Development and Implementation of a Study Tool for Cumulative Problem Solving in Thermodynamics

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Abstract

After noticing that some students in Thermodynamics classes have difficulty identifying the appropriate problem characteristics to solve thermodynamics problems, a tool was designed to help students clarify problem information. The problem set-up guide helps students identify: (i) problem type (i.e., closed or open system), (ii) processes that were present (e.g., adiabatic, isochoric), (iii) known properties (e.g., specific volume, temperature), and (iv) assumptions. The guide also allowed the students to record and organize additional properties found for each state. The tool was initially given during a quiz for Thermodynamics I (spring 2018), and its effectiveness was assessed using a survey. The guide was then presented to students in Thermodynamics II (fall 2018) to help in preparation for and during an examination. In general, student perception of the tool was positive; they expressed interest in using the tool both as a study guide and as an organizational instrument during tests.

Keywords

Thermodynamics, study aid

Introduction

Enhancing student learning in thermodynamic courses using various methods has been studied extensively[1-3]. Common approaches include incorporating computer technology[4-6] and adding experimental learning aids[7]. In this work, a thermodynamic study tool was developed to help students identify the type of first law thermodynamic problem and organize the given information and property determinations to develop their solution procedure. This was developed after recognizing that the testing structure for Thermodynamics in the Mechanical Engineering department at Mississippi State University often separated closed systems and open systems into separate tests until the final exam when both systems can be present on one exam. While this breaks the material into smaller amounts for the students to study, students often do not have to practice differentiating the two systems to perform well on the tests. It was noticed that for the final exam students had difficulty distinguishing the systems. This trend was also noticed in Thermodynamics II when the first law of thermodynamics was reviewed and tested during the first test. Another difficulty the authors saw was that students would miss information given in the problem statement or forget to find necessary properties. The authors developed a study tool that asked a series of questions to help students identify the type of first law problem as well as organize assumptions, properties, and processes that are either given in the problem or need to be found in order to solve the problem. The primary objective of this work was to aid in student comprehension and performance, with qualitative survey responses providing only preliminary results (presented here) to indicate the potential of the study tool. Quantitative data

and further investigation is planned for future work during the spring 2019 semester based off of the positive preliminary results.

Thermodynamic Study Tool

The thermodynamic set-up guide as shown in Figures 1 and 2 is a two page document with the first page being a flowchart outlining a series of questions to help the student identify the type of thermodynamic problem that they are solving. The first page also lists the first law of thermodynamics equation derived for a closed system, for a steady state open system, and for a transient open system. The continuity equation is also listed for the transient open system. Page two of the tool lists common assumptions in thermodynamic problems with a place to note whether those assumptions are applicable. Below the assumptions is a place for students to record known or found properties for multiple states. Types of processes are also listed at the bottom of the page so that students can circle applicable processes for the problem they are attempting to solve.

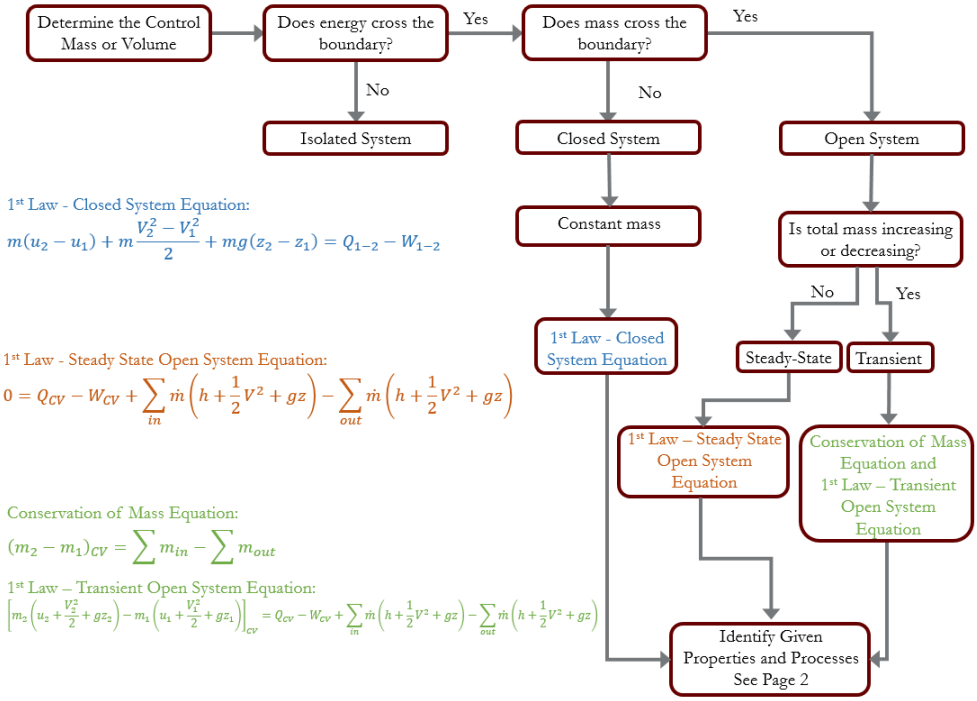
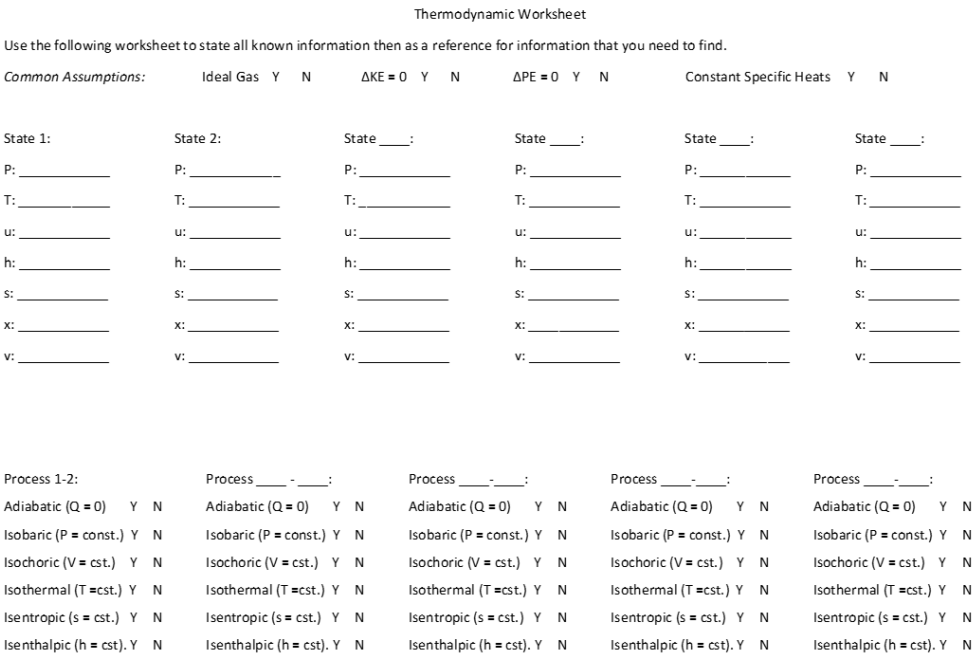


Figure 1. Page one of the thermodynamic study tool.



Thermodynamic Worksheet

Use the following worksheet to state all known information then as a reference for information that you need to find.

Common Assumptions: Ideal Gas Y N ΔKE = 0 Y N ΔPE = 0 Y N Constant Specific Heats Y N

State 1:	State 2:	State ____:	State ____:	State ____:	State ____:
P: _____	P: _____	P: _____	P: _____	P: _____	P: _____
T: _____	T: _____	T: _____	T: _____	T: _____	T: _____
u: _____	u: _____	u: _____	u: _____	u: _____	u: _____
h: _____	h: _____	h: _____	h: _____	h: _____	h: _____
s: _____	s: _____	s: _____	s: _____	s: _____	s: _____
x: _____	x: _____	x: _____	x: _____	x: _____	x: _____
v: _____	v: _____	v: _____	v: _____	v: _____	v: _____

Process 1-2:	Process ____ - ____:	Process ____-____:	Process ____-____:	Process ____-____:
Adiabatic (Q = 0) Y N	Adiabatic (Q = 0) Y N	Adiabatic (Q = 0) Y N	Adiabatic (Q = 0) Y N	Adiabatic (Q = 0) Y N
Isobaric (P = const.) Y N	Isobaric (P = const.) Y N	Isobaric (P = const.) Y N	Isobaric (P = const.) Y N	Isobaric (P = const.) Y N
Isochoric (V = cst.) Y N	Isochoric (V = cst.) Y N	Isochoric (V = cst.) Y N	Isochoric (V = cst.) Y N	Isochoric (V = cst.) Y N
Isothermal (T =cst.) Y N	Isothermal (T =cst.) Y N	Isothermal (T =cst.) Y N	Isothermal (T =cst.) Y N	Isothermal (T =cst.) Y N
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Figure 2. Page 2 of the thermodynamic study tool.

Implementation

The study tool was given to approximately half of a Thermodynamics I class in the spring of 2018 for use with an in-class quiz. The students were then asked to complete the quiz and answer survey questions. The tool was then made available to the students to study for the final exam as well as made available during the final exam. The survey questions that were asked of the Thermodynamics 1 class are shown in Table 1.

Table 1. Thermodynamics I survey questions.

Question	Question Statement
Q1	Complete problem 4.115 text. Express your answer, for Q, in a magnitude associated with units of kJ, but do not include units in your response. Enter your exact answer to the ones place. Remember to include negative signs if relevant.
Q2	Did you get the problem assistant handout?
Q3	Did you use the problem assistant handout (if you received it)?
Q4	How long did it take you to solve the problem?
Q5	Did the problem assistant handout help you to organize the problem/understand procedure for solving first law thermo problems?
Q6	Do you plan to use the problem assistant handout to study for the final exam?
Q7	Do you want to have problem assistant handouts available on final exam?

In the fall of 2018, the set-up guide was given to a Thermodynamics II class to prepare for the first exam, which includes a review of the first law of thermodynamics. It was also given for the students to use during the exam. The students were asked to complete a survey after they had taken the exam. They were also given the opportunity to make comments or suggest improvements about the study tool. The survey questions are shown below in Table 2.

Table 2. Thermodynamics II survey questions.

Question	Question Statement
Q1	Did you use the thermodynamic flowchart/worksheet to study for Test 1?
Q2	If you did not use the flowchart/worksheet do you plan to do so in the future?
Q3	If you used the flowchart/worksheet to study, how helpful was it in preparing for Test 1?
Q4	Did you use the flowchart/worksheet during the test?
Q5	If you used the flowchart/worksheet during the test, how helpful was it in identifying the type of problem?
Q6	If you used the flowchart/worksheet during the test, how helpful was it in organizing the given information?
Q7	If you used the flowchart/worksheet during the test, how helpful was it in organizing information that you had to find?
Q8	If you used the flowchart/worksheet during the test, how helpful was it in solving the problem?
Q9	Would you like the flowchart/worksheet available for preparing for future tests?
Q10	Would you like the flowchart/worksheet available during future tests?

Survey Results

For the quiz given in Thermodynamics I, only a small percentage of the class found the correct answer so it was difficult to draw any conclusions about whether the tool was helpful in determining the correct answer or not. 84 students took the quiz with 41 students receiving the handout. Of the 41 students that received the study tool, 27 students used it to help them solve the problem. 18 of those students felt that the study tool helped them organize the problem or understand the solution procedure. Although decreasing completion time was not intended by the authors as a primary objective, the students who used the study tool and completed the problem reported taking less time to solve the problem on average than the students who did not use the tool, as shown in Figure 3. However, the percentage of students who could not complete the quiz in the time allotted increased when using the study tool. After examining these results, a new objective for the study has been identified, and further investigation about whether the study tool helps shorten problem completion time is planned for the spring 2019 semester.

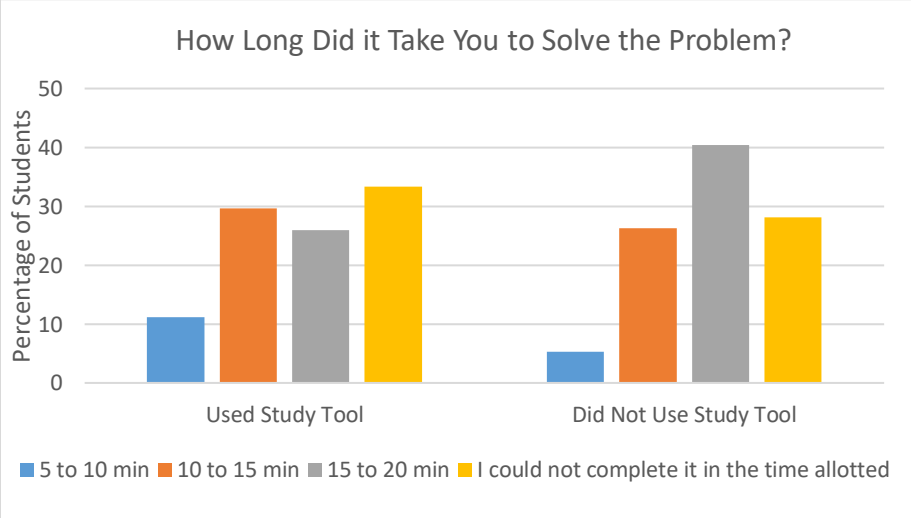

Figure 3. Time it took students to solve the quiz problem.

Figure 4 shows the student responses to questions 2, 6, and 7 in the Thermodynamics I class. Regardless of whether the students received the set-up guide for the quiz, the majority of students planned to use the guide to study for the final exam and wanted it available for use during the final exam.

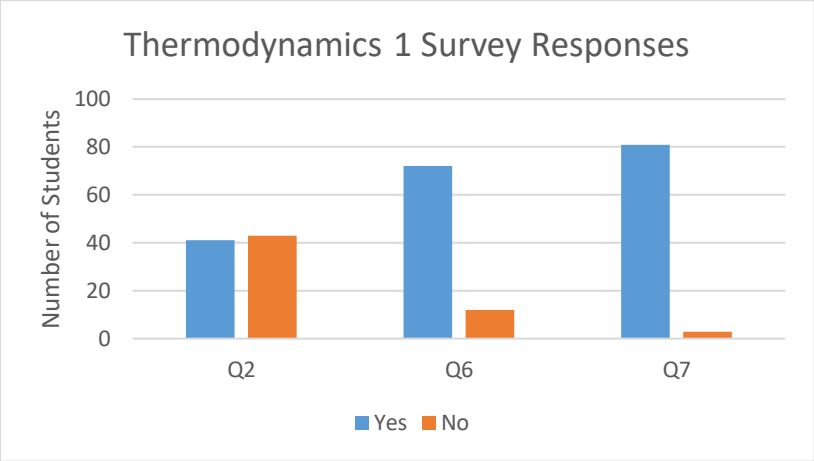

Figure 4. Survey responses for questions 2, 6, and 7 for Thermodynamics I.

For Thermodynamics II, 26 of 71 students used the study aid to prepare for their first exam. Of those students, 25 said that they planned to use the tool in the future with one student not answering the question. The majority of the students who used the set-up guide to study said that it was helpful for preparing for the first exam (question 3). 18 of the 46 students who did not use the study tool to prepare for the test stated that they planned to use it in the future. 20 students used the set-up guide during the test; 13 of which had used it for preparing for the test. Most of the students felt that it was helpful organizing the given information in the problem (question 6), identifying the type of problem (question 5), solving the problem (question 8), and organizing the information that they had to find (question 7). These questions were evaluated using the Likert scale where 5 represented strongly agree and 1 representing strongly disagree. The highest average corresponded to question 6 (3.95), and the lowest average corresponded to question 7 (3.75). The average Likert responses for questions 3, and 5 – 8 are presented in Figure 5. The mode for all of the questions presented was the agree response.

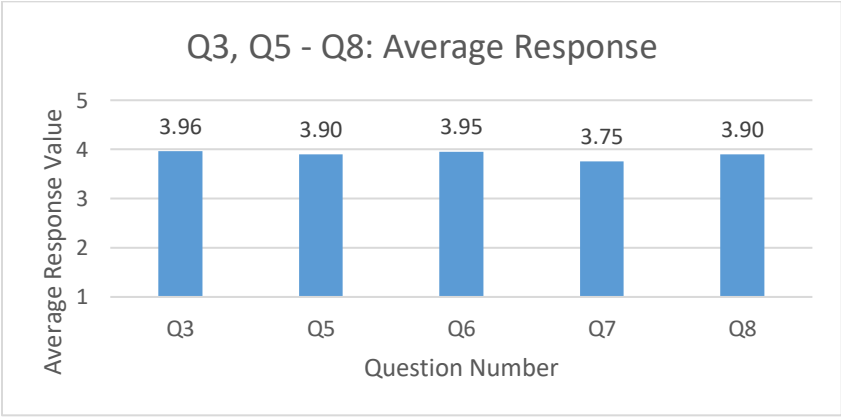

Figure 5. Average Likert responses to questions 3 and 5 – 8.

Figure 6 shows that the majority of students in the Thermodynamics II class wanted the study tool available to prepare for future exams and during exams. Most of the written feedback given by the students was positive with some students stating concern that it would take longer to solve the problem using the study tool. Some of the students stated that their unfamiliarity with the study tool caused their time concern during the test. Another possible reason that students felt that time constraints were an issue with the tool during the test was that they would have to write information twice, once on the worksheet and then repeat that information on the test. In the future, the students can be given a worksheet for each problem on the test and if they use the worksheet then that will be graded for their test.

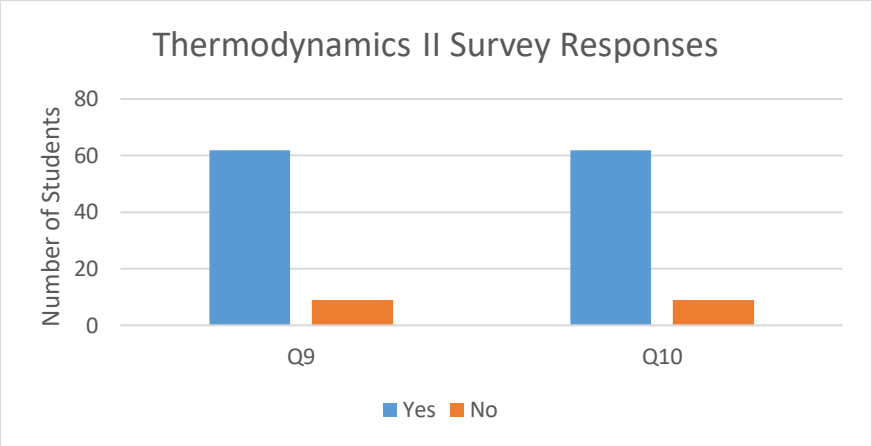

Figure 6. Survey responses for questions 9 and 10 for Thermodynamics II.

Conclusions and Future Work

This paper presents a thermodynamic study tool designed to help students identify first law thermodynamic problem types as well as organize problem information, both given and found. While the study tool was not used by all students in the surveyed Thermodynamics I and II classes, the majority of feedback received was positive, indicating that some students found it helpful in at least some part of solving thermodynamic problems. Most students in both courses wanted the study tool available to them in order to prepare for exams as well as having the tool available to them during the exam. The authors plan to offer this study tool to students in future Thermodynamics classes as an additional aid. The authors plan to let students use the study tool in a Thermodynamics I class during the spring 2019 semester and compare their test results to another section of Thermodynamics I class that did not have access to the study tool to see if the study tool affects student performance. The format of the Thermodynamics I class has also been updated to include examinations with both open and closed system types on the same test prior to the cumulative final exam.

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