PDF

Investigating the impact of problem properties on introductory and advanced student responses to introductory thermodynamics conceptual problems

Share

Mary Jane Brundage[1], David E. Meltzer[2], and Chandralekha Singh[1]

Show more

Phys. Rev. Phys. Educ. Res. **21**, 010127 – **Published 28 March, 2025**

DOI: https://doi.org/10.1103/PhysRevPhysEducRes.21.010127

Abstract

We use a validated conceptual multiple-choice survey instrument focusing on thermodynamic processes and the first and second laws of thermodynamics at the level of introductory physics to investigate the problem-property dependence of introductory and advanced student responses to introductory thermodynamics problems after traditional lecture-based instruction. The survey instrument has qualitative problems involving the same concepts across multiple problems related to internal energy, work, heat transfer, and entropy. The concepts for which we investigated problem-property dependence include, among others, (i) internal energy and entropy are state variables while work and heat transfer are path-dependent variables, (ii) internal energy is proportional to the absolute temperature for an ideal gas, (iii) work corresponds to the (signed) area under the curve on a PV (pressure-volume) diagram, and (iv) internal energy is constant but entropy increases in isolated systems undergoing spontaneous and irreversible processes. This study used survey data from over 1000 college students in introductory-level algebra-based and calculus-based physics courses as well as upper-level thermodynamics courses; the survey was administered after traditional instruction in relevant concepts for each group. Think-aloud interviews were carried out to gain additional insight into students' thinking as they responded to the survey problems. For concepts related to internal energy, heat transfer, and work, student responses for different concepts investigated often showed strong problem-property dependence, but advanced students, as a group, generally performed better than introductory students across different problems. For entropy concepts, introductory students consistently performed poorly across problem types, reflecting a persistent belief in the constancy of entropy. By contrast, upper-level students struggled consistently in cases where entropy was *not* increasing (e.g., net entropy change in a cyclic process). Our systematic investigation of problem-property dependence of student responses is novel for thermodynamics, made possible by the use of a survey that includes multiple varied problem scenarios involving the same underlying concept. In addition to yielding many previously unreported results regarding problem-property dependence in thermodynamics, our work confirms and extends, to new problem settings and student groups, findings previously reported through the study of more limited problem settings and student groups.