Mechanical Engineering 4431: Energy Conversion Systems

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Brief Course Description

This is a senior laboratory which emphasizes understanding of the operating principles of some of the component devices that are encountered in engines, power plants, and heating systems as well as experimental measurement, analysis, and reporting techniques. Students will build on their fundamental knowledge of thermodynamics, fluid mechanics, and heat transfer in analyzing the operating characteristics of real engines and heat exchangers. As a result, students will gain hands-on experience with the operating characteristics of common energy conversion devices (and a better understanding of how to apply their fundamental knowledge of thermo-fluid sciences), increase their understanding of statistical analysis methods, and practice oral and written presentation skills.

Prerequisites

AEM 3200 or CE 3400; ME 3303, 3701, 3702, or semester equivalent, upper division ME student

References

H. W. Coleman and W. G. Steele, Jr., *Experimentation and Uncertainty Analysis for Engineers*, John Wiley & Sons, New York, 1989.

M. J. Moran and H. N. Shapiro, *Fundamentals of Engineering Thermodynamics*, John Wiley & Sons, New York, 2nd ed. published 1992, 3rd ed. published 1996.

F. P. Incropera and D. P. DeWitt, *Fundamentals of Heat Transfer*, 3rd ed., John Wiley & Sons, New York, 1996.

R. Decher, *Energy Conversion: Systems, Flow Physics, and Engineering*, Oxford University Press, New York, 1994. (on reserve in library)

Stone, R, *Internal Combustion Engines*

Heywood, J.B., *Internal Combustion Engine Fundamentals*

Grading:

Lab Notebooks /pre-lab documents / participation	13%
Draft Reports	20%
Final Reports	40%
Oral Presentation I	7%
Oral Presentation II	10%

Due Dates:

Reports are due by 4:30 p.m. on the days indicated above. You must complete **all** written and oral material in order to receive a grade. Otherwise you will be given an incomplete. All late material will be assessed a penalty of 5% of the full grade for each day (or fraction thereof) that the material is late. Pre-labs are due before start of that particular laboratory session. **You will not be allowed to participate in the lab if you have not completed the pre-lab!**

Class Attendance:

Attendance at all lectures and labs is essential. If you miss a lecture, get notes from a classmate. If laboratory is missed, it will be your responsibility to arrange to make up the lab session contingent upon the availability of a teaching assistant; we do not guarantee that make-up laboratories will be possible.

Laboratory Notebooks

Objective:

This document describes what information should appear in lab notebooks and how they will be graded.

Background:

The purpose of a lab notebook is to create a permanent record of work performed in the laboratory. It should contain enough detail that engineers of similar background can understand what work was performed, and can repeat the experiments if desired. This is especially important for people in your group who will have to take over your work in the event that you are unavailable. In research and industrial settings, notebooks may also serve as evidence in intellectual property disputes and other litigation.

Apparatus:

A bound laboratory notebook, nominally 8.5" x 11" pages ruled with a square grid, each page numbered and accompanied by a numbered removable carbon. The bookstore carries an acceptable version numbered 43649. An option for the carbon paper notebook is a photocopy of applicable pages for pre-laboratory purposes.

Three ring binders are not allowed. The square grid aids in drawing neat sketches and quick graphs. The carbons will be turned in at the end of each lab period for feedback and/or grading; this enables us to evaluate your notebooks at the same time you are using them to write up your report.

Discussion:

1. Your notebook should document what was done, data obtained, and any observations made during the course of the experiment (including trends, drifts, etc.), as well as any conclusions deemed important. It should be neat and clearly organized. Enough information should be included such that you could refer back to the notebook in 5 years and still be able to understand what it was you yourself had done / thought about. We may ask you to answer specific questions to emphasize certain points, but that is not meant to limit the scope of the discussion. Any observations or references to other important materials should also be included. A notebook meeting the above description will receive a "B."

2. In industry, notebooks such as these and others (e.g. the design notebooks used in ME 5254) serve as references for fellow workers who may have to carry on your work in your absence, as well as legal documents. A good notebook in this case requires a more careful level of documentation, because your co-workers will need to be able to follow your work without you there to explain it. If your notebook meets that standard, it gets an "A".

3. Lab notebooks should be prepared before the experiment begins whenever possible. This helps in coordinating the operation of the equipment and the acquisition of data and is a key to keeping your notebooks neat and well organized. Lab notebooks not meeting the minimum standards described in (1) will receive a "C" or less.

Components of Notebook:

1. Objective (What and Why?)

2. Apparatus (sketch or drawing from packet)

3. Procedure (Detailed but succinct description of how data was obtained.)

4. A sample data table, including room for error estimates. The table should include a descriptive title or heading, units on all columns, and enough space to record all the information. You may need to extend across more than one page to leave room for all the data and a comment field. In some cases, you will actually be able to record all your data in the notebook (or paste in a hard copy of an appropriately labeled spreadsheet which you print out before you leave the lab), but in others, the length of the data set will be too long to make this practical. In the latter case, you should refer to the filename, drive, and computer where the information can be found.

5. Plots of data and/or intermediate results. These can be sketched by hand if your lab notebook has appropriate square grids or else you can paste in the output from a spreadsheet. You should note any formulas that allow you to obtain the results you are plotting, and a sample calculation is very helpful. Make sure to add trend lines and legends as needed (these can be done by hand). In general, the trend lines are what allow you to identify whether the experiment is proceeding according to expectations, and whether any data points need to be re-taken. For more information on plots, refer to the document describing lab reports.

6. Comment on any important trends you observe.

Notes:

Parts 1-3 can be paraphrased from the manual, but the notebook must be able to stand on its own.

Use headings in your notebook as appropriate to set off sections/discussions.

Do not erase anything, cross it out if it's wrong, and then do it over. Many people do sample calculations on scratch paper and transfer them into their notebook so the latter looks neater.

Summary:

Duplicate sheets from lab notebooks will be turned in at the end of each lab. Some of these will be reviewed for feedback purposes only, while others will be evaluated as part of the course grade. A good notebook will meet the requirements described above, and will form an excellent base from which the various reports can be generated.

Pre-laboratory requirements:

Pre-laboratory documents will be either a carbon or photocopied document of the notebook (similar to junior measurements lab). It will be handed in before the lab session begins.

Objective:

The object of the pre-laboratory document is initial investigation and familiarization with the experiment beforehand. The familiarization with the theories, predicted behavior, and procedures will be helpful at the time of processing the actual report. Acquisition of pertinent data will be more easily obtained. Also experiment efficiency may be increased and time required to accomplish the laboratory may be reduced.

Components:

The pre-laboratory document will include objective, schematic (may be copy pasted from manual but with any additional equipment included), general procedure with specifications (such as electrical load), and predicted behavior including sketched graphs and/or sample calculations.

Draft Lab Reports:

The draft report documents the experiment that was performed and provides a brief discussion of the results obtained. It organizes and clarifies the information that can be found in a good lab notebook, adding background material and a more detailed discussion of the results while simplifying the description of the experimental apparatus and procedure. From such a report, a peer group of engineers (or engineering students) who are familiar with the same general subject matter should be able to reproduce the experiment and perform their own analysis, such that they could either verify or dispute your results. The draft report should meet three objectives: 1) to justify the reasons for performing the experiment; 2) to record the results of the experiment so that they may be checked for correctness; and 3) to lay the foundation for your formal report. You should consider your audience to be familiar with the general engineering background associated with your experiment, but none of the specifics. This is a draft report, but it still should use grammatically correct sentences and be structured in a clear and concise manner. Your text and graphics need not be in final form, but should be neat and readable.

Draft reports should contain the following components:

1. Title Page

2. Introduction

3. Experimental Apparatus and Procedure

4. Results

A more detailed description of each section follows.

Title page:

Use a balanced layout, and include a title, name of person writing report, date(s) experiment was performed, and names of lab partners.

Introduction:

This section is written to provide the reader with the background needed to appreciate why you did the experiment and to understand your results. To accomplish this, you may need to provide a **brief** review of relevant theoretical material, including appropriate references. The more complete you make this draft document, the more feedback you will receive. Feedback will help you in preparing your final report so doing as much as possible here is a good idea. The introduction should provide:

1. The objective of the experiment.

2. Brief review of background theory. This may be as brief as describing principal variables and calculations. However it is in your interest to make this as complete as possible so you will get feedback for the final report.

3. A brief preview of what will be presented.

Experimental Apparatus and Procedure

This section should enable others to reconstruct your experimental apparatus and duplicate your procedure to test your results. It should include:

1. A description of the equipment and instrumentation used in obtaining the data, using diagrams as appropriate to facilitate the description. **Make sure to describe the instrumentation in detail, type units, range, and uncertainty.**

2. A summary of the procedure used in taking and processing the data, including a description of software if it is specific to the experiment.

A discussion of how to prepare good figures, including an example, can be found in the section on figures at the end of this document. The procedure does not have to be a detailed step-by-step list of what you did to obtain the data; the following example would be appropriate to convey the procedure to an engineering audience:

The tests were performed on a four-cylinder, 153 cubic inch Hercules engine, using an electric dynamometer to control the load and speed. The spark advance was varied over a range of 40 crankshaft degrees before top dead center (40° BTDC) to 5 degrees after top dead center (5° ATDC). Cylinder pressure traces were recorded with 1/4 degree crankangle resolution over the entire engine cycle using a Kistler model 999 piezoelectric pressure transducer and a Berkeley shaft encoder. These results were then converted to pressure-volume diagrams in order to investigate the effect of spark advance on indicated engine torque.

Results

You should present all of the principal results to be included in your final report, but you need not discuss them at this point. The results are generally presented in an orderly fashion a section at a time. You may find it necessary to add to your formal report some additional graphs, figures, and tables that are chosen to illustrate specific points. A good report will include the following:

1. Figures chosen to convey results in a clear fashion. The figures should be as close to final form as possible. We need to be able to look over your results to make sure that they are correct and presented in an appropriate manner. If this is not done, you run the risk of spending a lot of time discussing incorrect or incorrectly presented results during preparation of your final report.

2. A discussion of uncertainties in data and/or any assumptions that must be employed to arrive at your results.

Properly constructed figures will convey most of the information regarding key results to knowledgeable readers without the need for additional discussion. Each figure or table should be complete -- identified by a figure or table number, bearing a clearly understandable figure caption or table title, and indicating the units of any dimensional quantities displayed. The handout on figures and graphs provides more detail along with examples regarding how to prepare proper figures. Figures should be integrated into the text or placed at the end of each sub-section, not in an appendix at the back of the report.

In addition, a clear, concise discussion must accompany each figure. For the draft report these discussions should be brief and mainly address the integrity of the results—do they make sense?

It is equally important to qualify your analyses by discussing the uncertainties associated with your data and any additional assumptions you make in deriving your results. These will essentially convey how much confidence should be placed in your results.

Formal Lab Reports

The formal report documents the experiment that was performed and provides a detailed discussion of the results obtained and how those are important. It organizes and clarifies the information that can be found in a good lab notebook, adding background material and a more detailed discussion of the results while simplifying the description of the experimental apparatus and procedure. From such a report, a peer group of engineers (or engineering students) who are familiar with the same general subject matter should be able to reproduce the experiment and perform their own analysis, such that they could either verify or dispute your conclusions. Reports generally have three goals: 1) to justify the reasons for performing the experiment; 2) to record the results of the experiment; and 3) to allow others to evaluate the results. You should consider your audience to be familiar with the general engineering background associated with your experiment, but none of the specifics. This is a formal professional report, and hence it must incorporate grammatically correct sentences, be structured in a clear and concise manner, and contain professional quality text and graphics. You should <u>proofread</u> your work as well as spell-check it.

Formal reports should contain the following components:

1. Title Page
2. Abstract
3. Table of Contents (Optional for our reports, generally used for reports over 10 pages long.)
4. Introduction
5. Experimental Apparatus and Procedure
6. Results and Discussion
7. Conclusions and Recommendations
8. References
9. Appendices

A more detailed description of each section follows.

Title Page:

Use a balanced layout, and include a title, name of person writing report, date(s) experiment was performed, and names of lab partners.

Abstract:

One or two paragraphs which clearly and concisely present an overview of the report. Complete sentences must be used, not phrases. Nine out of ten readers will read only the abstract of an engineering report-- therefore, it is imperative that clear, concise, to-the-point information be used. Include information on the following. Make sure to include quantitative results.

1. What was done?
2. Key results.

3. Key conclusions.

Introduction:

This section is written to provide the reader with all the background needed to appreciate why you did the experiment and to understand your results and conclusions. To accomplish this, you may need to provide a brief review of previous work or of relevant theoretical material, including appropriate references. The introduction should provide:

1. The objective of the experiment.

2. Relevant background information.

3. An indication of the importance of the work.

4. A brief preview of what will be described.

Experimental Apparatus and Procedure

This section should enable others to reconstruct your experimental apparatus and duplicate your procedure to test your results. It should include:

A description of the equipment and instrumentation used in obtaining the data, using diagrams as appropriate to facilitate the description. Make sure to describe the instrumentation in detail, type units, range, and uncertainty.

A summary of the procedure used in taking and processing the data, including a description of software if it is specific to the experiment.

A discussion of how to prepare good schematics, including an example, can be found in the section on figures at the end of this document. The procedure does not have to be a detailed step-by-step list of what you did to obtain the data; the following would be appropriate to convey the procedure to an engineering audience:

The tests were performed on a four-cylinder, 153 cubic inch Hercules engine, using an electric dynamometer to control the load and speed. The spark advance was varied over a range of 40 crankshaft degrees before top dead center (40° BTDC) to 5 degrees after top dead center (5° ATDC). Cylinder pressure traces were recorded with 1/4 degree crankangle resolution over the entire engine cycle using a Kistler model 999 piezoelectric pressure transducer and a Berkeley shaft encoder. These results were then converted to pressure-volume diagrams in order to investigate the effect of spark advance on indicated engine torque.

Results and Discussion

The results are generally presented in an orderly fashion a section at a time together with associated discussions (as opposed to separately presenting all the data before proceeding to a lengthy discussion). In most cases, the discussions will be centered on graphs, figures, and tables that are chosen to illustrate specific points. A good report will include the following:

1. Figures chosen to convey results in a clear and convincing fashion.

2. A discussion of trends, their underlying causes, and important implications.

3. A comparison of your results with similar results from outside reading. For example, compare the efficiency of your device with comparable devices tested elsewhere.

4. A discussion of uncertainties in data and/or any assumptions that must be employed to arrive at your results and conclusions.

It is essential that you respond to the feedback that you receive on your draft report. Reports presenting incorrect results will not be accepted.

Properly constructed figures will convey most of the information regarding key results to knowledgeable readers without the need for the associated discussion. Each figure or table should be complete -- identified by a figure or table number, bearing a clearly understandable figure caption or table title, and indicating the units of any dimensional quantities displayed. The handout on figures and graphs provides more detail along with examples regarding how to prepare proper figures. Figures should be integrated into the text or placed at the end of each sub-section, not in an appendix at the back of the report.

In addition, a clear, concise discussion must accompany excellent figures in order to reach a general audience. Whenever possible, explain the underlying phenomena which cause the trends to appear as they do, and what implications, if any, that has for particular applications. For example, in discussing a plot of the temperature of a heated container versus time, it would be fairly pointless to say, "The temperature increases with time and then begins to level off." That will be apparent from a plot of the data. Although you may have to state that, don't drop it there--you are probably more interested with the rate of temperature rise, how you might change the rate, whether the temperature will level off before the container melts, or whether an associated increase in pressure might cause the container to explode.

It is equally important to qualify your analyses by discussing the uncertainties associated with your data and any additional assumptions you make in deriving your results. These will essentially convey how much confidence should be placed in your results.

Conclusions and Recommendations:

1. Summarize the main findings that were discussed in detail in the Results section.

2. Relate the results back to the objective and prior results cited in the Introduction.

3. You may include recommendations for future work if warranted.

References:

Cite complete references for any information that you draw on.

Appendices:

Appendices contain detailed information that is not necessary for the understanding of the key points in the body of the report, provided that the reader believes you when you state, "The details can be found in Appendix XXX." Of the 1 in 10 readers who actually read your report, fewer still will actually delve into the Appendices; yet that is where you must provide detailed documentation that is important to the experiment but too cumbersome for the general text. You should include Appendices on the following:

1. Raw data table (or disk, if the length is overwhelming).

2. Sample calculations

3. Computer programs.

4. Etc.

Graphs, Tables and Figures

These may appear in the Experimental Apparatus and Procedure and / or the Results and Discussion sections. Graphs and tables should be clear and logical. They should be freestanding and carefully labeled, such that the reader can understand them without referring to the text. Hence, you will have to choose figure captions and table titles carefully. You must number the figures and tables and include complete captions. Note that "x vs. y" or anything similar is rarely appropriate -- captions and titles should be descriptive of the experiment. It may be more instructive to include the origin of one or both axes in your plots, rather than using a highly magnified scale. Each graph should be properly scaled and drawn using standard data symbols and curve drawing techniques. An example is given below. You may merge the figures into the text or place them at the end of the respective sections. If you do the latter, the order of appearance of the graphs, tables, and figures should parallel the order of discussion. The text should reference the appropriate figures and tables by number rather than by title.

Oral Reports

Objective:

To provide students with some experience giving short oral presentations of their results, as well as to judge their understanding of the material that is being reported.

Background:

Motivation: Oral presentations are a cornerstone of communications between engineers and supervisors, management, and others. In many cases the oral report will be the only, or at least the most important, mode of information transfer. In fact, career advancement after the first three years on the job is closely linked to one's ability to communicate ideas orally. Therefore, it is important for students to develop skills for communicating in this format.

General Format: The general format of the oral reports is as follows:

1. The presentation will be given individually to the instructor and the TA; no other classmates will be in the room.

2. Use visual aids to explain the results of the lab. These will generally be 8.5" x 11" overhead transparencies. Choose font sizes (*e.g.* 18-24 pt) that could be read by an audience in a small conference room. **You will turn in one paper copy of the visuals you use**. Do not bring copies of your visuals for the reviewers to follow along--this is not generally appropriate for oral presentations, but is sometimes done for workshops.

3. The presentation is expected to take **15 minutes** for the midterm, **25 minutes** for the final. *You will be timed*; if you run over, you will be asked to bring your presentation rapidly to a conclusion. At 18 or 28 minutes you will be asked to sit down. Such an abrupt ending will probably force you to skip important points, which will impact your score. The instructor and TA will try to withhold questions until the end of your talk in order that your time adherence can be judged, but they may interrupt briefly to ask for clarification if the point in question seems important. This is similar to how semi-formal oral presentations occur in the real world. Hence, you should shoot to stay *under* the time allotment, and leave an extra minute or two buffer to allow for interruptions or onsets of "verbosities" caused by nervousness.

4. The presentation should be treated as though you're reporting the results to your engineering supervisor or clients who asked you to perform the work (or at least approved a proposal from yourself to perform the experiment). Hence, they will be familiar with the general concept, but not the details, of your work. You should assume that they may have forgotten many of the basic facts underlying the work, and so you should *briefly remind* them of all *important* characteristics and features of the apparatus / measurements.

5. The instructor and TA will make notes regarding strengths and weaknesses of your presentation. Try not to let the note taking fluster you, especially if you notice it when you're stumbling a bit. Even at these times, the comments are often simply notations for questions to ask later or simple suggestions for improving the rough parts. The comments are the principal mechanism for feedback about your presentation, hence, the need for the notes.

6. Some additional comments and a copy of the evaluation form appear on the following pages. Your presentation will be stronger if you read them.

Discussion of Content:

It is strongly recommended that you have <u>at least</u> one overhead in each of the following areas:

Title, including lab participants and date

Introduction: Motivation/objective and overview/outline

Schematic(s) of equipment

Figures showing results

Conclusions / Summary / Recommendations

The introduction is very important in an oral presentation. You must get the audience's attention and get them thinking about the information you are going to present. Don't dive right into the results of your lab. Chances are, your supervisor may have forgotten many of the details of what it was he asked you to do, or some members of the audience may not be familiar with your experiment in the first place. As you would do in an abstract, try to allude to the major points you want the audience to get out of your talk.

Expect to spend nominally 1.5 to 2 min. per slide, probably less for the title and outline slide (if you use one). This isn't a hard rule, but it's a good guideline. Any less time suggests that either the topic doesn't warrant a visual in the first place or you're going through it too fast. If you talk too fast, the audience will not be able to digest the information quickly enough, and will get the impression that you are presenting them with a flashcard show. If you have to spend more than two minutes, the visual is generally too complicated. Typically you'll have to simplify the experimental apparatus schematic from what you would put in a written report--your audience won't have time to study the overhead as closely as they would the printed version, and you almost certainly won't have time to discuss all of the instruments and data acquisition procedures. Try to boil the setup and procedure down to the essential pieces, and point those out. You may be able to spend shorter amounts of time on some subsequent result graphs if they are very similar to ones you have presented earlier, <u>and</u> if the point you are really trying to make is about the trend of the graph, not its details.

Make use of word slides to provide outlines, transitions between points, and summaries. Note, however, that the viewgraphs should appear in outline form as a guide to your presentation, not as transcripts for your talk. DO NOT SIMPLY READ YOUR VIEWGRAPHS BACK TO THE AUDIENCE. They will get the impression you are conducting an elementary school class. Also, you may wish to prepare notes for your presentation, but don't prepare a transcript. If you do, you'll probably have poor eye contact, and it won't come off very naturally. Along the same lines, don't expect your audience to do a lot of reading -- you want them to listen to the discussion you are providing which further explains or supports the points summarized on the overhead. You don't want them reading point A when you are discussing point B or vice versa. A good rule of thumb is 10 lines of text maximum per slide; most often, fewer are used.

The majority of your time should be spent discussing the results of your experiment, which should be presented graphically, just as you would in a report. Chose axes and scales that allow you to easily see important trends in your data. Don't simply connect the dots, and make certain the axes are properly scaled. Include error bars whenever possible. Often you will want to show several curves on the same set of axes, because the point(s) you will be trying to make will have to do with how the characteristic behavior of a piece of equipment changes as you change a certain parameter. In general, avoid using more than three or four curves per plot; if you really want to compare more curves, a useful trick is to present the first slide with three curves, then use a transparency to overlay additional curves (possibly using color for easy identification) onto the first set of axes. (Don't forget to put something on the overlay so you can line them up!) Discuss trends indicated by your data, and important conclusions that can be drawn from them. Answering questions of what the results imply and why the curves behave this way often provides the physical picture to the audience, which will convince them to believe your data/explanation. For example, if a curve appears linear, explain why you expect that kind of response; if it appears to roll-off after a certain level, explain what effect you think causes such behavior. Extrapolations of the data to other regimes often lead to useful physical insights, but be careful to justify why one would expect such an extrapolation to hold.

In all cases, make sure you point out connections between the current graph and things you have previously presented or things that are yet to come. Sometimes explanations of trends in graphs are easier to follow if you refer back to a schematic of the apparatus/device and sometimes they're easier to follow if you show governing equations. You'll have to decide the best way to clearly and concisely make your point.

End your talk with a summary or conclusion slide. The following phrase is often used to describe the organization of oral presentations: "Tell them what you're going to tell them, tell them, then tell them what you told them." These correspond roughly to the introduction, discussion of results, and conclusion sections. The conclusion should be concise (1-2 minutes), but it is essential that you restate the **main points** that you want your audience to go away with from your talk. State your conclusions in full sentences verbally but use bulleted phrases on your viewgraph. Avoid going overboard with details. There should be some sense of closure that relates back to what you said in the introduction.

Summary of Scoring:

A breakdown of how you will be scored is shown on the following page. To reiterate, we will be making notes during your presentation, both on things that you do well as well as on things that need improving. Our goal is to help you make better oral presentations, not to make you nervous.

ORAL PRESENTATION EVALUATION

STUDENT: ________________________________
OVERALL SCORE: _________

Scoring for each section is in percentages in increments of 5; point weighting of each section is shown at right. For each section, the percentage score corresponds to the following:

Exceptional (85-100): performance above expectation;
Good (65-80): meets most expectations;
Weak (60): does not meet expectations.

SECTION	SCORE and COMMENTS	POINTS
Intro. and Problem Statement		/20
(e.g., provides clear statement of the goal of the experiment and reasons for doing it)		
Apparatus and Measurements		/10
(e.g., clear indication of what and how measurements were made, equipment used)		
Discussion of Results		/20
(e.g., explains what results were obtained, what they mean, and how		

they fit together)		
Conclusions		/15
(e.g., discussion of conclusions which can be drawn from the data and how they relate to the goal of the experiment)		
Visual Aids		/20
(e.g., clear and useful graphs in presentation; readable text slides; right amount of material on each slide)		
Speaking Style		/15
(e.g., audience contact, clear flowing presentation, etc.)		

Kittelson, D. B. Laboratory Manual, Mechanical Engineering 4431: Energy Conversions Systems. 15 Oct. 2002. Mechanical Engineering, University of Minnesota. 7 Feb. 2003.