



Concept Inventory Assessment Tools

<http://www.foundationcoalition.org/concept>

Introduction

Motivated by the Force Concept Inventory (<http://modeling.la.asu.edu/R&E/FCIforw.html>) created by Halloun and Hestenes¹⁻⁴ and its impact on physics education, the Foundation Coalition is working to create concept inventories for specific engineering disciplines. The Force Concept Inventory (FCI) was designed to measure conceptual, not computational, understanding of Newtonian Mechanics. The questions focus on intuitive comprehension independent of knowledge of the terminology or numerical modeling. Following the lead of the FCI, faculty members are creating concept inventories for other disciplines. More information about concept inventories can be found in the paper by Evans and Hestenes.⁵

Waves Concept Inventory

Principal Developers

- Ron Roedel, Arizona State University, r.roedel@asu.edu
- Samir El-Ghazaly, Arizona State University, sme@asu.edu

The Waves Concept Inventory (WCI)^{6,7} is based on the FCI and consists of 20 multiple choice questions with 34 possible answers. The assessment asks a variety of questions that probe several areas of knowledge, including visualization of waves, mathematical depiction of waves, and wave definitions. Although the WCI is a multiple-choice examination, it allows for more than one correct choice for most of the questions. In fact, choosing more than one answer correlates with increasing understanding of the material. Work on the WCI started in 1995.

2000-01 Concept Inventories

Work on the following concept inventories started in October 2000.

- Thermodynamics
- Strength of Materials
- Signals and Systems
- Electromagnetics

Faculty members who are interested in the above areas should check out the section below related to specific concept inventories and contact the developers.

Thermodynamics Concept Inventory

Principal Developers

- Clark Midkiff, University of Alabama, cmidkiff@coe.eng.ua.edu
- Thomas A. Litzinger, Pennsylvania State University, TAL2@psu.edu
- D. L. Evans, Arizona State University, devans@asu.edu

Thermodynamics is a fundamental component in several engineering curricula, taught in a two-course sequence in many mechanical engineering programs. There are two versions of the Thermodynamics Concept Inventory (TCI)⁸, one for beginning students, the other for students entering the second course. A preliminary version of the first-semester TCI has been tested on a limited group of students. Broader scale testing, followed by refinement of the test instrument, is planned for the 2001-2002 period.

Strength of Materials Concept Inventory (SMCI)

Principal Developers

- Jim Richardson, University of Alabama, jrichardson@coe.eng.ua.edu
- Jim Morgan, Texas A&M University, jim-morgan@tamu.edu

The Strength of Materials Concept Inventory (SMCI)⁹ assesses mastery of fundamental concepts in a sophomore mechanics of solids or strength of materials course. Concepts examined include stress, strain and deformations due to axial, bending and torsional loads; failure of ductile and brittle materials, and axial buckling. Testing began at UA and TAMU in summer 2001 and will be available for testing at other schools in spring 2002.

Signals and Systems Concept Inventory

Principal Developers

- John Buck, University of Massachusetts-Dartmouth, JBuck@umassd.edu
- Kathleen Wage, George Mason University, kwage@gmu.edu

Linear signals and systems is a core component of undergraduate curricula in electrical and computer engineering. The Signals and Systems Concept Inventory (SSCI)¹⁰ measures students' understanding of fundamental concepts such as linearity, time-invariance, and transform representations. There are two versions of the SSCI, one for continuous-time (SSCI-CT) and a second for discrete-time (SSCI-DT). During the spring of 2001, the SSCI-CT was given at GMU and UMD. In 2001-2002, the SSCI-CT is being tested by a broader group of schools, including the U.S. Air Force and Naval Academies, as well as GMU and UMD.

Electromagnetics Concept Inventory

Principal Developer

- Branislav Notaros, University of Massachusetts-Dartmouth, bnotaros@umassd.edu

The Electromagnetics Concept Inventory (EMCI) is best suited for junior-level undergraduate EM courses in EE depts. It can be used in a variety of undergraduate and graduate EM-related courses in engineering and physics departments. EMCI Version 1.0 contains three exams:

- EMCI-Fields (electro and magnetostatic, and time-varying EM fields),
- EMCI-Waves (uniform plane waves, transmission lines, waveguides, and antennas)
- EMCI-Fields & Waves (a combination of the first two exams).

2001-02 Concept Inventories

Work on the following concept inventories started in October 2001.

- Circuits
- Fluid Mechanics
- Materials

Faculty members interested in working with developers to develop concept inventories in the above areas should contact a developer listed in one of the sections below.

Circuits Concept Inventory

Principal Developers

- Robert Helgeland, University of Massachusetts-Dartmouth, rhelgeland@umassd.edu
- David Rancour, University of Massachusetts-Dartmouth, drancour@umassd.edu

Circuit Theory is usually the first course in the major for electrical engineering and computer engineering students. Part One of the Circuits Concept Inventory (CCI) will measure a student's conceptual understanding of the basic properties of electricity, circuit components and linear time-invariant networks (DC and AC). Part Two will address frequency domain concepts, coupled inductors, convolution, impulse response, and transform techniques.

Fluid Mechanics Concept Inventory

Principal Developers

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Jay Martin, University of Wisconsin, martin@engr.wisc.edu
Ty Newell, University of Illinois at Urbana-Champaign, t-newell@uiuc.edu

The goal of the Fluids Mechanics Concept Inventory (FMCI) is to establish a common base of fluids concepts and provide instruments that could be used by faculty to evaluate the degree to which students in a given program have mastered those concepts. The inventory would be conducted in each of the fluids classes at the start of the semester to assess the knowledge of entering students and at the end of the semester to assess whether students have mastered the necessary concepts. An outcome of conducting the inventory might be modifications to the curriculum and courses to ensure that students obtain the necessary understanding of the basic concepts.

Materials Concept Inventory

Principal Developers

- Richard Griffin, Texas A&M University, richard.griffin@usma.edu
- Steve Krause, Arizona State University, skrause@asu.edu

An instrument is being developed to measure misconceptions on materials structure, processing, and properties. It will be used to examine student knowledge before and after teaching introductory materials engineering courses that are required by many engineering colleges. Considerable research shows that prior misconceptions are strongly held even in the face of good instruction. A better understanding of "prior knowledge" can help instructors improve instruction in their classes.

References for Further Information

1. Hestenes, David, Malcolm Wells, and Gregg Swackhamer (1992). Force Concept Inventory. *The Physics Teacher*, **30** (3), 141-151
2. Hestenes, David, and Ibrahim Halloun (1995). Interpreting the Force Concept Inventory. *The Physics Teacher*, **33** (8)
3. Halloun, Ibrahim and David Hestenes (1985). The initial knowledge state of college physics students. *American Journal of Physics*, **53**(11), 1043-1055.
4. Halloun, Ibrahim and David Hestenes (1985). Common sense concepts about motion. *American Journal of Physics*, **53**(11), 1056-1065
5. D. L. Evans and David Hestenes, "The Concept of the Concept Inventory Assessment Instrument," *Proceedings, 2001 Frontiers in Education Conference*, Reno, Nevada, 10-13 October 2001
6. R. J. Roedel, S. El-Ghazaly, Teri Reed Rhoads, and E. El-Sharawy, "The Wave Concepts Inventory – An Assessment Tool for Courses in Electromagnetic Engineering," *Proceedings, 1998 Frontiers in Education Conference*, November 1998, Tempe, AZ.
7. Rhoads, Teri Reed, Ron J. Roedel, "The Wave Concept Inventory - A Cognitive Instrument Based on Bloom's Taxonomy," *Proceedings, 1999 Frontiers in Education Conference*, San Juan, Puerto Rico, 10-13 November 1999
8. Midkiff, K. Clark, Thomas A. Litzinger, and D. L. Evans, "Development of Engineering Thermodynamics Concept Inventory Instruments," *Proceedings, 2001 Frontiers in Education Conference*, Reno, Nevada, 10-13 October 2001
One-page FIE2001 working paper: <http://fie.engrng.pitt.edu/fie2001/papers/1356.pdf>
FIE 2001 presentation: <http://foundationcoalition.org/thermo>
9. Richardson, Jim, and Jim Morgan, "Development of an Engineering Strength of Material Concept Inventory Assessment Instrument," *Proceedings, 2001 Frontiers in Education Conference*, Reno, Nevada, 10-13 October 2001
One-page FIE2001 working paper: <http://fie.engrng.pitt.edu/fie2001/papers/1353.pdf>
FIE 2001 presentation: <http://foundationcoalition.org/strength>
10. Wage, Kathleen E., and John R. Buck, "Development of the Signals and Systems Concept Inventory (SSCI) Assessment Instrument," *Proceedings, 2001 Frontiers in Education Conference*, Reno, Nevada, 10-13 October 2001
One-page FIE2001 working paper: <http://fie.engrng.pitt.edu/fie2001/papers/1358.pdf>
FIE 2001 presentation: <http://foundationcoalition.org/system>

Whether you're just getting started or looking for some additional ideas, the Foundation Coalition would like to help you incorporate concept inventory assessment instruments into your engineering classes through workshops, web sites, lesson plans, and reading materials. For suggestions on where to start, see our web site at <http://www.foundationcoalition.org> or contact: Jeffrey Froyd at froyd@ee.tamu.edu or 979-845-7574.