
AC 2012-4715: "MINI" RESEARCH PAPERS FOR ENHANCING HEAT TRANSFER LEARNING OBJECTIVES

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“Mini” Research Papers for Enhancing Heat Transfer Learning Objectives

Abstract

Teaching courses such as heat transfer can prove challenging. It is difficult to cover the large quantity of material in the time frame that a single semester allows. Working many example problems significantly helps with student’s understanding of the topic but diminishes the lecture time and hence, limits the amount of material that can be covered.

One solution to help with challenging and material laden courses (i.e. Thermodynamics, Fluids, Heat Transfer, etc.) is to assign a significant number of homework problems. However, the effectiveness of homework has been lessened by the student’s availability of most solution manuals on line. Additionally, large quantities of homework for the students transfer to a large time commitment on already taxed professors for grading. Therefore, the question is: how do you increase the amount of material absorbed without increasing the students’ workload excessively?

This paper deals with “mini” research papers assignments. The term “mini” research papers refer to papers less than 5 pages. The papers should contain the important aspects of a full research papers, namely: introduction, theory, procedure, results, conclusions and a reference requirement of at least three peer reviewed papers.

The case study papers specifically address a certain concept in the broad field of heat transfer. For heat transfer, there are three sub-categories that stand out; conduction, convection and radiation. A mini research paper was assigned for each topic. The subject of each research paper included data taken in class from a simple heat transfer experiments. This greatly helped

the students to visually experience the practical side of the theory they learned in lecture. Students were placed in teams of two to three. Each team was given the same data for the problem. Using teams allowed students to collaborate and learn from each other while working on the paper and it helped to limit the demand on the instructor.

The “mini” research paper experiments used were very inexpensive but cemented aspects of difficult concepts. Students were able to observe actual heat transfer topics, a benefit over just doing homework. The actual graphs are plotted on the same graphs as the theoretical curves and the students are to comment on the similarities and differences. Some university engineering programs have an adjacent heat transfer laboratory class to help students visualize the various topics, but some do not.

Having the assignment be “mini” research papers instead of actual research papers lessens the work impact but at the same time increasing the students’ writing opportunities. This active learning technique motivates the students to become interested in the practical aspects of the three experiments conducted in this class.

Introduction

One of the areas in which many engineering students are deficient is their writing and communication skills. Although engineering students are required to take several laboratory type classes, which include laboratory reports, and technical writing type English classes, there still exists the need for more writing opportunities. This paper deals with one method to give the students more opportunities to write research papers without significantly increasing their work load. This method also does not significantly increase the grading load of the instructor. Being able to adequately research a topic is also an important tool in an engineer's arsenal. This teaching method promotes active learning as the primary learning objective.¹ The research data is taken in class with active participation from the students.

The term "mini" research papers refers to research papers limited to five pages. Although short, each research paper must include the basics of a full paper: introduction, theory section, procedures, results, conclusions and references. The course used to develop this procedure was undergraduate Heat Transfer. Three simple experiments were conducted during class and the data taken was given to the entire class. The students were divided into small groups and allowed two weeks to write the report.

Learning Objectives

There are three major learning objectives as well as some minor ones. The major objectives are as follows:

- To further develop the engineering students' technical writing abilities.

- To expand the students' ability to thoroughly research a technical topic.
- To enhance the learning of the subject at hand, in this case, heat transfer with a “hands on” technique.

These objectives are achieved by keeping the groups small (two to three students per group) to ensure every student must contribute significantly to the research paper. By posing an engineering problem to the students without giving them the solution procedure, allowed the students to struggle on their own and discover how to systematically solve the problem. This “problem based learning style” strongly enforces the material in the students' intellect.²

Other objectives include working with others in groups. There exists a perception that engineering students lack personal skills in social situations. Many times perception is reality. By working in groups, students develop valuable inter-personal skills that will greatly aid them in the future. Also in engineering, a students' ability to develop solutions to complex problems is extremely important for their future. By allowing them to struggle with a problem, develops these types of skills.

“Mini” Research Project Guidelines

To limit the amount of extra work for the students and instructor, the “mini” research papers were limited to five double spaced pages excluding cover page, table of contents, references and appendixes. Therefore, there existed a premium on brevity. Other requirements were 12 point font and Times New Roman type face. This ensured the authors did not cram 20 pages into five by altering the font size and style. A minimum of three peer reviewed articles were required for

a reference requirement. Other references such as the heat transfer text book was allowed, but the text book did not count toward the three peer reviewed articles requirement. This requirement was very important. The university library has an online system to aid students in researching topics such as the ones studied in these papers. Many undergraduate students don't know the difference between a peer reviewed article and an internet site such as Wikipedia. This process tries to teach that distinction.

Experiments

Since there are three major topic areas in heat transfer, conduction, convection and radiation, three “mini” research papers were assigned. A few requirements from the instructor's point of view were as follows:

- The experiments must be simple enough that they could be conducted during a one hour class period.
- The material used for each experiment must be relatively inexpensive.
- The experiments should be easy to understand and relatively easy to conduct.

The heat conduction experiment dealt with contact resistance. A scrap steel round bar had one end turned smooth on a lathe (smooth end) and the other end cut with a torch (rough end).

Figure 1 shows each of these two ends.

The rod was drilled with five equally spaced temperature wells (1/8 inch diameter) to allow a K-type thermocouple to measure centerline temperature of the rod. One end of the rod was placed in contact with a bronze plate resting on a hot plate. Figure 2 shows this experimental setup.

After the five thermocouple well temperatures were measured and the base plate temperature collected, the rod was flipped over and the temperature measurements repeated.



Figure 1: a) smooth end of the rod; b) rough end of the rod.



Figure 2: Conduction experimental setup

This data was plotted and fit with a 4 degree polynomial trend line. The constant term of the polynomial gives the temperature of the bar at $L=0$. By taking the derivative of the polynomial, first degree term gave the heat transfer to the rod via Fourier's law,³

$$q = -Ak \frac{dT}{dx}$$

The first degree term at $L=0$ becomes the slope at the interface, giving the heat transfer across the interface, and therefore the contact resistance can be calculated by the following equation,

$$R_c = \frac{T_A - T_B}{q_x''}$$

The heat convection experiment used the same hot plate and bronze plate. A high velocity fan provided the force convection fluid flow, measured with a handheld anemometer. Figure 3 shows the convection experimental setup. Temperature was measured at several points on the hot plate. With the air temperature and velocity information, Reynolds number and Nusselt numbers can be calculated along the length of the plate, leading to the convection coefficient.

With the convection coefficient and the average temperature of the plate, the heat transfer can be found by Newton's Law of cooling,⁴

$$q = Ah(T_{\infty} - T_s)$$



Figure 3: Convection experimental setup.

The final experiment dealt with radiation heat transfer and natural convection.^{5,6} Three metal plates were painted and used as radiation surfaces. Two were painted flat black and the third was painted satin white. Figure 4 shows the experimental structure created to separate the plates. The same hot plate was used to heat one of the black plates while temperatures were taken of each plate. By conducting an energy balance over each plate, the emissivities were calculated and compared to published results.

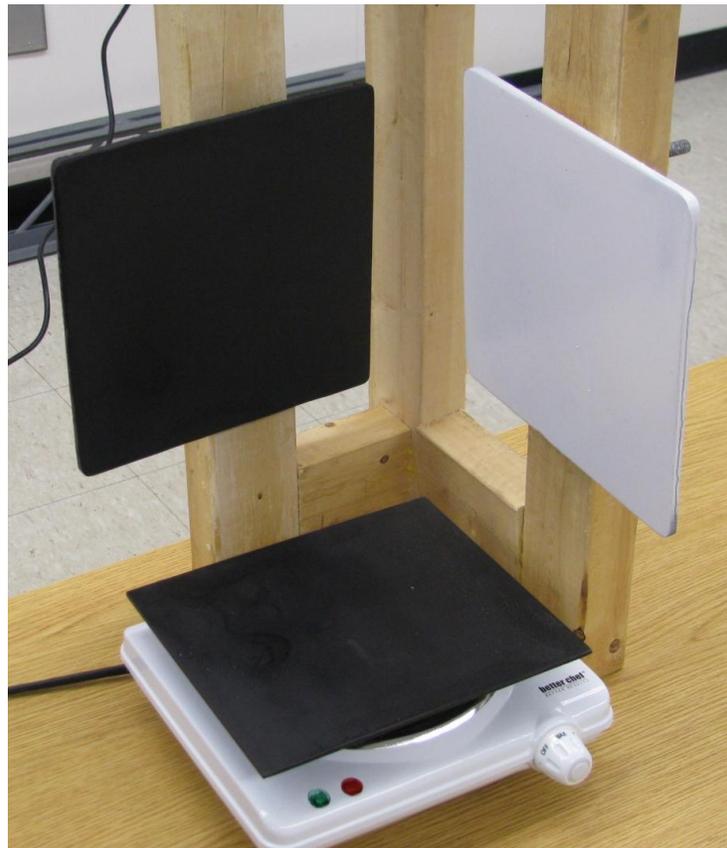


Figure 4: Radiation experimental setup

Conclusions

These experiments were very inexpensive but gave the students valuable insight into experimental methods and data collection. The first set of papers was very inadequate from a technical paper standpoint, but the second showed a big improvement over the first paper. The improvement continued on the third set of papers. The third set was very acceptable, for the most part. The articles cited by the student transformed from non-technical internet sites to actual peer reviewed articles. Their abilities to actually research articles adequately, drastically improved from the first paper to the last. Student reviews showed that many of the students believed they learned more in this course than similar courses they have taken.

Giving engineering students more opportunities to research engineering topics and write technical papers were the main goals of these “mini” research papers. To achieve these goals while not significantly adding to the instructor or the students’ work load is the significant outcome. While certain classes might have laboratory classes associated with them at certain universities, they may not at others. The students can still get a taste of this learning opportunity with this method of active learning.

References

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