AC 2007-1722: ASSESSING THE RELATIONSHIP BETWEEN STUDENT ENGAGEMENT AND PERFORMANCE IN THERMODYNAMICS COURSES - PHASE I

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Assessing the Relationship Between Student Engagement and Performance in Thermodynamics – Phase 1

I. Introduction

Many of the thermo-fluids courses, and in particular Thermodynamics, are often taught with traditional teaching methods and textbooks. Introductory thermodynamics, in particular, is prone to elicit a negative impression from students who perceive the subject as too abstract. Even though the topics covered often have a real-world basis they are generally simplified and only offer a superficial impression of industry applications. The result is that many students have excessive difficulty with the subject and do not develop a "feel" for the topic or the associated real-world equipment[1,2]. Unfortunately the relevant educational research and literature is clear in the belief that greater student impact, understanding, and retention can only be achieved with greater student engagement[3]. In part, this engagement must come by presenting material and problems in the context of concrete applications or requirements and by connecting problems to the student's pre-existing knowledge. As part of a NSF Course, Curriculum, and Laboratory Improvement (CCLI) grant new educational material is being developed for the thermodynamics curriculum. This material is being offered under the name "Engaged in Thermodynamics". It is intended to combine real world scenarios, problems, and solutions in a way that promotes greater student engagement in the learning process. Through increased student engagement it is believed that higher student performance will result.

A case history details how a particular problem was actually solved, while a case problem presents an open-ended problem with the solution still unknown. In contrast, a case study presents an ideal or benchmark solution[4]. The material being proposed will take elements of each of these and add to it sufficient background information for the student to form a connection to the real-world environment. Each Engineering Scenario will be based on a real-world engineering facility in a form similar to, but expanded from, a case study. The scenario will include extensive background information on the facility, including items such as images and schematics of key components, narratives on facility history and purpose, and information on the engineering personnel responsible for the facility. For each scenario a series of problems will be developed. These problems will take one of three possible forms: skill-based problems, short design problems, and large design problems. While each scenario will center around one engineering facility, the topics covered by these problems will span several chapters or topics in a traditional textbook. This will allow problems to be used from a single scenario throughout the semester. A greater sense of cohesion and continuity in the material will therefore be possible. By basing these problems on a specific and well-researched facility the instructor's knowledge is fortified and the students' interest can be exploited to encourage greater engagement.

It is evident that this material could be used in a variety of ways. At the most basic level Scenario problems could be used to replace traditional homework problems. While at the other end of the spectrum they could provide the basis for a range of active and problem based learning experiences in the classroom. Clearly there will be different formats of use and different resulting levels of engagement. In order to evaluate the validity of the Scenario concept

and the various delivery formats a series of data collection and assessment procedures are being planned and implemented. These procedures include textbook focus groups, a combination of pre- and post-course concept inventories, periodic engagement surveys, and a concluding focus group "debriefing" with the students. This information is being correlated with performance on examinations and will be compared to control case data from previous years.
An educational consultant outside the department is being utilized in order to track data by individual students through the Institutional Review Board.

For this initial phase of research three questions have been focused on; 1) What is the most appropriate and engaging format for the Scenario material?, 2) How can performance and engagement be measured for the grant purposes? and 3) Does merely changing the homework format impact engagement or performance?. This paper will present the assessment methodology used including the definitions and evaluations of engagement which have been developed with student input and feedback. The paper will then detail the results from assessment during a first semester thermodynamics course and previous control courses. Results which generate a picture of a "typical" thermodynamics course at this institution will be described. It is expected that these results can be equally applied to improve student engagement in engineering courses other than thermodynamics and toward addressing pedagogical aspects of thermodynamics instruction not directly related to engagement.

II. Assessment of Existing Textbook Formats

Before any material was generated as part of this grant a study was conducted with the Spring 2006 Applied Thermodynamics students concerning delivery formats. Existing thermodynamics textbooks which use different formats were given to the students at the end of the semester to examine and compare. The intent was to obtain information on how students use their textbooks and which features they prefer. This is guiding the development format of the Scenario material. The texts selected had different characteristics in terms of inclusion of real world aspects, overall format, and linkage to electronic material. Due to the ongoing nature of the research (i.e. the focus group will be repeated this year) and the small sample size (only 9 students) the authors are refraining from naming the exact texts at this time. Instead they have been described in general terms of format and incorporation of real world aspects, where real world aspects implies a discussion about a specific application and could be viewed analogously to the "real world aspects" accreditation criterion.

Four different texts were selected as described in Table 1. In this case Textbook A was the textbook which the students had used throughout the semester. Copies of the texts were distributed to the focus group students for review on a rotational basis approximately two weeks before the focus group discussion. During the focus group students were given a written survey ranking different aspects of general textbook use and comparisons between the different texts. A focus group discussion was then held between the grant assessment coordinator, the course instructor, and the students concerning the different texts.

Table 1: Selection of textbook used in the student focus group

Textbook A	Traditionally formatted text	Periodic real world comments and examples
Textbook B	Traditionally formatted text	Greater use of real world specifics
Textbook C	Graphically formatted text	Numerous real world aspects included
Textbook D	Largely online text	Limited real world comments

With regard to what kind of material would inspire you to do unassigned reading or research using the textbook, students gave responses showing a strong desire for real world aspects:

> "Actual systems, problems and solutions in real life applications."
> "Real life systems – maybe some design problems."
> "Real life industry example problems."
> "Design problem, problems that involve student everyday life."
> "More information about systems that are not as well researched, such as Stirling engines, also more info on the actual machines, so we could recognize components when we see them."
> "Great color pictures with detailed descriptions of the pictures, more example pictures, design problems, example problems."

In combination with the focus group questions several other aspects emerged. More than just real world aspects students were looking for specifics; specific up-to-date values and process descriptions. While students appreciated full color photographs of actual equipment the advantage did not outweigh the basics such as a high number of quality homework problems. Interestingly the students also showed high concern for the formatting of tables and appendices. Perhaps the most interesting factor to emerge from the focus group discussion was the student's impression of online textbook material. Online material was not well appreciated. Concerns about access to the material during lecture and in areas not Internet enabled were high. Unless specifically assigned, many students admitted they did not use the available online student material or instructional aids. With regard to a text they preferred a paper text, solidly constructed, and with information complete enough so that it could be used in other courses or for the Fundamentals of Engineering exam. This feedback flows somewhat contrary to existing opinions and trends and needs to be reexamined with the next group of students.

III. Measuring Student Performance and Engagement

To determine any changes in student performance in the thermodynamics course appropriate measures of assessment are required. Grades on course material such as examinations are commonly used to provide a grade assessment. However, for the purposes of these studies a more in-depth analysis was required. In addition to course grades a thermodynamics concept inventory is being used. Concept inventories are intended to measure understanding of the core concepts which are expected either as prerequisites or outcomes of a course. They can also be used to analyze common student pre- and misconceptions. Perhaps the best known concept inventory is the Force Concepts Inventory (FCI)[5]. The Thermodynamics Concept Inventory (TCI) is relatively new and is under continued development through the Foundation Coalition[6].

To maintain consistency with the previous control groups, version 5.1 of the TCI is being used (Table A4). The concept inventory was administered on the first and last day of the semester so that an indication of change could be determined. Since this grant is specifically concerned with student interest and real world content, a few brief questions were added to the start of each concept inventory (Table A3). These asked the students to initially rate on a five point scale their expected interest, the expected real world content, and how much they expected to work on the course material. When the concept inventory was given at the end of the semester the students were asked to rate what their actual interest, the real world content, and what their work level was.

Evaluating student engagement is a much more difficult undertaking which starts with defining "engagement". One of the best known and most commonly used measures of student engagement is the National Survey of Student Engagement (NSSE)[7]. Combining the NSEE, the Faculty Survey of Student Engagement (FSSE), and ABEC EC2000 the Center for the Advancement of Scholarship on Engineering Education (CASEE) has developed the "Survey Measuring Student and Faculty Engagement in Engineering Education" in both student and faculty formats[8]. For this research a survey of student engagement was needed which could be used throughout the semester. While the CASEE survey is comprehensive and tested it is also 5 ½ pages long. This did not meet our assessment needs so a shorter "Opinionaire" was created which students could take quickly several times during the semester. The NSSE and CASEE surveys were used as guides but major input on the survey opinionaire questions came from senior undergraduates who have been working on this project as Research Assistants. Four areas were identified as good indications of student engagement; a desire to learn more, asking more questions in class, talking/thinking about the material more, and coming better prepared for class. It is interesting to note that these categories were initially arrived at by discussion with the undergraduate assistants and yet they closely match the engagement criteria used by other researchers[8] as well as the CASEE survey. Each of these four areas was subsequently evaluated using a five point Likert scale (Table A2). In addition, students were asked what their impression was of their performance in the course, what they thought was the most engaging thing about the course, and what they thought was the least engaging thing. The opinionaire was given three times during the semester, one class period after each of three hour exams. Therefore data was collected at approximately the 1/3 point, 2/3 point, and end of the semester.

Finally to help fill in the gaps, two additional assessment items were taken from existing surveys used in the department and university. The first is the standard end of semester course evaluation form. Lastly, an end of semester accreditation outcome survey was used. This survey identifies the ABET outcomes which have been defined for the specific course and asks students to rate their content on a five point scale.

IV. Assessment and Data Analysis

Assessment data has been pulled together from three different offerings of the ME241 Engineering Thermodynamics course at Minnesota State University Mankato. During Fall 2004 one section of approximately 50 students was taught by Instructor X. During Fall 2005 one section of approximately 40 students was taught by Instructor Y. During Fall 2006 two sections, each with 20-25 students, were taught by Instructor X and Y. These two sections were organized similarly with identical homework assignments and examinations. Homework was graded by the same grader and examination grading was split between the two instructors for uniformity. For the Fall 2006 analysis, data for students who dropped the course or who did not complete one of the two concept inventories was not included in the analysis. Data for students who had previously taken Thermodynamics was also removed from the analysis group. This created a final cohort size for the Fall 2006 assessments of 33 students.

For the Fall 2006 offering the preliminary Engaged in Thermodynamics materials were made available to the students. This consisted of an extensive website which detailed the operation of all components of the campus facilities plant, included some manufacturer data, video interviews with plant personnel, and draft homework problems based on the plant. During the semester several of the draft problems were assigned as homework (approximately 1/8th of the total homework assignments). In addition, a design problem based on the scenario was assigned as part of the homework grade. Since the material is still under development no other use of the material was made during this semester.

The results of the pre- and post-concept inventories show good agreement between the Fall 2005 and Fall 2006 semesters (Table 2). The average percent of correct answers and the standard deviation are almost identical. While this does not demonstrate an improvement due to use of the draft problems none was expected, due to the preliminary nature of the material at this time. What was demonstrated are some interesting results concerning concept development in thermodynamics. Even though the average is similar between semesters when the results are analyzed by problem (Table 3) there are many differences between the two semesters. For instance, on question #8 the Fall 2005 students did worse after the course where the Fall 2006 students improved. Question #10 shows a similar trend but reversed between years. Of more interest are the results for questions #4, 5, and 21. For these questions results for both offerings were consistent and demonstrated that the students performed poorer on these questions after taking the course.

The comparison of Question B (given with Concept Inventory) shows good agreement between the two years (Table 4). The initial values of approximately 4.0 shows that students come into the course with a fairly high expectation of being interested. However, after the course this value has slipped slightly to 3.4. Question C concerned the student's impression of real world problems in the course (Table 5). Initial values were consistent between years at approximately 4.3. During Fall 2005 the students rated their exposure to real world problems after the semester at only a 3.1 showing that their expectations were not fully met. The Fall 2006 results also showed a decrease but it was much less with the end of semester value still at 4.0. Question D explored the student's perception of how hard they planned to work and actually did (Table 6). The results show minor changes across the semester and years which are within the calculated standard deviations. In general the student response was fairly neutral.

The Opinionaire results also demonstrate interesting results when examined across the course of the semester (Table 7 and Figure 1). This survey format was only given to the Fall 2006 course. Question #1 deals with the students' desire to learn more in the course. The results show a clear downward trend during the semester indicating students are losing interest. Question #2 examines engagement from the point of asking questions about the material. While the changes are more subtle there is a downward trend across the semester. Question #3, which measured the extent of students talking/thinking about the material, showed an opposite trend, however. While the changes were well within the standard deviation there was a consistent increasing trend. Question #4 examined student preparation for the course. There was no consistent trend and results were near the mid-range. Question #5 asked students to rate how well they thought they were doing in the course. There was a slightly decreasing trend.

To determine if there were relationships between the opinionaire responses and concurrent examination grades, correlation analyses were performed between each question and the most recent examination score (Table 8). There were no consistent trends and very little indicated correlation for the first three questions. The fourth question demonstrated a slight correlation at roughly the 10% level. As might be expected, the strongest correlation was for Question #5 with correlations of 30 to 44%. To determine if the student level of asking questions, talking about the material, or course preparation has a link to a student's desire to learn, additional correlation analyses were performed (Table 9). Ironically, the results indicated that there was no correlation between desire to learn and asking questions in class. There was a minor link between being prepared for class and desire to learn. However, the largest correlation (which was still only 13%) was between exam scores and students talking about the material.

Students were also asked to provide examples of the most and least engaging aspects of the course on each Opinionaire. The most often reported item for engagement was something related to real world aspects. Out of 33 respondents in the final cohort, 23 students mentioned real world aspects at least once during the semester. Of these 14 students mentioned real world aspects two or more times. Other engaging factors mentioned were learning new problem solving methods and new thermodynamic concepts. The top responses for least engaging material included use of the thermodynamic tables, general confusion about the topic, and entropy.

V. Conclusions and Future Work

The results presented are part of an ongoing pedagogical research project. They will be used to guide future assessment and provide a control case to compare to. There were several conclusions demonstrated at this phase based on the original three questions.

1*) What is the most appropriate and engaging format for the Scenario material?*
Student review of existing textbooks demonstrated a very practical attitude. A text which is clear, understandable, and complete is desired. Concerning specific engagement factors, students did not indicate that online or electronic formats are more engaging. In fact, there was a decided dislike of this medium expressed. Additional study will be necessary to determine if this is a factor of poorly designed material or mismatching the material's strengths with its use. On the other hand, strong engagement was indicated for inclusion of real world aspects, for both descriptive and visual content. However, engagement for these inclusions decreases if the material is not detailed or if it seemingly takes away from other portions of the text (such as having additional homework problems).

2) How can performance and engagement be measured for the grant purposes?
A combination of performance and engagement instruments has been demonstrated. The results paint a fairly consistent picture of a typical Thermodynamics cohort at Minnesota State University. Opinionaire results and post-course surveys indicate that interest and the desire to learn the material steadily declines during the semester. There is a partial correlation indicated between this decrease in interest and students asking questions. However, several new questions were also posed by these assessment results. With regard to the concept inventories, several questions must be analyzed further to determine why student performance would decrease following the semester. Student opinionaire results also indicate that as student interest in learning and asking questions decreases students start to talk/think more about the material. It is unclear if this represents an unidentified cause and effect process or a problem with the assessment instruments. Work will continue on each of these items as the assessment process moves toward evaluation of the full Engaged in Thermodynamics material.

3) Does merely changing the homework format impact engagement or performance?
Based on the Opinionaire comments and the textbook focus group the most engaging aspect of thermodynamics is the inclusion of real world problems and aspects. Students come into the semester with an expectation of real world problems. Using a traditional textbook and course format these expectation may not be met, as indicated by the assessment results. However, using the preliminary Engaged in Thermodynamics material these expectations appeared to be better addressed. No changes in student performance were indicated at this stage of material development.

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Table 2: Comparison of concept inventory results for subsequent course offerings.

	Start of Semester		End of Semester	
	Average (%)	Standard Deviation	Average (%)	Standard Deviation
Fall 2005	48.6	11.2	59.6	9.9
Fall 2006	51.8	11.1	61.6	9.6

Table 3: Concept inventory results by question

Question	F05 pre	F05 post	% change	F06 pre	F06 post	% change
1	61.1	64.7	3.6	52.4	61.8	9.4
2	88.9	94.1	5.2	77.5	85.3	7.8
3	83.3	94.1	10.8	77.5	100.0	22.5
4	44.4	35.3	-9.2	52.3	38.2	-14.1
5	77.8	70.6	-7.2	88.7	76.5	-12.2
6	44.4	52.9	8.5	38.2	70.6	32.4
7	0.0	17.6	17.6	2.2	23.5	21.3
8	22.2	17.6	-4.6	24.9	38.2	13.4
9	55.6	64.7	9.2	63.6	32.4	-31.3
10	50.0	64.7	14.7	63.7	55.9	-7.8
11	94.4	100.0	5.6	95.5	94.1	-1.3
12	72.2	58.8	-13.4	52.5	61.8	9.3
13	44.4	47.1	2.6	59.4	79.4	20.0
14	22.2	41.2	19.0	31.8	29.4	-2.4
15	50.0	41.2	-8.8	57.0	73.5	16.6
16	66.7	70.6	3.9	79.5	50.0	-29.5
17	55.6	94.1	38.6	41.0	88.2	47.2
18	88.9	100.0	11.1	86.4	94.1	7.8
19	11.1	76.5	65.4	38.7	88.2	49.6
20	94.4	94.1	-0.3	77.9	97.1	19.2
21	38.9	23.5	-15.4	45.0	41.2	-3.8
22	11.1	52.9	41.8	9.1	41.2	32.1
23	33.3	35.3	2.0	22.6	26.5	3.8
24	66.7	76.5	9.8	43.2	61.8	18.5
25	27.8	58.8	31.0	16.1	50.0	33.9
26	88.9	76.5	-12.4	77.2	67.6	-9.5
27	33.3	64.7	31.4	36.2	82.4	46.2
28	38.9	64.7	25.8	50.1	76.5	26.4
29	0.0	41.2	41.2	13.5	26.5	12.9
30	11.1	11.8	0.7	20.3	47.1	26.7
31	55.6	70.6	15.0	47.7	44.1	-3.6
32	16.7	35.3	18.6	31.9	44.1	12.2

<u>Table 4: Pre- and Post- values for student rated interest (Question B)</u>

	Start of Semester		End of Semester	
	Average	Standard Deviation	Average	Standard Deviation
Fall 2005	3.9	0.5	3.4	0.9
Fall 2006	4.0	0.7	3.4	1.0

<u>Table 5: Pre- and Post- values for student expectation of real world problems (Question C)</u>

	Start of Semester		End of Semester	
	Average	Standard Deviation	Average	Standard Deviation
Fall 2005	4.4	0.6	3.1	0.9
Fall 2006	4.2	0.4	4.0	0.7

Table 6: Pre- and Post- values for student expectation of effort in the course (Question D)
<u>(for this case a low value indicates a high level of effort)</u>

	Start of Semester		End of Semester	
	Average	Standard Deviation	Average	Standard Deviation
Fall 2005	2.9	1.1	2.8	1.1
Fall 2006	2.1	0.9	2.5	1.0

<u>Table 7: Responses for Opinionaire questions</u>

Point in semester	**1/3**	**2/3**	**End**
Question 1			
Average	3.50	3.29	2.74
Std. Deviation	1.01	0.97	0.82
Question 2			
Average	3.53	3.48	3.35
Std. Deviation	0.86	1.0	1.05
Question 3			
Average	3.6	3.77	3.84
Std. Deviation	0.93	0.84	0.86
Question 4			
Average	3.13	3.16	3.10
Std. Deviation	0.86	0.93	0.91
Question 5			
Average	3.07	2.74	2.71
Std. Deviation	1.05	0.82	1.07

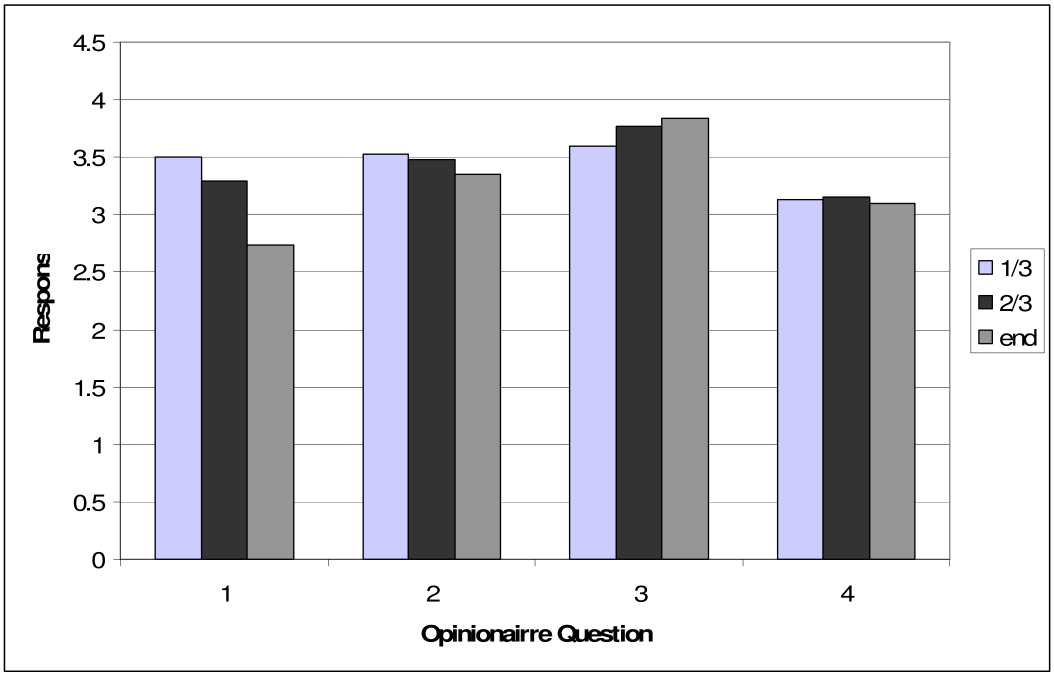


Figure 1: Changes in Opinionaire response across the course of the semester.

<u>Table 8: Correlation of exam grades with opinionaire questions (r^2)</u>

Point in semester	1/3	2/3	End
Question #1	0.0983	0.0269	0.2720
Question #2	0.0397	0.1386	0.0038
Question #3	0.0311	0.0188	0.0430
Question #4	0.1381	0.1111	0.1195
Question #5	0.4368	0.3525	0.2955

<u>Table 9: Correlation of student interest in learning with other opinionaire questions (r^2)</u>

Point in semester	1/3	2/3	End
Question #2	0	0.0001	0.0150
Question #3	0.1345	0.1342	0.1580
Question #4	0.0774	0.0169	0.0770

Table A1: Focus Group Questions Concerning Textbook Usefulness

LIKERT SCALE QUESTIONS (5 point)
Key: SA=strongly agree; A=Agree; N=Neutral; D=Disagree; SD=Strongly Disagree

1. I was able to look at each book.
   If D or SD was selected:
   Which one(s) were not looked at?

2. I found the course textbook valuable.

3. I used the course textbook for other things besides homework?
   What were the other uses?

Answer for each of the textbooks:

4. The problems and examples represent real-world situations.

5. The chapters and topics appear to connect with each other?

6. The text shows actual systems?

7. The problems and examples involve actual systems.

FILL IN THE BLANK QUESTIONS

8. Rank the four texts in order (A-D) with most helpful as A. etc.?

9. What kind of material would inspire you to do unassigned reading or research using the textbook (information on actual systems, design problems, more examples, etc.)?

10. How important is it to you to see and work with real-world problems? Which text has the most real-world problems?

11. What is the most interesting or engaging problem or example you found when looking through the texts? Which text was it in?

12. Do any of the texts provide better information on how to approach open-ended design problems? Which one(s) were best for this?

13. Do all of the texts appear to cover the same content? If not, what are the differences?

14. Overall, is there one text format you liked better than the others?

15. Are there any other comments you can share about the various textbooks?

Table A2: Student Opinionaire used to measure student engagement.

The following questions deal with your engagement in this course. Please use the scale provided (1-5) for your answers.

1. Compared to other courses in mechanical engineering, do you find yourself wanting to learn more in this course?

1 2 3 4 5
NO YES

2. Compared to other courses in mechanical engineering, are you asking more questions about the material? (in and outside of class)

1 2 3 4 5
NO YES

3. Compared to other courses in mechanical engineering, do you talk/think more about the material in this course?

1 2 3 4 5
NO YES

4. Compared to other courses in mechanical engineering, do you find you are preparing better for this class?

1 2 3 4 5
NO YES

5. How well do you think you are doing in this course so far?

1 2 3 4 5
POOR EXCELLENT

6. What do you find the most engaging thing about this course so far?

7. What do you find the least engaging thing about this course so far?

Table A3: Survey questions asked with Concept Inventories

Question A: Have you previously taken or attended a Thermodynamics course?

Yes **No**

Question B: I expect to be interested in the subject material of this course (circle the extent to which you agree)

Strongly disagree **Disagree** **Neither agree or disagree** **Agree** **Strongly Agree**

Question C: I expect to be exposed to real world problems in this course (circle the extent to which you agree)

Strongly disagree **Disagree** **Neither agree or disagree** **Agree** **Strongly Agree**

Question D: I do NOT plan to read the text or solve homework problems beyond those assigned.

Strongly disagree **Disagree** **Neither agree or disagree** **Agree** **Strongly Agree**

<u>Table A.4 Thermodynamics Concept Inventory (TCI version 5.1)</u>

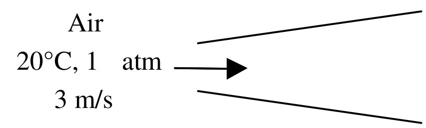
For additional information concerning this concept inventory please refer to the Foundation Coalition resources or contact Clark Midkiff (cmidkiff@bama.ua.edu)

For Questions 1 and 2: Air is contained in a sealed tank of fixed volume. The air in the tank is initially at 20°C and 1 atm (101.3 kPa). It is then heated to 250°C.

1. What will happen to the density of the air in the container? (a) Density will decrease (b) Density will not change (c) Density will increase (d) Insufficient information.

2. What will happen to the energy of the air in the container? (a) Energy will decrease (b) Energy will not change (c) Energy will increase (d) Insufficient information.

For Questions 3 and 4: Air at 20°C, 1 atm steadily enters a perfectly-insulated circular duct at a low velocity (3 m/sec). The duct diameter increases in the direction of flow as shown in the figure to the right.



3. As air flows through the duct, its velocity: (a) Increases (b) Remains the same (c) Decreases (d) Insufficient information.

4. As air flows through the duct, its energy: (a) Increases (b) Remains the same (c) Decreases (d) Insufficient information.

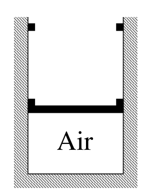
5. A pot of water is boiling open to the atmosphere when the pot is sealed by a tight lid, and continued heating causes the pressure to rise. Compared to before the lid was added, the temperature: (a) Increases (b) Remains the same (c) Decreases (d) Insufficient information.

6. Heat from a source at 550 K is added to the working fluid of an engine operating at a steady rate. The temperature of the surroundings is 300 K. The efficiency of this process is defined as the ratio of the mechanical power produced by the engine to the rate at which heat is provided. The maximum efficiency of this engine is: (a) Much greater than 1 (b) About equal to 1 (c) Much less than 1 (d) Insufficient information.

7. To determine the efficiency of a piston-and-cylinder based engine that uses air as a working fluid, which properties need to be known? (a) Air in the engine (b) Metal of the engine's pistons and cylinders (c) Atmosphere surrounding the engine (d) Both engine air and metal material (e) Engine air, engine metal, and surrounding atmosphere.

8. An electric water heater consists of a perfectly-insulated tank filled with water and fitted with an electric heating element. Water enters the tank at 10°C and exits at 50°C at a pressure greater than 1 atm. The efficiency of the water heating process is defined as the energy provided to the water divided by the electrical energy provided to the heating element. The efficiency of the water heating process is: (a) Much greater than 1 (b) About equal to 1 (c) Much less than 1 (d) Insufficient information.

For Questions 9 – 11: Air at high pressure and ambient temperature is contained in a perfectly insulated piston-cylinder device as shown to the right. Stops prevent the piston from moving up. The stops are then removed and the piston quickly rises into the atmospheric pressure air above it until a second set of stops is encountered that prevents it from leaving the cylinder.



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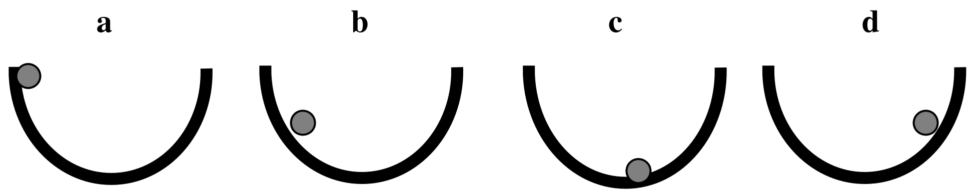
9. The temperature of the air: (a) Increases (b) Remains the same (c) Decreases (d) Insufficient information.

10. The energy of the air in the cylinder: (a) Increases (b) Remains the same (c) Decreases (d) Insufficient information.

11. Work is done by the air in this process. (a) Agree (b) Disagree (c) Insufficient information.

12. A 25 kg steel ball at 300°C is held 100 m above the ground. The ball is then released and begins falling. The ball cools as it falls, and the ball continues to accelerate as it falls. Air friction is negligible. The total energy of the ball is greatest: (a) The instant it is released (b) Midway through its fall (c) Just before it hits the ground (d) After it strikes the ground (e) The energy remains constant.

13. Consider a marble that is held at the lip of a bowl. The marble is released, with no force added, and begins to roll down into the bowl. Assuming the rolling process is frictionless, for which of the figures below does the ball have maximum energy?

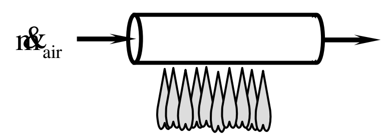


e
Energy is the same for all positions

14. The property of temperature: (a) Can be measured directly (b) Cannot be measured directly, but must be determined indirectly by measuring another property that depends on temperature (c) Can be measured either directly or indirectly.

15. There is no conceptual or theoretical limit on how high a temperature can be achieved. (a) Agree (b) Disagree (c) Insufficient information.

For Questions 16 – 19: Air flows steadily and essentially at constant pressure through a pipe that is heated by a furnace, as shown to the right.



16. What happens to the velocity of the air as it flows through the pipe? (a) The exit velocity is greater than the inlet velocity (b) The exit velocity is the same as the inlet velocity (c) The exit velocity is less than the inlet velocity (d) Insufficient information.

17. What happens to the mass flow rate of air as it flows through the pipe? (a) The mass flow rate increases (b) The mass flow rate remains the same (c) The mass flow rate decreases (d) Insufficient information.

18. What happens to the energy of the air as it flows through the pipe? (a) The energy increases (b) The energy remains the same (c) The energy decreases (d) Insufficient information.

19. What happens to the entropy of the air as it flows through the pipe? (a) The entropy increases (b) The entropy remains the same (c) The entropy decreases (d) Insufficient information.

For Questions 20 and 21: Air in a piston-cylinder device is initially at 70°F and 5 atm in surroundings that are at 70°F, 1 atm. The piston is initially locked in place. After the locks are removed, the piston moves to a new position. At the end of the process, the air in the piston-cylinder device is at 70°F, 2 atm. Frictional effects are negligible.

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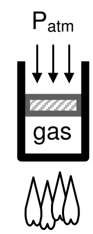
20. Work is done by the air in the piston-cylinder device during this process. (a) Agree (b) Disagree (c) Insufficient information.

21. There is no heat transfer involved in this process. (a) Agree (b) Disagree (c) Insufficient information.

22. H_2O is vaporized in a boiler that contains a burning fuel. To determine the energy increase of the H_2O per unit mass, (a) Only fuel properties must be known (b) Only boiler material properties must be known (c) Only H_2O properties must be known (d) Boiler material and H_2O properties must be known (e) All three sets of properties must be known.

23. A rigid, constant volume container containing a mass that could be solid, liquid and/or gas is brought into contact with a much hotter object. The temperature of the contents: (a) Always increases (b) Always decreases (c) Always increases or remains the same (d) Could increase, decrease or remain the same.



Questions 24 - 28 pertain to the picture to the right, which depicts a gas heated and expanding in a sealed, frictionless, piston-and cylinder arrangement, where the piston mass and the atmospheric pressure above the piston remain constant.

24. The *density* of the gas will: (a) Increase (b) Remain the same (c) Decrease (d) Insufficient information.

25. The *pressure* of the gas will: (a) Increase (b) Remain the same (c) Decrease (d) Insufficient information.

26. The *energy* of the gas will: (a) Increase (b) Remain the same (c) Decrease (d) Insufficient information.

27. The *entropy* of the gas will: (a) Increase (b) Remain the same (c) Decrease (d) Insufficient information.

28. In this process: (a) Work is done *on* the gas (b) Work is done *by* the gas (c) No work is done (d) Insufficient information.

29. Consider the best possible heat engine working in air at 25°C. The engine continuously converts heat from a source at 300°C to work, and heat is continuously transferred into the engine at a rate of 100 kJ per second. The maximum possible rate at which the engine can continuously produce work is: (a) Greater than 100 kJ per second (b) Equal to 100 kJ per second (c) Almost 100 kJ per second (d) Significantly less than 100 kJ per second.

30. A gallon of hot water is mixed with a gallon of cold water in a perfectly insulated container. The total entropy of the water after it is mixed compared to the total entropy of the water before it is mixed is: (a) Greater (b) The same (c) Less (d) Insufficient information.

Questions 31 and 32 refer to two masses of the same solid, incompressible material with a constant specific heat. Mass A is 2 kg with Temperature A of 200°C. Mass B is 1 kg with Temperature B of 400°C.

31. Both masses are cooled to 0°C. Which mass has a greater total internal energy change, ΔU? (a) $\Delta U_A > \Delta U_B$ (b) $\Delta U_A = \Delta U_B$ (c) $\Delta U_A < \Delta U_B$ (d) Insufficient information.

32. By cooling which mass to 0°C is it possible to produce the most work? (a) Mass A (b) Mass B (c) The maximum potential is the same for cooling both masses (d) Insufficient information.