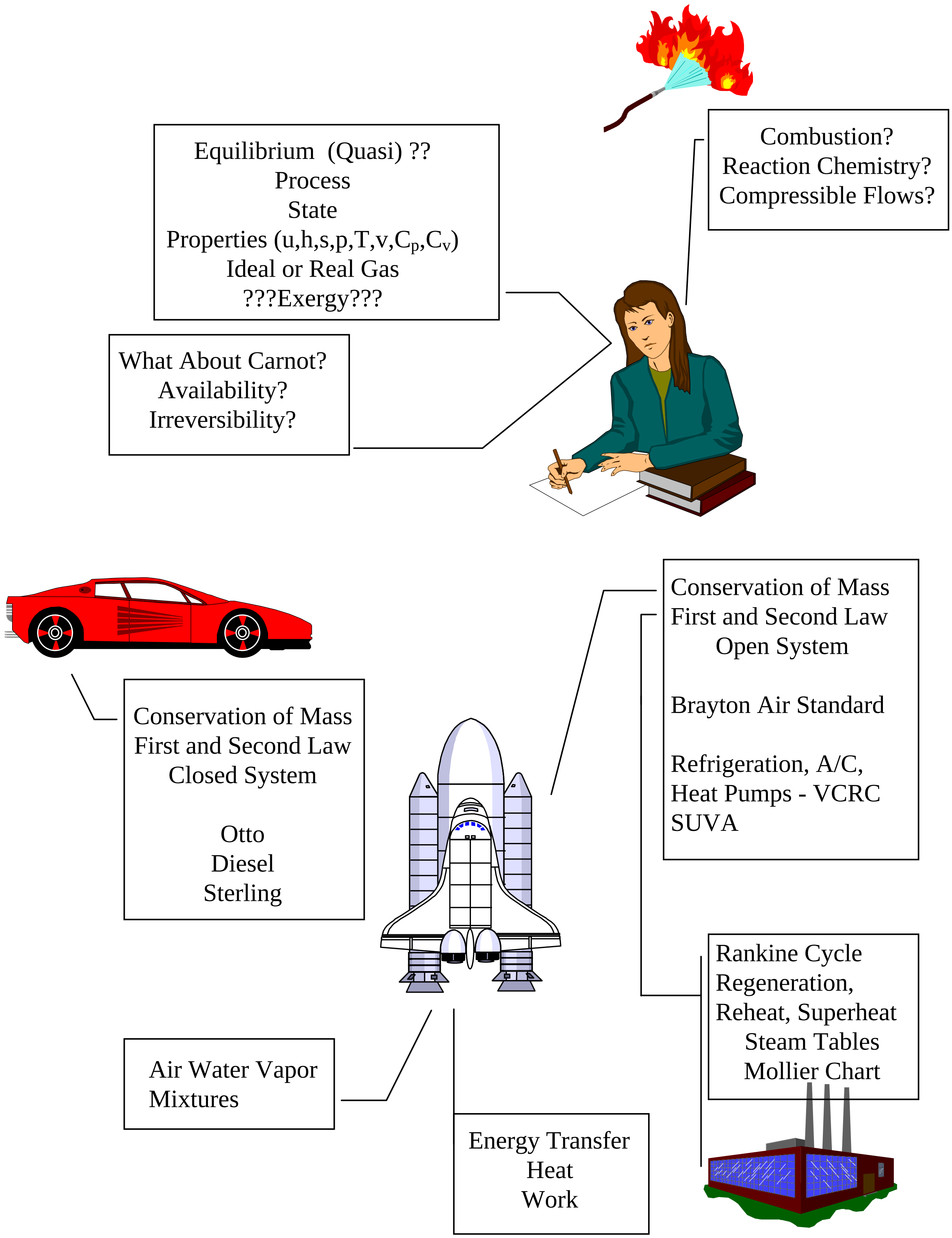

Figure 2. Non-Linear, Device Oriented Thermodynamics Map