Thermodynamics Primer – A Concise Media-Enhanced Thermodynamics Textbook

A. Description of the Project: In an effort to enhance student learning in the engineering department's **Thermal Fluid Sciences I** course, I have written the first edition of a **Media-Enhanced Thermodynamics textbook** and have introduced this textbook in EGR 250 at the beginning of the Spring 2019 semester.

1. **Background:** Since starting at Union eight years ago, I have been teaching the **Thermal-Fluid-Sciences I** course to engineering students in both the mechanical and electrical engineering concentrations. This course combines topics from Thermodynamics, Fluid Dynamics, and Heat Transfer, exposing students to three significant sub-fields of engineering. For general engineering programs, such as Union's (which constitute the minority), it is typical to teach these topics in a combined course sequence, while most discipline-specific engineering programs (the majority) teach one or more courses on each of the three topics.

   Covering the large number of topics included in this course has proven to be a challenge to students in the past. In order to enhance student learning, I have in recent years flipped the class by developing a set of 20+ online Blackboard LMS lessons, each consisting of roughly 45 minutes of short screencasts interspersed with quiz questions. Further, in-line with recent "best practices/trends" in Thermodynamics education, I have re-organized the course content such that both the 1st and the 2nd law of thermodynamics are introduced at the beginning of the course. While this move to re-structure the content of Thermodynamics courses has been reflected in several recently published Thermodynamics textbooks, none of the existing integrated Thermal-Fluid Sciences textbooks currently reflect this change in content organization.

2. **Project Details:** In order to,

   I. address the limited availability of textbooks that combine Thermodynamics, Heat Transfer, and Fluid Dynamics

   II. include best practices in Thermodynamics education, and

III. build on the success of the flipped-classroom lessons

I have written a concise "media-enhanced" thermodynamics textbook for students in EGR 250 at Union. The textbook has been typeset in LaTeX and the current – first edition – of this **Thermodynamics Primer** was completed during January of 2019 and has replaced the traditional text as the primary thermodynamics textbook in EGR 250. The **Thermodynamics Primer** condenses the essential material in thermodynamics to 76 pages and supplements/enhances the written content by **directly linking to screencasts** which provide example problems and added explanations. An excerpt from "Chapter 3: The 2nd Law of Thermodynamics" is shown in Figure 1 on the following page. The symbols highlighted in yellow (highlights 1-3) are links to screencasts that I have recorded that are hosted on YouTube. The video symbol appears throughout the book, linking to the more than 200 screencasts I have developed for EGR 250. Highlighted in red (highlights 4-5) are references to the MoodleRooms/Blackboard LMS Lesson and Quiz which are relevant to that particular textbook material. Using the PDF version of the **Thermodynamics Primer**, students thus have immediate access to in-depth explanations and example problems that supplement the written content by selecting the links, which then open the media content. Figure 2 shows an example of the screencast related to "Highlight 1" in Figure 1. (I would be happy to share the PDF of the Thermodynamics Primer with the committee.)

B. How the Project differs from current teaching ideas and methods in the field:

Flipped classroom approaches and the use of screencasts have received increasing attention throughout the engineering disciplines in recent years. One of the leading contributors in this area has been the University of Colorado, where the "LearnChemE" educational resources have been developed. As part of this effort, J.R. Elliot and C.T. Lira have developed a website supplement (http://www.learncheme.com/screencasts/thermodynamics/textbook-elliottlira-2nd) to their "Introductory Chemical Engineering Thermodynamics" textbook, which provides students with screencasts that support the textbook content. The **Thermodynamics Primer** developed for EGR 250 at Union takes the next steps towards developing a fully integrated media enhanced thermodynamics

3 Chapter 3: The 2^{nd} Law of Thermodynamics

Note: Some of the illustrations follow closely the discussions by Henning Struchtrup in "Thermodynamics and Energy Conversion."

3.1 Introduction

We have all experienced the 2^{nd} Law of thermodynamics in real life. For example, when a hot cup of coffee is placed in a room, it will eventually cool down to room temperature (room temperature in turn will increase slightly). This observation cannot be explained solely with the 1^{st} law of thermodynamics, since the conservation of energy $\Delta E = Q - W$ would be satisfied for 3 possible scenarios:

1. The coffee cools down and the room heats up until an equilibrium temperature is reached.
2. Both coffee and room maintain their temperatures
3. The coffee gets hotter and the room cools down

1

While all 3 scenarios can satisfy the 1^{st} Law, we know that the first scenario will take place – systems tend towards equilibrium. Thus, the 1^{st} **Law is insufficient** to fully describe the system behavior and another physical law must exist – the 2^{nd} **Law of Thermodynamics**. This is further illustrated by **Part 1 of this Example**. 2

3.2 Entropy and the 2^{nd} Law

3.2.1 Isolated Systems[15] 4

3

From experience we know that **physical systems tend towards equilibrium** – specifically, any **isolated** physical process will eventually reach a steady-state at which the system state stops changing. Mathematically/physically we can thus attribute some "property" to our system which is constant at equilibrium and has derivatives pointing towards equilibrium elsewhere.

While it might be easiest to think of this steady-state as a "valley" – such as a ball rolling down a hill and eventually coming to rest as shown in Figure 1(a), thermodynamics has traditionally defined this property as having a 'maximum' value at the equilibrium state as shown in the Figure 1(b). If we call this property S, we can make the following statements:

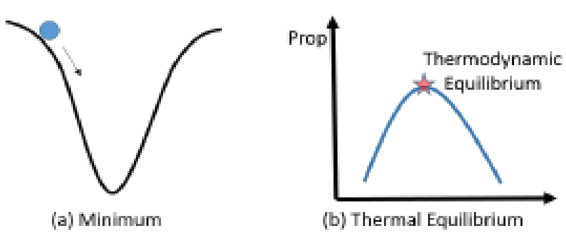

Figure 1: Thermal Equilibrium

[15] see MoodleRooms Quiz 7 Question 1

5

39

Figure 1: Excerpt from Chapter 3 of "Thermodynamcis Primer"

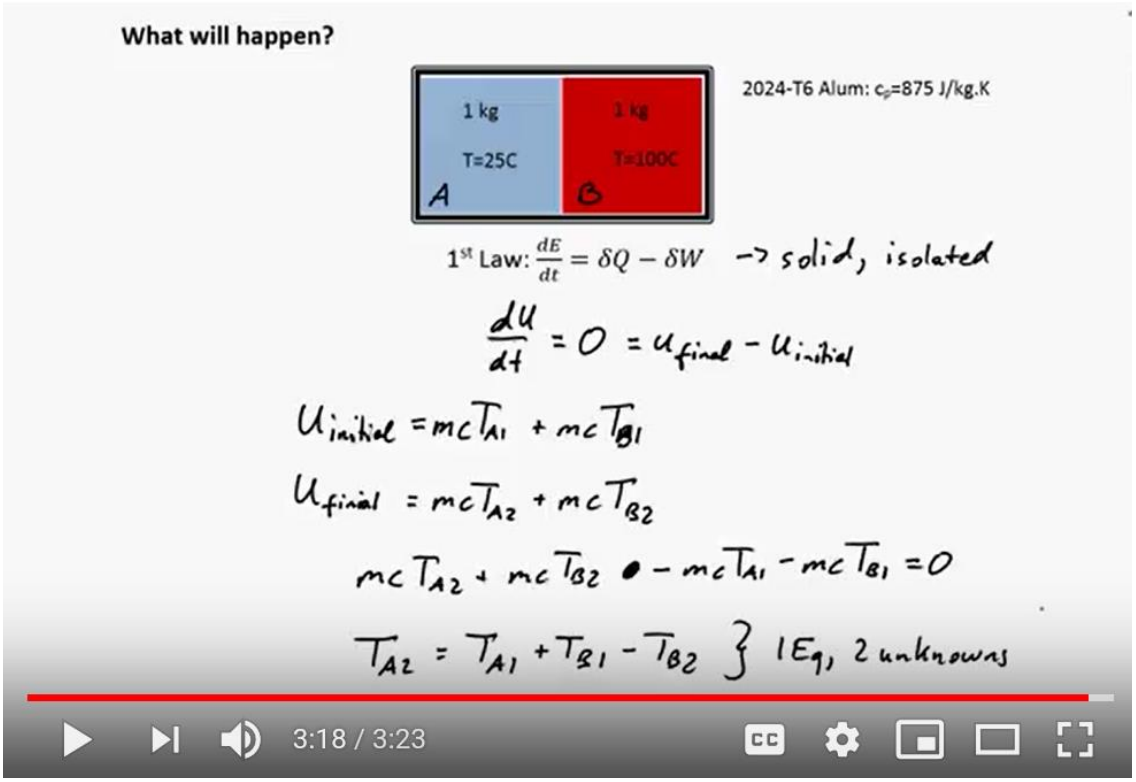

Figure 2:Snapshot of the "The 1st Law of Thermodynamics is Insufficient" Screencast

textbook where the screencasts are an integral component of the textbook. Further, writing this textbook with the audience of Union students in mind allows for the natural integration of faith and learning, as shown by the following excerpt from the **Thermodynamics Primer's** introduction.

While it is energy that sustains us from a physical perspective, as Christians we believe that the underlying source for our sustenance is God, our Creator and Sustainer. In Hebrews 1:3a (NLT) the Bible states: (also Psalm 104 and Col. 1:16-17)

"The Son radiates God's own glory and expresses the very character of God, and he sustains everything by the mighty power of his command."

In this light, being entrusted by God as stewards of His creation (see Gen 2:15), should serve as extra motivation for us as Christians to become wise users of energy as a resource entrusted to us by God.

Figure 3: Excerpt from Chapter 1 of the Thermodynamics Primer

C. Your opinion of the success of the Project and how it can be improved:

1. **Success of the Project:** The introduction of the media-enhanced textbook has been the current focus of my efforts to enhance student learning in EGR 250. Students seem to appreciate the organized and condensed nature of the Thermodynamics Primer and its integration with online content and Blackboard LMS lessons. Compared to past years, students seem to be gaining a clearer understanding of the course material. EGR 250 is a difficult course that has required me to provide students with re-take exam opportunities to make-up for poor test performances in the past. Having just concluded the 8-week coverage of Thermodynamics for the spring 2019 course, I am excited to report that students this year showed improved performance on all thermodynamics exams – on average one letter grade better than during the spring 2017 and 2018 semesters as shown in Table 1, below. However, it must be noted that the sample size – 10, 11, and 7 students, respectively – is small and it remains to be seen if this positive trend continues.

Table 1: EGR 250 Average Exam Performance

	Spring 2017	**Spring 2018**	**Spring 2019**
Thermo Exam 1	70/100	76/100	84/100
Thermo Exam 2	64/100	71/100	83/100
Thermo Final	74/100	71/100	82/100

2. **Future Improvements:** Writing the Thermodynamics Primer as a textbook for EGR 250 is a work in progress, and space allows for only a brief glimpse at planned improvements for this project. Most of the screencasts currently used as media-enhancements were originally recorded as supplements to the original textbook for the course. Having completed the first edition of the text for this spring semester, it is my goal to re-work the screencasts to develop them specifically for the Thermodynamics Primer. I further plan to extend the text to also cover the Fluid Dynamics and Heat Transfer topics in EGR 250. Given the media-enhanced focus and the goal to more strongly couple faith and the discipline throughout the text, I do not plan to publish yet another printed thermodynamics text, but rather to make the media-enhanced PDF version of the text freely available.