Poster presented at the 2007 Pacific Northwest Regional ASEE Meeting
Pullman, Washington

The Engineering of Everyday Things

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April 2007

1 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 that 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 developing as part of the *Engineering of Everyday Things* curriculum. Those experiments cover core concepts in the thermal and fluid science courses in a typical BSME curriculum.

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

Thermodynamics	Fluid Mechanics	Heat Transfer
Blender	Tank Draining	Hair Dryer
Bicycle Pump	Sudden Expansion	Toaster
	Power Supply Fan	

2 Pedagogy in Three Steps

Our approach is to cover the material three times:

1. In-class demonstration
2. Conventional lecture, with reference to the demonstration
3. Laboratory exercise

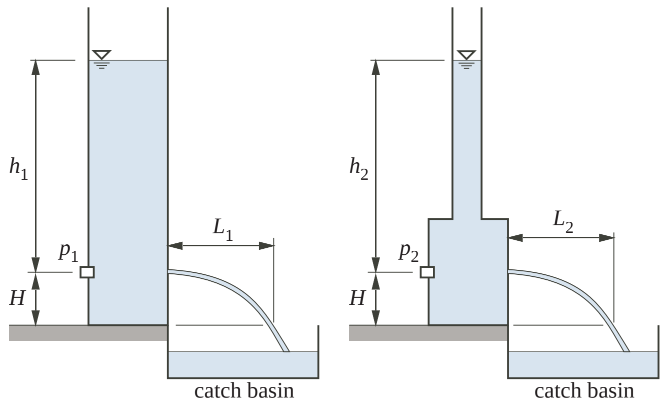


Figure 1: Two tank configurations for the tank-draining experiment. The tank on the right has a cross section area that varies with elevation.

Demonstration: The in-class demonstration is given *before* the students have attended lecture on the core concepts being covered. The demonstration is intended to pique the students' interests, and to expose their misconceptions about the core concept. We begin by explaining the apparatus without running it. Students are then asked to write down predictions of how the apparatus will respond when the experiment is conducted. We collect these responses and then run the demonstration.

Lecture: The middle step — lecture — is conducted as a typical class. Where appropriate, references to the in-class demonstration are made, but otherwise there is no strong attempt to teach to the demonstration.

Inquiry in the Laboratory: In the last step, students perform a one to two hour laboratory exercise. The effort in the lab is equivalent to one or two homework problems, but the emphasis is not on grading the student work. Students perform a guided-inquiry exercise to discover how the core concepts being taught are manifest in the behavior of the device. LabVIEW VIs are provided to students: the focus of the exercise is on manipulating hardware and collecting data, not on the details of data acquisition. We presume that students will have a separate course in instrumentation and data acquisition.

3 Tank Draining

A hydrostatics experiment involves two water-filled tanks as depicted in Figure 1. Both tanks have small hole in the side a distance H from the base. A pressure transducer is located opposite of the hole, and also a distance H from the base. The jet of water issuing from the hole follows a parabolic arc. A digital

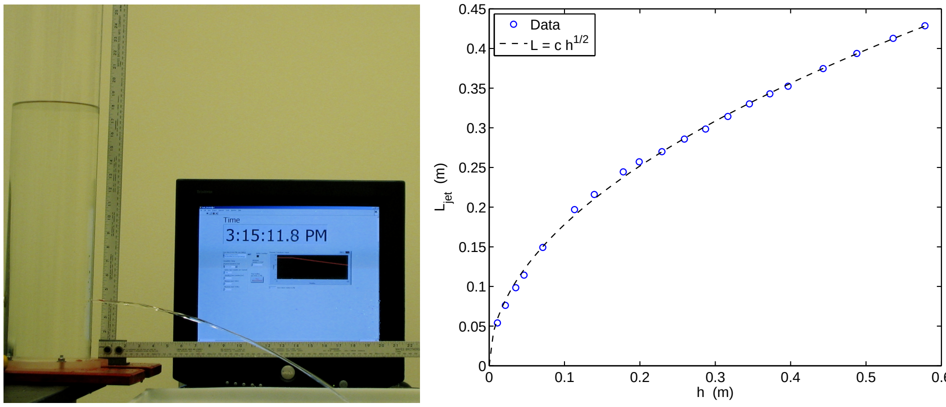


Figure 2: Photograph of the tank-draining experiment (left) and plot of $L = f(t)$ data from the experiment.

camera is used to measure the jet trajectory (like Saleta et. al [3]) and a pressure transducer is used to measure the fluid height (like Libii and Faseyitan [2]).

The experiment is designed to cause students to confront the misperception that pressure is due to the "weight of water" above the plane in which the pressure is measured. The experiment also provides an application of the energy equation, and it introduces the concept of a minor loss coefficient.

Pressure transducer data is recorded by a low-cost USB-based data acquisition system. The LabVIEW VI 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 jet issuing from the hole in the side of the tank. From a sequence of photographs, a table of L versus t values is constructed. Application of the energy equation shows that $L = c\sqrt{h}$ 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 $L(t)$ and the curve fit of $Lc\sqrt{h}$ to the data.

4 Blender

Figure 3 shows the kitchen blender experiment that is used to demonstrate equivalence of work and energy—a modern version of Joule's experiment.

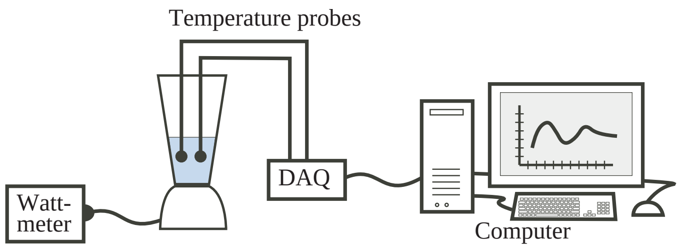


Figure 3: Equipment used in the blender experiment.

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

Tag	# of students	Explanation
W	1	Temperature increases because work is being done on the fluid
W	1	$dU = Q - W$, but $W = 0$ so "only heat energy is changing"
	2	An increase in pressure causes the water to heat up.
	4	Heat will be transfered from the electric motor.
M	9	The blender will increase the molecular motion of the water.
M	8	Friction between the blender blades and the water.
M	4	Mechanical or kinetic energy is transfered to the fluid.

In-Class Demonstration: The blender to filled to about one third of its volume. The water and blender are allowed to come into thermal equilibrium. Before turning on the blender, students in the class are asked to provide written responses to the following questions.

1. How will the temperature of the thermocouples change when the blender is turned on? Will the water temperature increase, decrease, or stay the same? Will the change be large or small?
2. Why will the temperature of the thermocouples change the way you predicted? Use formulas as well as words to explain your choice.

The blender demonstration was recently given to a Thermodynamics class taught by MME faculty at Portland State University. The class consisted of 27 undergraduate students in Mechanical Engineering, Civil Engineering, and Electrical Engineering. The demonstration was given *before* the principle of work and the first law of thermodynamics were discussed in lecture. Twenty-five of twenty-seven students said the temperature of the water would increase when the blender motor was turned on.

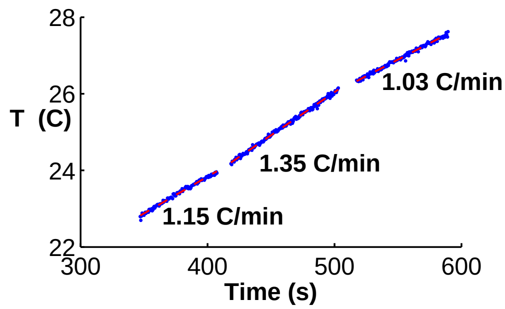


Figure 4: Measurements of temperature rise versus time for the blender at different speeds: *Chop*, *Puree*, *Chop*.

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 responses, all of which involve a mechanistic or microscopic explanation for the increase in temperature. Only a very small minority (2 out of 25) invoked the principle of work.

To be fair, the students' only prior exposure to thermodynamics was in their physics courses. The responses in Table 2 show that there is a need to explain that the First Law of Thermodynamics can be used to account for energy transfers without reference to the underlying mechanisms.

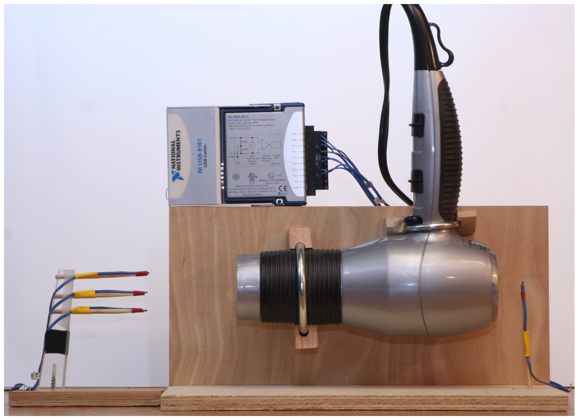
After the in-class demonstration, the blender was run at different speeds. Figure 4 shows the temperature data and least squares fits of straight lines to the temperature data. The differences in the rate of temperature increase are slight, but measurable.

5 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 apparatus can be used to teach the first law of thermodynamics [1].

Figure 5 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 moveable holder for three thermocouples. Upstream, and to the right, of the hair dryer inlet is another thermocouple. The thermocouple signals are recorded by a four-channel, USB-based data acquisition system connected to a laptop.

The first law of thermodynamics shows that if the heater power is constant, an increase in the fan speed will cause the exit air temperature to *decrease*. The data in The table of data in Figure 5 show that this is not the case. Holding the "heat" setting constant and increasing the fan speed causes the air temperature to increase because the heating element is thermostatically controlled. In other words the thermal boundary condition for the heating element is constant



	Heater Setting		
Fan	Cool	Warm	Hot
Low	25	46	52
High	26	55	70

Figure 5: Photograph of the prototype hair dryer apparatus (left). Representative temperature measurements downstream of the heater (right). Temperatures in °C.

temperature, not constant heat flux. Connecting the hair dryer to a wattmeter confirms that the power input to the hair dryer increases when the fan speed increases.

6 Assessment Questions

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

1. Are there significant gains in student understanding of concepts (factual knowledge) in the topic areas covered by the learning exercises? Concept Inventory instruments will be used to track year-over-year learning of student cohorts.

2. Do the learning exercises improve students' qualitative reasoning about problems in the thermal and fluid sciences?

3. Does the attitude of students toward the laboratory exercises differ by gender, ethnicity, previous exposure to engineering practice, concurrent employment, and other factors?

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

7 Status and Acknowledgement

For more information, visit `eet.cecs.pdx.edu`.

Status:

- The project is funded with a two-year, NSF CCLI grant, starting April 1, 2007.
- Experimental hardware has been created and prototype deployments of the blender, hair dryer, bicycle pump, toaster are being tested during the Spring Quarter at Portland State University
- Background surveys and a Fluids Concept Inventory have been administered.

Funding is from the National Science Foundation Division of Undergraduate Education, Award #DUE-0633754. The program officer is Dr. Barbara Anderegg.

Co-PI is Robert Edwards in the Mechanical Engineering Technology Program at Penn State-Erie.

References

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[3] Martín Eduardo Saleta, Dina Tobia, and Salvador Gil. Experimental study of Bernoulli's equation with losses. *American Journal of Physics*, 73(7):598–602, 2005.