DEVELOPMENT OF ENGINEERING THERMODYNAMICS CONCEPT INVENTORY ASSESSMENT INSTRUMENTS

Clark Midkiff, University of Alabama
Thomas Litzinger, Penn State University
Don Evans, Arizona State University

Objectives

- Develop a simple inventory to test student conceptual understanding of thermodynamics at the beginning and at the conclusion of an introductory course.
- Thermodynamics is taught as a two-course sequence in many mechanical engineering curricula, so two instruments, “beginning” and “intermediate,” are eventually desirable.
- This presentation focuses on development of the beginning level instrument.

Inspiration

- Like the other efforts sponsored by the Foundation Coalition, the "Force Concepts Inventory," developed by Halloun and Hestenes, served as the model for this effort.
- The FCI asks simple, pictorially based questions that assess student mental models of force behavior ("the initial knowledge state").
- The FCI has been successfully used to evaluate a broad and diverse set of physics curricula and pedagogical methods.

Constraints

- A thermodynamics concepts inventory should:
  - be brief, not burdensome
  - not require a calculator, etc.
  - be repeatable across diverse student populations
  - assess student understanding of concepts that are fundamental to understanding thermodynamics

Typical Student Background

- The typical student entering a first thermodynamics course will already have taken:
  - one or two semesters of calculus
  - one or two semesters of chemistry
  - a semester of physics
- Chemistry and physics both introduce concepts that are used extensively in a thermodynamics course.

Background Sources

- From chemistry, a typical student has been exposed to:
  - behavior, phases and properties of substances
  - ideal gas relations
  - balancing simple chemical reactions
  - heat and temperature
  - chemical thermodynamics and equilibrium

Background Sources

- From physics, a typical student has been exposed to:
  - forms of energy- kinetic, potential, internal
  - work
  - temperature, temperature scales
  - heat, specific heat, latent heat
  - thermodynamic processes (isothermal, etc.)
  - First and Second Laws
  - conversion of heat to work, entropy

Subject Matter Categories

- To develop the thermodynamics concept inventory (TCI), course pre-concepts were classified:
  - basic concepts and definitions
  - properties and behavior of matter
  - work and heat
  - mass conservation
  - First Law
  - Second Law

TCI Development Process

- Following an examination of the classification of subject material, the authors “brainstormed” to develop potential questions.
- Common student misconceptions noted by authors and colleagues in teaching undergraduate thermodynamics was the primary basis for question development.

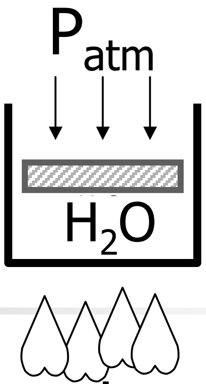
TCI Subject Matter Distribution

- The present version of the TCI has 30 questions with this distribution:
  - basic concepts and definitions- **4** questions
  - properties and behavior of matter- **11**
  - work and heat- **5.5**
  - mass conservation- **3.5**
  - First Law (conservation of energy)- **4.5**
  - Second Law- **1.5**

Subject Distribution Justified

- The distribution of subject matter over the questions clearly does not reflect relative division of time spent in the class itself.
- The question distribution largely reflects what is expected of students upon enrollment in the thermodynamics course.

Sample Questions



- The questions pertain to the picture above, which depicts H_2O being heated in a sealed, frictionless, piston-and cylinder arrangement, where the piston mass and the atmospheric pressure above the piston remain constant.
- The *density* of the H_2O will: (a) Increase (b) Remain constant (c) Decrease.
- The *pressure* of the H_2O will: (a) Increase (b) Remain constant (c) Decrease.
- The *energy* of the H_2O will: (a) Increase (b) Remain constant (c) Decrease.

General Comments re/ TCI

- Present version is probably too long
- The test is not as "pictorial" as desired- now a total of 6 pictures, though many apply to several questions.
- Test does not present enough "attractive distracters," i.e., incorrect answers that appeal to false student mental models.

Discussion of Selected Results

- Major patterns in raw understanding- students frequently:
  - fail to see that if mass and volume are constant, density must be constant.
  - fail to recognize Second Law limit on conversion efficiency of heat to work.
  - do recognize difference between work and heat transfer processes.

Discussion of Selected Results

- Major distribution patterns:
  - high variability of responses on problems involving conservation of energy in masses either in motion or heating/cooling.
  - surprising variability on conservation of mass in steady flow systems.
  - high variability in seeing that if heat transfer and work are constant, then total energy is constant for a steady system.

Discussion: TCI *vs.* FCI

- Is it possible to construct a test on thermo-dynamic concepts that is directly analogous to the force concepts inventory?
  - Thermo has intuitive, everyday experiential components, but also many definitional and technical aspects.
  - Thermo is not as visual as forces and motions.

Conclusions

- The development of the TCI is clearly a "work in progress," but a version of the test is available for public use.
- The authors would appreciate suggestions of questions and feedback on the TCI instrument.
- Send comments and requests for tests to: *cmidkiff@coe.eng.ua.edu*