The Engineering of Everyday Things

Gerald Recktenwald and Robert Edwards

April 2007 Pacific Northwest ASEEE Meeting, Washington State University, Pullman

Core Concepts – Everyday Hardware

We are beginning a research project involving laboratory exercises for core undergraduate classes in the thermal and fluid sciences. Students perform experiments on everyday technology such as a hair dryer, a bicycle pump, a blender, a computer power supply and a toaster, or very simple hardware such as a tank of water with a hole in it, or a pipe section with a change of area. The equipment is chosen because it is familiar to students, or at least the physical principles of operation are easy to understand. The laboratory exercises are designed to engage students by showing the everyday application of their coursework, and to expose their misperceptions about the engineering principles at work.

Table 1 lists the seven experiments we are designing as part of the Engineering of Everyday Things curriculum. These experiments cover core concepts in the thermal and fluid sciences curriculum in a typical BSME curriculum.

Table 1: Courses in the BSME curriculum supported by the experiments.

<table>
<thead>
<tr>
<th>Experiment</th>
<th>Course</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Thermocouples</td>
<td>Fluid Mechanics</td>
<td>Heat Transfer</td>
</tr>
<tr>
<td>Blender</td>
<td>Tank Draining</td>
<td>Hair Dryer</td>
</tr>
<tr>
<td>Bicycle Pump</td>
<td></td>
<td>Power Supply Fan</td>
</tr>
</tbody>
</table>

Figure 1: Two tank configurations for the tank-draining experiment. The tank on the right has a cross section area that varies with elevation.

A hydraulics experiment involves two water-filled tanks as depicted in Figure 1. Both tanks are initially filled to the same level. A pressure transducer is located opposite the hole, and also a distance H from the base. The jet of water issuing from the hole is the “jet” of water. A digital camera is used to measure the jet trajectory (like Nalbant and others [13]) and a pressure transducer is used to measure the fluid height (like Lihy and FWizy [9]).

The experiment is designed to cause students to confront the misconception that pressure is due to the “height of water” above the plane at which the pressure is measured. The experiment also provides an application of the energy equation, and it introduces the concept of a linear flow coefficient.

Pressure transducer data is recorded by a low-cost USB-based data acquisition system. The LabVIEW controlling the data collection displays a large clock. The computer monitor is arranged as shown in left half of Figure 2 so that the camera can record both the time and the arc of the water issuing from the hole in the side of the tank. A sequence of photographs, a table, a new curve values is constructed. Application of the energy equation shows that \( H - \frac{c^2}{2g} \) where \( c \) is a constant and \( H \) is the height of the free surface measured from the elevation of the hole. Figure 2 shows the measured \( H(t) \) and the curve fit of \( H(t) \) to the data.

Figure 2: Example of data from the tank-draining experiment (left) and plot of travel time for the data from the experiment.

Table 2 shows a categorical grouping of reasons students gave to justify their prediction that the water temperature in the blender would increase. The “M” tag identifies the three largest groups of reasons, all of which involve a mechanistic or thermodynamic explanation for the increase in temperature. Only a very small minority (2 out of 25) invoked the principle of work or energy. To be fair, the students’ only prior exposure to thermodynamics was in their physics courses. The responses in Table 2 show that it is not enough to explain that the first law of Thermodynamics can be used to account for energy transfers without reference to the underlying physics. Students do not appear to be using a framework with which they can systematically explore the energy content of the process.

Hair Dryer

A hair dryer is a good example of an open thermodynamic system, and it provides a concrete example of the application of an energy balance. Edwards has described how this concept can be used to teach the first law of thermodynamics [1].

Figure 3 shows the hair dryer apparatus we are using to demonstrate core concepts in heat transfer. To the left, and downstream of the hair dryer exit is a movable holder for three thermocouples as well as a device to rotate the streams. The hair dryer exit is another thermocouple. The thermocouple signals are recorded by a four-channel, USB-based data acquisition system. The data in Table 2 shows a categorical grouping of reasons students gave to justify their prediction that the water temperature in the blender would increase. The “M” tag identifies the three largest groups of reasons, all of which involve a mechanistic or thermodynamic explanation for the increase in temperature. Only a very small minority (2 out of 25) invoked the principle of work or energy. To be fair, the students’ only prior exposure to thermodynamics was in their physics courses. The responses in Table 2 show that it is not enough to explain that the first law of Thermodynamics can be used to account for energy transfers without reference to the underlying physics. Students do not appear to be using a framework with which they can systematically explore the energy content of the process.

Table 2: Explanations given by students to justify their prediction that the temperature of the water would increase when the blender was turned on.

<table>
<thead>
<tr>
<th>Tag</th>
<th>students</th>
<th>Explanation</th>
</tr>
</thead>
<tbody>
<tr>
<td>M1</td>
<td>10</td>
<td>Pressure increases because work is done on the fluid</td>
</tr>
<tr>
<td>M2</td>
<td>8</td>
<td>Water vaporizes and there is evaporation</td>
</tr>
<tr>
<td>M3</td>
<td>7</td>
<td>Water cools the air and the air cools the water</td>
</tr>
<tr>
<td>M4</td>
<td>3</td>
<td>Mechanical or kinetic energy is transferred</td>
</tr>
</tbody>
</table>

When the results of the experiments are combined with class discussion and feedback, the following outcomes are achievable:

- The students’ understanding of the fundamental principles of thermodynamics is improved.
- The students are more engaged in the laboratory exercises.
- The students’ attitudes and motivation toward the subject improve.
- The students’ understanding of the material is improved.
- The students are better prepared for future courses.
- The students are better prepared for future careers.

Figure 3: Photograph of the prototype hair dryer apparatus (left). Representative temperature measurements downstream of the heater (right). Temperature in °C.

Assessment Questions

Data is being collected to determine if there are any differences in student learning and attitudinal responses according to gender, previous exposure to engineering, concurrent employment, and other factors. The assessment plan addresses how the experiments influence the following outcomes:

- The students’ understanding of the fundamental principles of thermodynamics is improved.
- The students are more engaged in the laboratory exercises.
- The students’ attitudes and motivation toward the subject improve.
- The students’ understanding of the material is improved.
- The students are better prepared for future courses.
- The students are better prepared for future careers.
- The students are better prepared for future employment, and other factors.

The preceding questions and their answers are the means to determining whether we reach our goal of improving student learning.

Table 3: Assessment Questions

<table>
<thead>
<tr>
<th>Question</th>
<th>Expected Answer</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Are there significant gender differences in student understanding of thermodynamics?</td>
<td></td>
</tr>
<tr>
<td>2. Do the laboratory exercises improve students’ quantitative reasoning abilities?</td>
<td></td>
</tr>
<tr>
<td>3. Do the attitudes of students toward the laboratory exercises differ by gender, ethnicity, previous exposure to engineering practice, concurrent employment, and other factors?</td>
<td></td>
</tr>
</tbody>
</table>

For more information, visit us: ocse. pse. edu

References