

## **AC 2007-873: COMPUTER SIMULATION OF THERMODYNAMICS EXPERIMENTS**

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# Computer Simulation of the Thermodynamics Experiments

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## Abstract

The discussion about effectiveness of online courses and technology-based instructional strategies in learning environments still continued since the late 1960's when several universities began offering distance learning of engineering courses via televised instruction. More and more educational units strive to deliver distance courses because the technological innovations have open up new vistas to be explored in imparting education. Probably, there is not a universal approach how to use the Internet to introduce the various scientific disciplines. One of the biggest hurdles to offering distance courses to undergraduates is requirement of the laboratories. This paper presents an example of the computer simulation of the thermodynamics laboratory experiments for undergraduate students. It also presents some ways in which each student should do independent laboratory work and should not obtain extraordinary help on this work that will have being on his/her true grade. It provides a further step into the realm of introduction the thermodynamics course on the Internet.

## Introduction

Today, educational institutions are increasing their use of the computer based technology in the teaching environments<sup>1</sup>. There are various ways how to use this technology, but basically the computer-mediated learning can be used as single teaching medium or it can be used in combination with traditional classroom experience<sup>2</sup>. Online classes have advantages and disadvantages<sup>3</sup>. This is actually means that there is not a universal approach how to use the internet for education, especially for courses with laboratories. There are still discussions how to utilize the distance education to undergraduates when the laboratories are involved<sup>4</sup>. Meanwhile some universities are using the lab-based courses on the internate<sup>5,6,7,8</sup>. There is an indication of developing simulation in the laboratory classroom environment for thermo science course<sup>9</sup>. Our own experience in using a combination of the two-way audio/visual system for long distance education together with placing the course notes on the electronic Blackboard shows better results than traditional classroom teaching. Using the Blackboard allows student to print out the class notes and preliminary study the material before class session begins. But this experience pertained to the Statistics course that does not have laboratories.

The Thermodynamics class, MCT 3150, in the Engineering Technology program requires laboratory work after the theory section of the class is completed. These laboratories are completed in group format and currently account for 25% of the grading for the entire class. Groups are divided up; the laboratories are performed, and upon completion, reports in writing and oral presentation take place. These written report and presentation represent each group as a whole. At completion, each student in the group receives the same grade. This current grading procedure, to some, may seem unfair. Students believe they did more work than others, and the final grade should reflect this work.

The objective of the computer simulation of the thermodynamics laboratory experiments is to give each student the ability to become familiar with the set up before attempting the hands on laboratories and to perform experiments with individual data. It also opens the way to introduce the course on Internet for long distance learning. Each student can be held more responsible for his or her own grade. With this simulation, the instructor can give on-line quizzes or homework related to the laboratories that are completed at the end of the semester. Upon implementation, the grading structure and the laboratories should have different grading sections. An example would be 10% hands on laboratories, 5% presentation, and 10% towards submitted work to the simulation. This can be altered depending on the university policies and instructor grading procedures.

The computer simulation represents experiments originally designed for the Technovate Air Conditioning and Refrigeration Education System. This computer simulation was designed as an aid to the teaching of the Thermodynamics class and to show the procedure and guidelines to perform, in a professional manner, the laboratory experiments. Each page for the experiment was designed along with setting up to 20 different sets of data to be used with the simulation. A window was formatted into the program to allow an instructor to have access to check submitted solutions. From this window, the instructor can change the data as needed. The combination of Excel together with Visual Basic for Application is used to design the computer simulation.

The simulation is available on line and can be viewed, or the instructor can post it on the electronic Blackboard.

### Air Conditioning System

The Air conditioning and Refrigeration Learning System, Model 7086, is a unique type of learning system. It is constructed to easily and conveniently allow all phases of an air conditioning or heat pump cycle to be observed, analyzed, changed or made to malfunction. It is the most efficient way as of yet to learn the principles of air conditioning and refrigeration. Model 7086 is fully operational and is identical in many aspects to commercial air conditioning and refrigeration equipment using Refrigerant in a closed compression cycle.

Students can observe changes occurring in the system. Glass tube “windows” in the inlet, center and outlet sections of the evaporator and condenser coils allow students to observe refrigerant behavior both as a liquid and a gas. Operating conditions may be varied over a broad range of parameters by opening and/or closing the valves that are strategically located throughout the learning system. These valves, along with electrical faulting switches, allow the introduction of operating malfunctions that could conceivably occur in the field. Operation conditions can be varied by changing speeds of the fan motors, under-or over-charging refrigerant, or introducing excess oil into the system. Students then diagnose and correct these faults.

Paired thermometer and pressure gauges are located at strategic points in the cycle. A flow meter to measure rate of refrigerant flow is located in the liquid line before the metering devices. The student therefore can gather data on what is taking place both electrically and mechanically in the cycle. He/she can easily understand and master the cycle operation. Theoretical comprehension is further enhanced because the electrical circuit panel is diagrammed and the windowed cabinet on the system’s reverse side permits this diagram to be related to the actual circuit wiring.

The Air Conditioning and Refrigeration “Learning System”, Model 7086 is a fully operational unit designed for classroom demonstration and student experiments. All components (except the compressor) are mounted on a vertical panel so the functions and configurations may be studied separately. The learning system complements any text on air conditioning and refrigeration. The “Learning System” is designed for lecture-demonstrations, for student experimentation, and for learning the diagnosis and correction of a wide range of malfunctions, Figures 1,2,3, and 4.

## Experiments

The following experiment set-ups are exactly what will be used for the simulation. They are presented as they appear in the simulation. All tabulate data along with a  $\pm 5\%$  error are provided on line.

The following is a list of the provided experiments:

1. Determination of Superheat
2. Work, Energy and Power
3. Condenser Heat Rejection
4. Evaporator Heat Absorption
5. Evaporator Heat Absorption (alternate method)
6. Time to reach steady state condition
7. Thermostatic Expansion Valve Operation

## Examples of Experiments

### Experiment 3 – Condenser Heat Rejection

Purpose: To calculate the heat (kJ/s) rejected by the condenser into the air.

Definition: Heat is transferred from the hot refrigerant vapor to the condenser tubes, (shown below), fins and finally to the air. In steps 2 through 5, this rate of heat rejection is calculated by measuring the amount of heat picked up by the air assuming refrigerant is in the system.

Procedure:

- (1) You have started the system and allowed the unit to run for 5 minutes to stabilize.
- (2) You take multiple measurements at different locations on the condenser and come up with an average velocity of 5.074 m/s. The area of the fan is calculated to be  $.07297\text{m}^2$ , and is known to be  $.3048\text{m}$  diameter.
- (3) You now take measurements of the air temperature entering and leaving the condenser. Air in is \_\_\_\_\_, and air out is \_\_\_\_\_.
- (4) Calculate the mass flow rate kg/s of air flowing past the condenser as follows:
  - a.  $\text{m}^3/\text{s}$  = (air velocity) (area of fan)
  - b.  $\text{kg/s}$  =  $(\text{m}^3/\text{s})$  (density of air)
  - c. Density of air  $\sim 1.2 \text{ kg/m}^3$
- (5) Calculate the heat rejected by the condenser as follows:
  - a. Heat rejected =  $(\text{kg/s})$  (specific heat of air [Cp]) \* (Temperature difference of air)
  - b. Heat rejected = kJ/s
  - c. Specific heat of air [Cp] = 1.008 kJ/kg K

#### Experiment 4 – Evaporator Heat Absorption

Purpose: To calculate the heat (kJ/s) absorbed by the evaporator from the air.

Definition: Heat is transferred from the hot refrigerant vapor to the condenser tubes and fins and finally exhausted to the air. Assuming refrigerant is in the system, the same principles apply in the evaporator heat absorption as in condenser heat rejection. The only difference is that the process is reversed. Theoretically, in a completely insulated system, the difference between the heat given off by the condenser and the heat gained by the evaporator would be the energy added to the system to run the compressor. That is, the condenser heat loss should be the sum of the evaporator heat absorption plus the energy needed to run the compressor motor.

Procedure:

- (1) You have started the system and allowed the unit to run for 5 minutes to stabilize.
- (2) You take multiple measurements at different locations on the evaporator and come up with an average velocity of 5.074 m/s. The area of the fan is calculated to be  $.07297 \text{ m}^2$ , and is known to be  $.3048 \text{ m}$  diameter.
- (3) You now take measurements of the air temperature entering and leaving the evaporator. Air in is \_\_\_\_\_, and air out is \_\_\_\_\_.

- (4) Calculate the mass flow rate kg/s of air flowing past the evaporator as follows:
- $m^3/s = (\text{air velocity}) (\text{area of fan})$
  - $kg/s = (m^3/s) (\text{density of air})$
  - Density of air  $\sim 1.2 \text{ kg/m}^3$

(5) Calculate the heat absorbed by the evaporator as follows:

- Heat absorbed = mass flow rate of the air (kg/s) (specific heat of air [Cp])
- Heat absorbed = kJ/s
- Specific heat of air (Cp = 1.008 kJ/kg K)

Set up for on line computer simulations of experiments.

- Student to log on using Student ID and full name.
- Explanation of the equipment that will be used during the labs. (Provided by Instructor)
- Introduction of the procedure to perform the experiments and how to use the system. (Provided by Instructor)
- The type of the refrigerant will be specified for student reference. (Provided by Instructor)
- Student inputs which experiment he/she was assigned, then the program is directed to the correct experiment for completion.
- Once into the assigned experiment, an explanation of what is being looked for will be given, the student will then calculate what is asked for in the explanation and have an area to submit their calculations. (Multiple data provided by Instructor)
- After submitting calculations, student will see the proper calculation and cannot re-enter an answer. (Proper format of calculation provided by Instructor)
- Log out and proceed to next assignment by re logging in. (Note: student will not be allowed to enter same experiment twice)
- Instructor will have a control panel that will tabulate all submitted solutions that only he will be able to access.
- Submitted solutions will appear red for incorrect, and green for correct on instructors control panel with  $\pm 5.0 \%$  accuracy.

Examples of set of data for experiment 3

		First Blank	Second Blank		Answer must be between	
Experiment 3	Average Velocity of air passing over Condenser	Temp. in average (condenser) (°C)	Temp. out average (condenser) (°C)	Answer (KJ/s)	+5% Answer	-5% Answer
	V=5.074 m/s	15	10	2.24	2.35	2.13
Condenser Heat Rejection		16	10	2.687	2.82	2.55
	Fan Diameter is .3048m	17	10	3.13	3.29	2.98
	Area = .07297m <sup>2</sup>	18	10	3.58	3.762	3.40

Calculate the kg/s of air flowing past the condenser:		19	10	4.037	4.234	3.83
a. $m^3/s = (\text{air velocity})(\text{area of fan})$	Density of air (given)	20	10	4.48	4.70	4.25
b. $kg/s = (m^3/s)(\text{density of air})$	$\rho \sim 1.2 kg/m^3$	21	10	4.93	5.17	4.68
		22	12	4.48	4.70	4.25
Calculate the heat rejected by the condenser:	Specific heat of air (given)	23	12	4.93	5.17	4.68
a. Heat rejected = $(m \text{ air})(C_p \text{ of air})(\Delta T \text{ of air})$	$C_p = 1.008 \text{ kJ/kg K}$	24	12	5.37	5.648	5.10
		25	12	5.82	6.11	5.53
		26	12	6.27	6.58	5.95
		27	14	5.829	6.11	5.535
		28	14	6.27	6.581	5.95
		29	14	6.72	7.05	6.38
		30	14	7.16	7.52	6.80
		31	14	7.61	7.99	7.23
		32	16	7.16	7.52	6.80
		33	16	7.61	7.99	7.23
		34	16	8.06	8.46	7.66

Similar set of data is provided for all other experiments.

## Conclusions

This project created value for the Thermodynamics course. This was done by clarifying existing experiments for the students using the on-line tool before entering the laboratory. The computer simulation of the Thermodynamics laboratory experiments is the first but important step to introduce the Thermodynamics course on line and for the long distance education.

However, the placement of the equipment description on line, the computer simulation and the following exercises using computerized data are considered only as preparation for the actual laboratory experiments. Student should be familiar with the equipment itself and how actually to perform the experiments. Student also should be involved in troubleshooting. Computer simulation definitely will reduce the time necessary to actually perform laboratory experiments, increase the effectiveness of mastering the course. This also will create the climate where each student will be responsible for his/her own grade.

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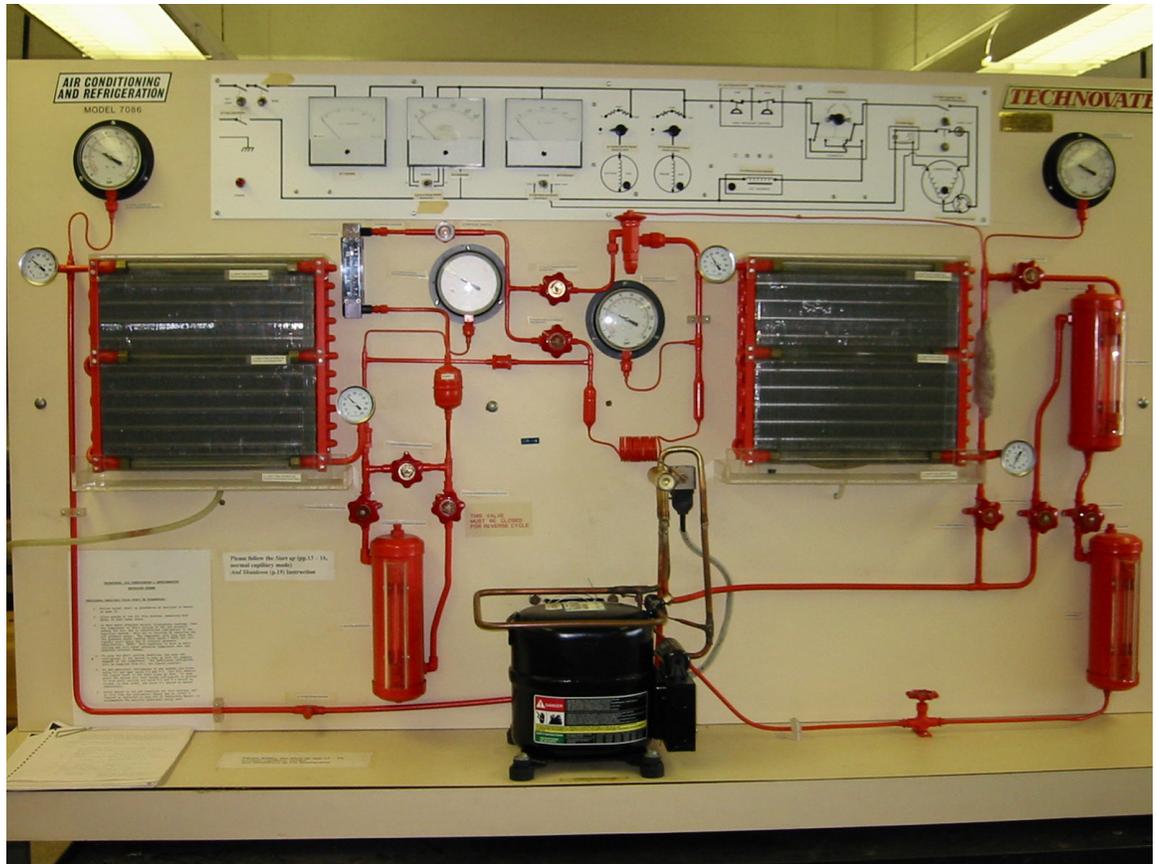
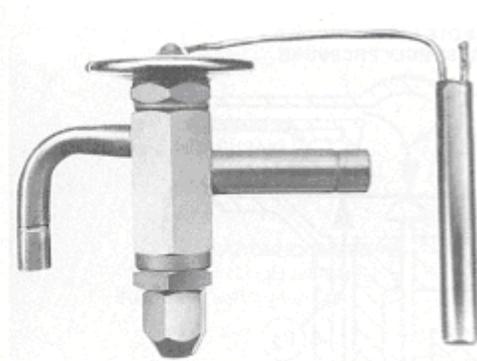
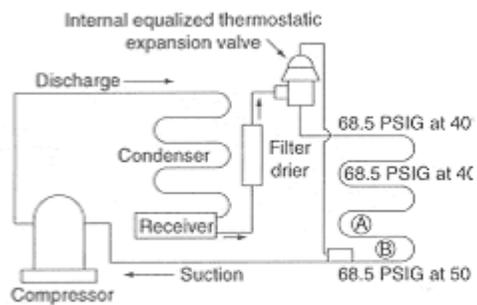


Figure 1. Technovate Air Conditioning and Refrigeration Learning System, Model 7086.



Thermostatic expansion valve  
(Courtesy of Alco Controls Div.,  
Emerson Electric Co.)



Basic refrigeration schematic

Figure 2. Thermostatic Expansion Valve

Figure 3. Basic Refrigeration Schematic

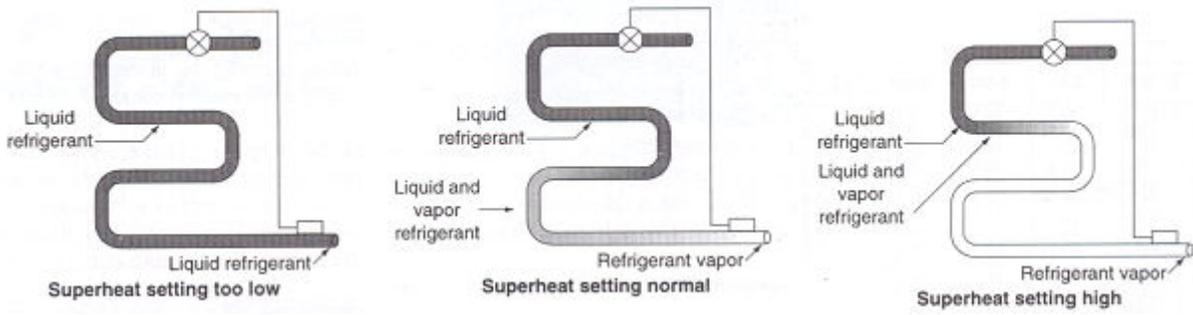


Figure 4. Relationship of Superheat and Evaporator Capacity