New Directions in Physics Education

David E. Meltzer
Department of Physics and Astronomy
Iowa State University

Outline

- Review of education-related projects in Department of Physics and Astronomy
- Overview of Physics Education Research Group (PERG)
- Discussion of PERG projects
  - and local & national impact

Recent Teaching Awards

John Lajoie

- LAS Outstanding Introductory Teaching Award, 2000

Steve Kawaler

- LAS Master Teacher 1999-2000
- J.H. Ellis Award for Excellence in Undergraduate Introductory Teaching, 1999

1999 ISU Teaching Awards

1999 ISU Teaching Award Recipient

Steven D. Kawaler

Professor of Physics and Astronomy

The James Huntington Ellis Award for Excellence in Undergraduate Introductory Teaching

The James Huntington Ellis Award for Excellence in Undergraduate Introductory Teaching recognizes a faculty member who, in teaching an introductory course, demonstrates creativity in improving its quality, excites interest and involvement without compromising scholarship, and enhances student performance in future courses. Ellis graduated from Iowa State's division of industrial science in 1928 and had a successful financial services brokerage career that spanned more than 50 years. Ellis established this award to honor those professors like his "who made their courses interesting." A $1,000 award is granted.

Steven Kawaler is an outstanding teacher, with top ratings from the students. He organized the stars, galaxies, and cosmology parts of the freshman non-major course, Astro 150. He then created a new second course called Astronomy Bizarre for non-majors who wanted to pursue the material in more depth. In 1994 he co-authored a textbook, Introduction to Stellar Structure, with C. J. Hansen. He has directed the Ph.D. research of two students and is very active teaching at both the undergraduate and the graduate level. He is consistently rated both by peers and by students as a truly exceptional teacher. In 1995 he was awarded the By-Fellowship to take a yearÕs leave of absence at Churchill College, Cambridge, England. He is an expert in pulsating white dwarf stars that have time variations of a day or two, meaning that these stars should be observed by coordinated telescopes located strategically around the earth so that continuous observations can be made as the earth spins.

Dr. Kawaler received his B.A. from Cornell University and his Ph.D. from the University of Texas-Austin. He came to

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Paul Canfield

- LAS Master Teacher Award 2001-2002

College of Liberal Arts & Sciences

News Index March 27, 2002

Research masters

Four College of Liberal Arts and Sciences faculty members named Master Teachers for their work with undergruate assistants

Four faculty members in the College of Liberal Arts and Sciences (LAS) at Iowa State University have been named Master Teachers for 2001-02.

This is the third year of the LAS Master Teacher program, which recognizes teachers who have a reputation for using unique methods to enhance student learning. This year's awards recognize individuals who have been successful in involving Iowa State undergraduates in research situations. Previous LAS Master Teacher classes have focused on technology use in the classroom and large lecture classroom instruction.

The LAS Master Teachers are Paul Canfield, professor of physics and astronomy

Research masters

For four faculty members in the College of Liberal Arts and Sciences, involving undergraduate students in the research process is vitally important.

As a result, the four have been chosen as LAS Master Teachers for 2001-02. The Master Teacher program recognizes teachers who have a reputation for using unique methods to enhance student learning. This year's awards recognize individuals who have been successful in involving Iowa State undergraduates in research situations.

The four LAS Master Teachers, who will plan teaching methods seminars and in-class demonstrations throughout the academic year, are:

Paul Canfield, professor of physics and astronomy. Canfield fully involves undergraduates in areas of his research group and has served as a mentor for the honors program since 1997.

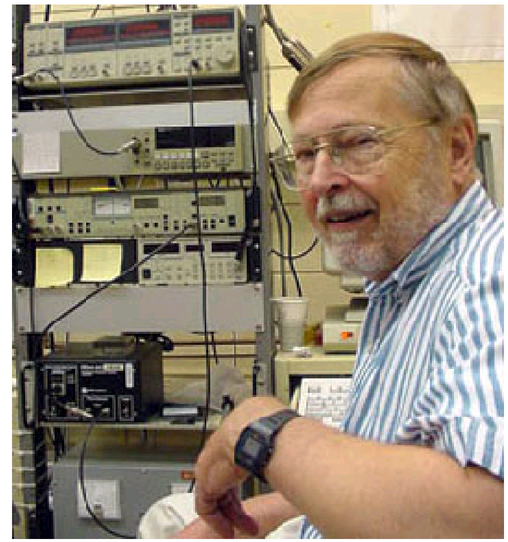
Many of his students have published papers in top academic journals and after graduating from Iowa State have been accepted into top graduate programs.

"Paul's incorporation of undergraduates in research has been exemplary over the years and his style of mentoring is highly interactive and stimulating," said Alan Goldman, professor and

IOWA STATE UNIVERSITY

College of Liberal Arts & Sciences

Lynch receives White Graduate Faculty Award



David Lynch, Distinguished Professor of physics and astronomy, was one of two Iowa State faculty members to receive the Margaret Ellen White Graduate Faculty Award during the 2001 Spring Convocation earlier in April.

The award is given annually to two professors who have been resourceful and influential role models to graduate students, while enhancing the student-professor relationship.

The award was founded in 1987 by Margaret Ellen White, a former administrative assistant on campus. Graduate student senators nominate a faculty member of the graduate faculty from their department who has worked with at least six graduate programs of study. A Graduate Student Senate committee reviews the nominations to choose the finalists, who are then recommended by a university panel as final recipients of the award.

For more information contact
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515-294-7742

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Lawrence Hill - Technology Coordinator
Andrew Borcherding - Web Designer

Page Viewing or Printing Problems

Education-Related Projects

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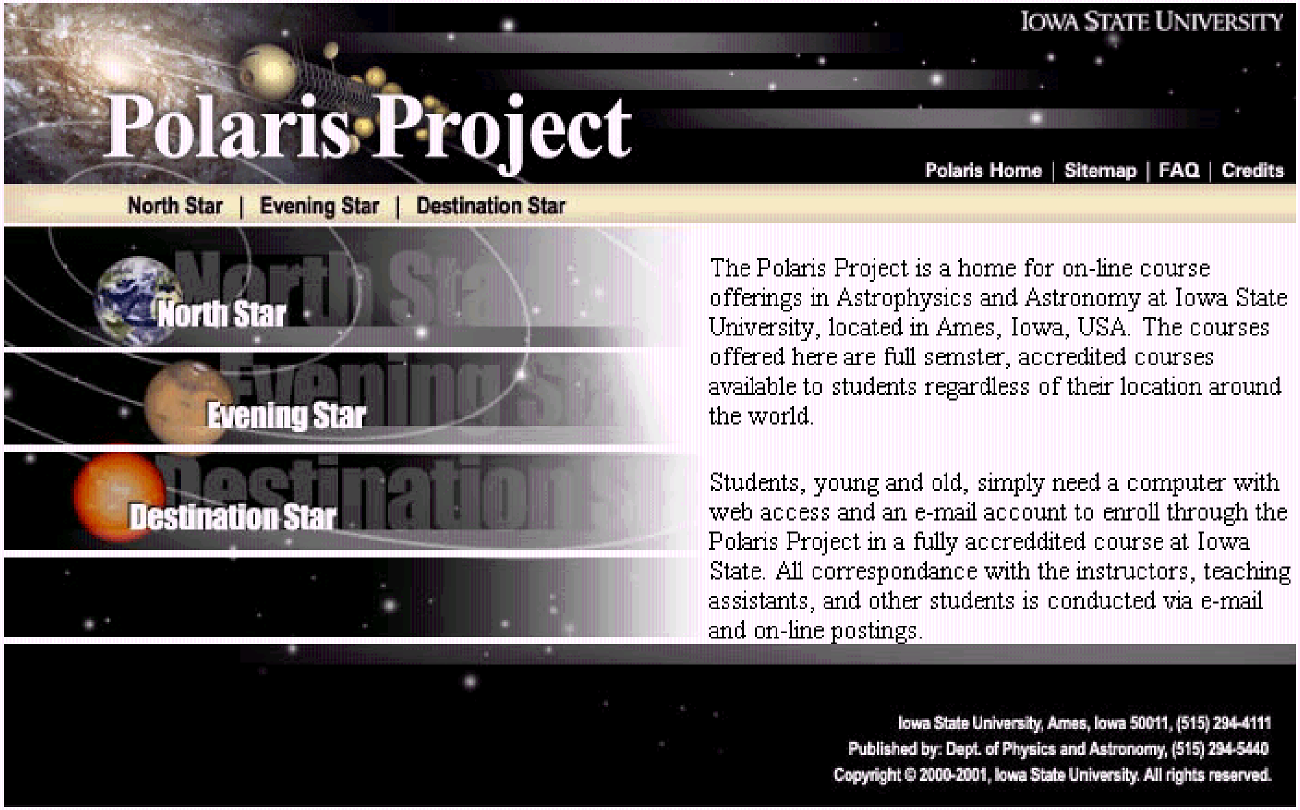

[On-line courses in Astronomy and Astrophysics]

The People Behind Polaris Project

Polaris Project Manager and Creative Developer:	Douglas Bennett
Scientific Authority:	Dr. L. W. Willson
Lead Web Designer and 3D Artist:	Travis Engelhaupt
Web Designers and Graphic Artists:	Eunice Cho Anne MacDonald Premnath Sundharam E. Yuwono
Technical Advisor:	J. Willson
Pedagogical Advisor:	J. Dostal

This project was made possible by support provided by the Department of Physics and Astronomy, and the encouragement of Alan Goldman, Department Executive Officer.

Photo Credits

- **Image of the Earth and Other Planets Used Frequently** - Courtesy of Jet Propulsion Laboratory. Copyright (c) California Institute of Technology, Pasadena, CA. All rights reserved. Based on government-sponsored research under contract NAS7-1407.
- **Star Trails Image** - Courtesy of Anglo-Australian Observatory. Used with permission. http://www.aao.gov.au/images.html
- **3D Model of Greek Ship Used in North Star** - Courtesy of Greg Crowfoot. Used with permission.

Online astro class offers interactive learning

Jana McBride (Iowa State Daily)
August 31, 2000

A new way of looking at the stars will soon be available online through Iowa State.

The Polaris Project, a series of semester-long online astronomy classes, will enable students from around the world to explore the night sky via the Internet. The 100-level course, which is geared mainly toward college freshmen and advanced high school students, is expected to be offered this spring.

"There are a lot of things we can do that a book can't," said Lee Anne Willson, university professor of physics and astronomy who spearheaded the program.

Advantages of the online classes include animation of diagrams, computer graphics, discussion and chat groups, Willson said. Another potential of the online class will be to build cooperative arrangements with students worldwide, she said.

The initial idea for the Polaris Project came from a workbook Willson created several years ago for an introductory astronomy class. Production Manager and Creative Director Doug Bennett, graduate assistant in astronomy and physics, and graphic designer Travis Engelhaupt were two students who helped make the project a reality.

Engelhaupt, sophomore in computer science, said his involvement in the project happened by luck. A physics major at the time of the development, Engelhaupt was at a Physics Club meeting when Willson asked for help from students. Engelhaupt said he spends anywhere from three to 40 hours per week on the project.

"When the deadlines come around, then you're wishing you were someplace else," he said, even though he said it is still worth it. "We used a lot of great technology and new software on the market to aid us. I am really pleased with what we have."

Several students are enrolled in the trial run of the first course, titled North Star, which explores the night sky starting in the backyard. Willson said students who want to be part of the initial testing can still sign up for Astronomy 290 and earn a credit for offering feedback.

"We're looking for people with a variety of backgrounds and interests in astronomy," she said. "We need to find all

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AWSFL008-DS3

NSF Award Abstract - #9987976

REU Site for Research in Physics and Astronomy at Iowa State University

NSF Org	PHY
Latest Amendment Date	June 24, 2002
Award Number	9987976
Award Instrument	Continuing grant
Program Manager	Lawrence S. Brown PHY DIVISION OF PHYSICS MPS DIRECT FOR MATHEMATICAL & PHYSICAL SCIEN
Start Date	May 1, 2000
Expires	April 30, 2003 (Estimated)
Expected Total Amount	$161100 (Estimated)
Investigator	Marzia Rosati mrosati@iastate.edu (Principal Investigator current) Alan I. Goldman (Co-Principal Investigator current) John M. Hauptman (Co-Principal Investigator current) Steven D. Kawaler (Co-Principal Investigator current)
Sponsor	Iowa State University 2207 Pearson Hall, Room 15 Ames, IA 500112207 515/294-5225
NSF Program	9134 EDUCATION & INTERDISCIP RESEAR
Field Application	0000099 Other Applications NEC
Program Reference Code	9178,9250,SMET,

Abstract

The goal of the Research Experiences for Undergraduates (REU) site in the Physics and Astronomy Department of Iowa State University is to encourage more students to continue their science education in upper-division courses and graduate programs, and to help them realize their full potential. Each summer, undergraduate students will spend 10 weeks actively engaged in basic research projects under the direction of faculty members. Students will be integrated into the research groups of their mentors, providing a

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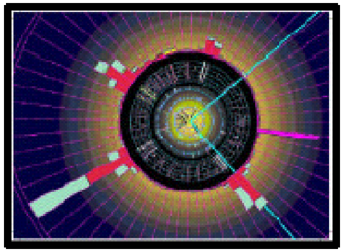


Research Experiences in Physics and Astronomy for Undergraduates

Program:

Join us to participate in basic research with a faculty advisor in one of the following areas: astronomy, condensed matter physics, high energy physics and nuclear physics.

Eligibility:

To apply, you must be US citizens or permanent residents. Women and minorities are especially encouraged to apply. Preference is given to physics and astronomy majors who will have completed their junior year by this summer.

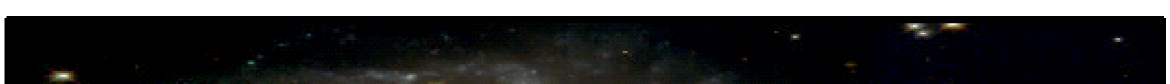
Support:

$3000 stipend for the 10-week summer appointment
travel costs up to $500
Free on-campus housing.

To apply:

Web site: http://www.public.iastate.edu/~physics/REU
E-mail to: reu-physics@iastate.edu
Mail: REU Program c/o Ms. Erlene Mooney
Department of Physics and Astronomy
Iowa State University
Ames, IA 50011-3160 USA

Application deadline is February 24, 2002.



[Summer research program for undergraduates]

Research Experiences for Undergraduates (REU) in Physics and Astronomy

with the support of

National Science Foundation & Iowa State University

May 28 -- August 2, 2002

REU/ISU is a program of research experience in physics and astronomy for undergraduates at Iowa State University. All interested undergraduates are invited to apply for this 10 week summer program of research in the Department of Physics and Astronomy of Iowa State University in Ames, Iowa. The starting and ending dates are flexible and may be adjusted to fit personal schedules.

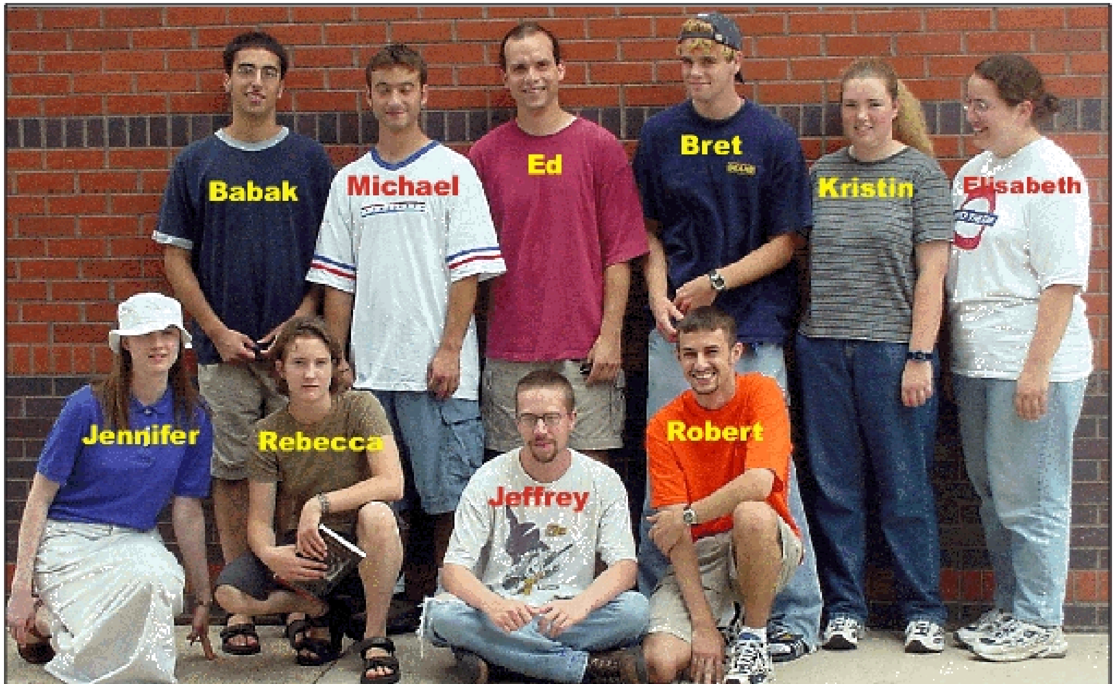
INTERNSHIPS are available with research groups in Condensed Matter, High Energy, Nuclear Physics, Astrophysics. Students will work on projects spanning the diverse interests of a comprehensive research department. During the 10 week internship, students will carry out well-defined projects within research groups composed of graduate students, postdocs and faculty members.

ELIGIBILITY REQUIREMENTS: You must be a US citizen or permanent resident enrolled in an undergraduate degree program in physics or engineering physics. Members of groups under-represented in Physics are especially encouraged to apply.

STIPENDS: stipend is $300/week. In addition, we will support travel (receipts) to and from your home address or home institution up to $500, and

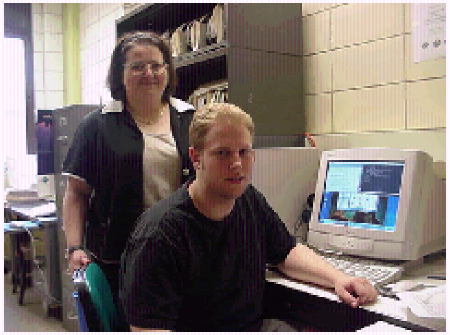
Iowa State University
Department of Physics and Astronomy

2001 REU in Physics and Astronomy



Research Experiences in Physics and Astronomy for Undergraduates
Iowa State University Summer 2001

Summer jobs



It's something that Marzia Rosati, assistant professor of physics and astronomy, has wanted to offer for several years. In fact it's a dream that dates back to her own undergraduate education.

"I wish I could have had this opportunity," she says.

Instead Rosati and the physics and astronomy department had to settle on offering the Research Experience for Undergraduates (REU) program this past summer. Through a three-year National Science Foundation (NSF) grant, the department established a 10-week internship program on the Iowa State campus.

Nine students from colleges and universities across the Midwest were selected to participate last summer in the first year of the grant. Internships were provided to the undergraduate physics majors with ongoing Iowa State research groups in condensed matter, high energy, nuclear physics and astrophysics. Each student was assigned a faculty mentor and carried out well-defined projects within those research groups.

Rosati, who coordinates the REU project, had explored offering such a program in recent years. Several other college physics departments offer

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College of Liberal Arts & Sciences

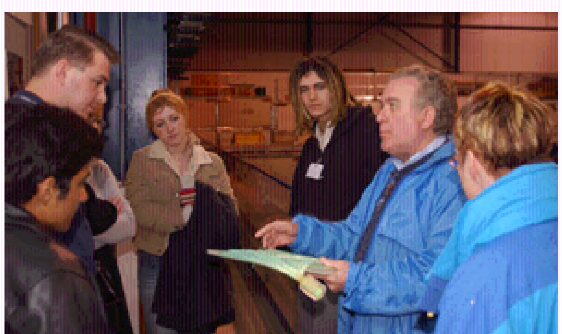
Newspaper physics

New learning community combines physics, English.

Every day John Hauptman, professor of physics and astronomy, looks at the newspaper - several newspapers.

Not only does he peruse the local media, but he also looks at newspapers from all over the nation.

"I've always liked newspapers," he said. "I usually spend a couple of hours a day reading newspapers because they typically provide a breadth and depth that other media can't."



Throughout his teaching career, Hauptman has brought newspapers into his classroom. Now Hauptman has taken that approach one step further with a "newspaper physics" course that has developed into a learning community with the Department of English.

This unique learning community links

This unique learning community links physics at the 101 level and English 105. Students meet for two hours of physics and two hours of English per week. In addition, every other week, the students join a two-hour writing workshop composed of Jennifer Thornburg, who teaches the English component of the learning community, and a maximum of four students.

"The physics discussions are appropriate for non-science students," Hauptman said. "We actually talk about things in the newspaper that relate to physics. There is so much more stuff than I can include in the class."

The learning community includes students from majors throughout campus, including journalism, engineering, political science, English, psychology, design and public relations. Education major Claire Robyt decided to take the course even though it didn't count for any of her credits.

[Combined Physics + English course with writing workshop]

"I thought it sounded like a good way to teach a science course and I thought I could learn something that I could relate in an elementary or middle school classroom," she said.

Some of the newspaper articles that Hauptman has discussed with a physics aspect include pole vaulting, satellite photos of an ancient settlement in northeastern Syria, "snow

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CENTER FOR TEACHING EXCELLENCE

IOWA STATE UNIVERSITY

Home | About Us | Events | Services | Resources | Fellowships | Campus Programs

2002-2003 Miller Faculty Fellowships

Title:	**Developing Higher-Order Problem-Solving Skills in Introductory Physics**
Proposer(s):	Craig Ogilvie; David Atwood
Department(s):	Physics & Astronomy
College(s):	LAS
Abstract:	Many science and engineering students attempt to solve problems by searching their memories for the "right" equation that they can then plug values into. Because this "plug-and-chug" approach fails for complex and unfamiliar problems, students trained in this way often struggle while at university and as they begin their future careers. Our goal is for students to learn a problem-solving process that focuses on identifying the underlying principles within the complex problem and from there building a solution. Key will be having students practice the process in highly-interactive small groups within a large enrollment course. We will implement these changes first in one course (Phys 222) and if this is successful it will be rolled-out over the next two years to all sections of introductory calculus-based physics courses (221 and 222). These changes will impact 1000 students for two semesters each year. Armed with stronger problem-solving skills, students will be better prepared to solve complex and original challenges throughout their academic career and then lifelong in their professional occupations.

Last Updated: 14 Mar 2003 http://www.cte.iastate.edu/fellowships/miller/proposals2002-2003.html Contact

[New instructional methods and assessment techniques for physics problem-solving]

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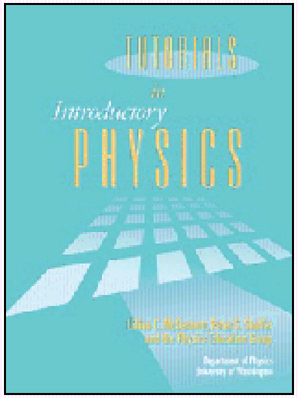
UW Department of Physics

[Research-based active-learning curricular materials for Physics 221]

Tutorials in Introductory Physics

L.C. McDermott, Peter S. Shaffer, and the Physics Education Group
at the University of Washington

First Edition
Prentice Hall, Upper Saddle River, NJ, 2002
ISBN 0-13-065364-0



Tutorials in Introductory Physics is a set of instructional materials intended to supplement the lectures and textbook of a standard introductory physics course. The emphasis in the tutorials is not on solving the standard quantitative problems found in traditional textbooks, but on the development of important physical concepts and scientific reasoning skills.

There is increasing evidence that after instruction in a typical course, many students are unable to apply the physics formalism that they have studied to situations that they have not expressly memorized. In order for meaningful learning to occur, students need more assistance than they can obtain through listening to lectures, reading the textbook, and solving standard quantitative problems.It can be difficult for students who are studying physics for the first time to know what they do and do not understand and to learn to ask themselves the type of questions necessary to come to a functional understanding of the material.

Tutorials in Introductory Physics provides a structure that promotes the active mental engagement of students in the process of learning physics.

Questions in the tutorials guide students through the reasoning necessary to construct concepts and to apply them in real-world situations. The tutorials also provide practice in interpreting various representations (e.g., formulas, graphs, diagrams, verbal descriptions) and in translating back and forth between them. For the most part, the tutorials are intended to be used after concepts have been introduced in the lectures and the laboratory, although most can serve to introduce the topic as well.

The tutorials comprise an integrated system of pretests, worksheets, and homework assignments. The tutorial sequence begins with a pretest. These are usually on material already presented in lecture but not yet covered in tutorial. The pretests help students identify what they do and not understand about the material and what they are expected to learn in the upcoming tutorial. They also inform the

Physics Education Research Group (PERG)

David E. Meltzer, Director

Physics Education
Research Group

Department of Physics and Astronomy
Iowa State University
Ames, Iowa

Welcome to the website for Iowa State University's Physics Education Research Group! Follow the links on the navigation bar to find out more about our teaching and research.

About Us
Learn about the purpose and goals of Iowa State's PERG.

Members
Find contact information for students and faculty involved in the PERG.

Media
Watch physics education in action at Iowa State.

Links
Find other physics education resources on the web.

Current Projects
Explore the PERG's latest projects.

Publications and Preprints

www.physics.iastate.edu/per/

Collaborating Faculty

Tom Greenbowe (Chemistry Dept.)
Laurent Hodges
Craig Ogilvie
Lee Anne Willson

Post-doc (part-time)

Irene Grimberg

External Collaborators

Kandiah Manivannan (Southwest Missouri State University)
Leith Allen (Ohio State University)
Laura McCullough (University of Wisconsin-Stout)

ISU PERG Students

Undergraduate Students

Agnes Kim (teaching assistant)

Nathan Kurtz

Sarah Orley (teaching assistant and website designer)

Eleanor Raulerson (Grinnell student, now at U. Maine)

Graduate Students

Tina Fanetti, (M.S. 2001; Co-Major Prof.: L. Willson)

Jack Dostal (defended M.S. thesis 2000, not yet graduated)

Larry Engelhardt (switched to Condensed Matter Theory)

Ngoc-Loan Nguyen (M.S. expected 2003)

Warren Christensen

Active PER Groups in Ph.D.-granting Physics Departments

> 10 yrs old	5-10 yrs old	< 5 yrs old
*U. Washington (1 S, 1 J, 1 R)	U. Maine (2 J)	Oregon State (1 S p-t)
*Kansas State (1 S, 1 J)	Montana St. (1 S)	Iowa State (1 J)
*Ohio State (1 S [ret], 1 J)		City Col. N.Y. (1 J + 1 J ED)
*North Carolina State (2 S + 2 p-t)		Texas Tech (1 S p-t, 1 J)
*U. Maryland (1.5 S + 0.5 S Ed)		U. Central Florida (1 J)
*U. Minnesota (1 S p-t, 2 [S, J] Ed)		U. Pittsburgh (1 S p-t, 1 R)
*San Diego State (1 S)		Western Michigan (1 J)
*Arizona State (1 S [ret], 1 J)		Worcester Poly. Inst. (1 J)
U. Mass., Amherst (2 S, 2 R)		
Harvard (1 S p-t)		
Mississippi State (2 S)		
U. Oregon (1 S)		
U. California, Davis (1 R)		

S = senior (tenured) fac.; J = junior fac.; p-t = part-time; R = research fac. (non-tenure track)
ret = retired or retirement imminent; ED = collaborating faculty in College of Education
*more than one Ph.D. awarded within last 10 years

Goals of Physics Education Research (PER)

In order to improve effectiveness and efficiency of physics instruction:

- Measure and assess *learning* of physics
- Develop improved instructional methods and materials
- Critically assess and refine instructional innovations

Process of Physics Education Research

- Investigate students’ learning difficulties
- Develop (and ***assess***) curricular materials that address learning difficulties
- Implement (and assess) new instructional methods that make use of improved curricula

ISU PERG Major Projects

- **Basic Research**
  - students' reasoning in thermodynamics
  - role of diverse representational modes in learning
    - student understanding of vectors
- **Curriculum Development**
  - interactive lecture
    - (*Workbook for Introductory Physics)*
  - curricular materials for thermodynamics
- **Instructional Methods**
  - methods for large-enrollment classes:
    - "Fully Interactive Lecture"

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Research Basis for Curriculum Development

(NSF-funded thermodynamics project with T. Greenbowe)

AWSFL008-DS3

NSF Award Abstract - #9981140

Development of Active-Learning Curricular Materials in Thermodynamics

NSF Org DUE

Latest Amendment Date June 13, 2000

Award Number 9981140

Award Instrument Standard Grant

Program Manager Duncan E. McBride
DUE DIVISION OF UNDERGRADUATE EDUCATION
EHR DIRECT FOR EDUCATION AND HUMAN RESOURCES

Start Date May 1, 2000

Expires April 30, 2003 (Estimated)

Expected Total Amount $149479 (Estimated)

Investigator David E. Meltzer dem@iastate.edu (Principal Investigator current)
Thomas J. Greenbowe (Co-Principal Investigator current)

Sponsor Iowa State University
2207 Pearson Hall, Room 15
Ames, IA 500112207 515/294-5225

NSF Program 7427 CCLI-EDUCATIONAL MATERIALS DEV

Field Application 0000099 Other Applications NEC

Program Reference Code 7427,9178,SMET,

ISU CTE: 1999-2000 Miller Fellows

Fellows: David Meltzer, Thomas Greenbowe

Proposal Title: "Development of Active Learning Curricular Materials in Thermodynamics for Physics and Chemistry"

Description: This is a project to create new curricular materials for the study of thermodynamics, which would have a direct impact on instruction both in the Department of Physics and Astronomy, and the Department of Chemistry. We will utilize educational resources that are uniquely available at Iowa State University, combining the capabilities of the Education Research Groups in both Physics and Chemistry. By targeting the subject of thermodynamics - a field that lies precisely on the borderline between Physics and Chemistry - we will be able to bring to bear the extensive experience of both our groups. We will create new instructional materials of immediate use in Physics courses and in Chemistry courses. These materials center on "active-learning" worksheets, consisting of carefully structured and sequenced sets of questions and exercises. They are designed to elicit common conceptual difficulties, and then to guide students to confront and resolve these difficulties.

Research Basis for Curriculum Development

(NSF-funded thermodynamics project with T. Greenbowe)

- Investigation of second-semester calculus-based physics course. (Physics 222: mostly engineering students)
- Written diagnostic questions administered last week of class in 1999, 2000, and 2001.
- Detailed interviews carried out post-instruction with 32 volunteers during 2002.

Primary Findings

*Even **after** instruction, many students (40-80%):*

- believe that heat and/or work are state functions independent of process
- believe that net work done and net heat absorbed by a system undergoing a cyclic process must be zero
- are unable to apply the First Law of Thermodynamics in problem solving

Student reasoning regarding work, heat, and the first law of thermodynamics in an introductory physics course

David E. Meltzer, Department of Physics & Astronomy, Iowa State University, Ames, IA 50011

Abstract: Written quiz responses of 653 students in three separate courses are analyzed in detail.

There has been relatively little research on student learning of thermodynamics in physics courses at the university level. A recent study by Loverude *et al.*[1] has made it evident that students at the introductory level (and beyond) face many significant difficulties in learning fundamental thermodynamic concepts such as the first law of thermodynamics.

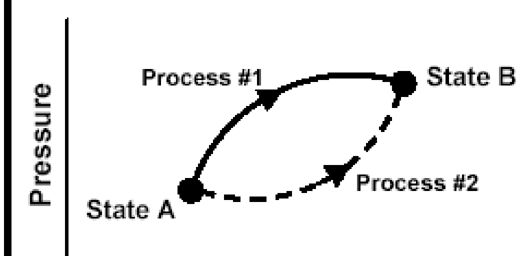
I have been engaged in an ongoing project with T. J. Greenbowe to investigate student learning of thermodynamics in both physics and chemistry courses.[2] As part of that investigation, a short diagnostic quiz has been administered over the past two years in the calculus-based introductory physics course at Iowa State University (ISU). This quiz focuses on heat, work, and the first law of thermodynamics.

At ISU, thermodynamics is studied at the end of the second semester of the two-semester sequence in calculus-based introductory general physics. This course is taught in a traditional manner, with large lecture classes (up to 250 students), weekly recitation sections (about 25 students), and weekly labs taught by graduate students.

The 1999 and 2000 classes were taught by the same instructor, using a different textbook in each course. The 2001 course was taught by a different instructor, using the same text that was employed in the 1999 course. Both instructors are very experienced and have taught introductory physics at ISU for many years.

The quiz was administered in two different ways: in 1999 and 2001, it was given as a practice quiz in the final recitation session (last week of class). In almost all cases it was ungraded; one instructor used it as a graded quiz. In 2000 the quiz was administered as an ungraded practice quiz in the very last lecture class of the year.

This *p-V* diagram represents a system consisting of a fixed amount of ideal gas that undergoes two ***different*** processes in going from state A to state B:



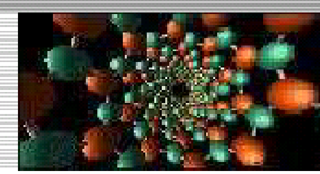
Gordon Research Conference on Physics Research and Education
June 11-15, 2000
at Plymouth State College

Jan Tobochnik, Kalamazoo College and Harvey Gould, Clark University, co-chairs
Beth Ann Thacker, Texas Tech University, vice-chair

This series of conferences will focus on how research in physics and research in physics education can be used to improve the teaching of physics, primarily at the undergraduate level. The first conference will emphasize the teaching of thermal and statistical physics. Special attention will be given to areas of current research and technological interest which can be included in such courses, physics and chemistry educational research on conceptual understanding of thermal physics and probability, and innovative curricular materials and approaches. The goal is to bring together workers who are active in research in thermal and statistical physics, researchers in the new field of physics education, and people who teach courses in statistical and thermal physics.

Sunday, May 11

DEPARTMENT of Physics



Events

Student Learning in Thermodynamics: Exploring the Chemistry/Physics Connection.

Who: Prof. David Meltzer - (Iowa State University)
Where: Smith Lab, Room 1094
When: Monday, February 26, 2001 at 10:30
Type: Physics Education Seminar

Description: Students are exposed to thermodynamics concepts at multiple points during their academic career, often including both chemistry and physics courses in high school and college. At Iowa State University the education research groups in both the Physics and the Chemistry departments have begun a joint investigation of the dynamics of student learning of thermodynamics. We are exploring student learning difficulties with various thermodynamic concepts, as well as possible interactions between the chemistry and physics curricula and their impact on students' conceptual understanding. I will present some of our preliminary results and discuss the directions in which our investigation is proceeding.

New Approaches to Meteorology Education Course for University Faculty

The confluence of a national call for improving undergraduate education (e.g., Scrutiny of Undergraduate Geoscience Education, Shaping the Future, and Geoscience Education: A Recommended Strategy), the rapid development of technology, and the emergence of new models of how students learn have created a climate for a reassessment of how the foundation courses in undergraduate meteorology programs are taught. Most of the required meteorology courses are now characterized by a lecture format which many educators have argued focuses on memorization of factual information that promotes the development of superficial understandings and inert knowledge. The goal for this course is

[At the University Corporation for Atmospheric Research]

The New Approaches to Meteorology Education course for University Faculty will use thermodynamics as the topic for hands-on learning for faculty seeking to improve the learning environments for students. Topics to be addressed will include: how students learn, demonstrating learning, establishing course goals and choosing instructional media. During this course, faculty will be exposed to tools such as streaming media, portfolio assessment, and course managers. They will also be introduced to resources from the meteorology community such as the COMET multimedia data base, interactive java activities and MetApps. The faculty will use contemporary pedagogies to create group projects that will be pilot versions of innovative approaches to helping students understand principles of atmospheric thermodynamics.

Upon completion of the course, participants will be encouraged to engage in a follow-up project to continue to develop instructional materials for their own courses.

Course organizers are Dr. Doug Yarger, Emeritus Professor, Iowa State University, Dr. Greg Byrd and Dr. Joe Lamos, COMET Education and Training. The course program committee also includes representatives of the UCAR community.

Time	Tuesday

Some Strategies for Instruction

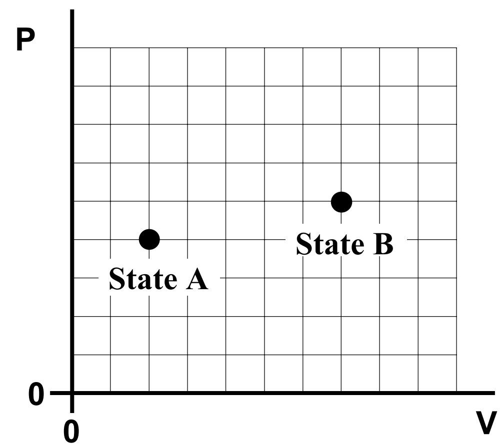
- Try to build on students' understanding of state-function concept.
  - most *do* understand this within context of energy
- Focus on meaning of heat as ***transfer*** of energy, ***not*** quantity of energy residing in a system.
- Develop concept of work as energy transfer mechanism.

Thermodynamics Worksheet

For an ideal gas, the internal energy U is directly proportional to the temperature T. (This is because the internal energy is just the total kinetic energy of all of the gas molecules, and the temperature is defined to be equal to the *average* molecular kinetic energy.) For a monatomic ideal gas, the relationship is given by $U = \frac{3}{2}nRT$, where n is the number of moles of gas, and R is the universal gas constant.

1. Find a relationship between the internal energy of n moles of ideal gas, and pressure and volume of the gas. Does the relationship change when the number of moles is varied?

2. Suppose that m moles of an ideal gas are contained inside a cylinder with a movable piston (so the volume can vary). At some initial time, the gas is in state A as shown on the PV-diagram in Figure 1. A thermodynamic process is carried out and the gas eventually ends up in State B. Is the internal energy of the gas in State B *greater than*, *less than*, or *equal to* its internal energy in State A? (That is, how does U_B compare to U_A?) Explain.

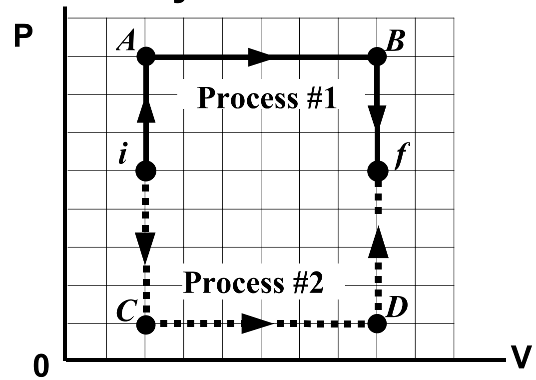


3. If a system starts with an initial internal energy of $U_{initial}$ and ends up with U_{final} some time later, we symbolize the *change* in the system's internal energy by ΔU and define it as follows: $\Delta U = U_{final} - U_{initial}$.

   a. For the process described in #2 (where the system goes from State A to State B), is ΔU for the gas system *greater than zero*, *equal to zero*, or *less than zero*?

   b. During this process, was there any energy transfer between the gas system and its surrounding environment? Explain.

Thermodynamics Worksheet



7. Rank the *temperature* of the gas at the six points *i*, *A*, *B*, *C*, *D*, and *f*. (Remember this is an *ideal* gas.)

8. Consider all sub-processes represented by straight-line segments. For each one, state whether the work is positive, negative, or zero. In the second column, rank all six processes according to their ΔU. (Pay attention to the sign of ΔU.) If two segments have the same ΔU, give them the same rank. In the last column, state whether heat is added *to* the gas, taken *away* from the gas, or is *zero* (i.e., *no* heat transfer). ***Hint:* First determine *U* for each point using the result of #1 on page 1.**

Process	Is W +, –, or 0?	rank according to ΔU	heat added *to*, taken *away*, or *zero*?
$i \rightarrow A$			
$A \rightarrow B$			
$B \rightarrow f$			
$i \rightarrow C$			
$C \rightarrow D$			
$D \rightarrow f$			

9. Consider **only** the sub-processes that have $W = 0$. Of these, which has the *greatest* absolute value of heat transfer Q? Which has the *smallest* absolute value of Q?

10. Rank the six segments in the table above according to the absolute value of their W. *Hint:* For processes at constant pressure, $W = P\,\Delta V$.

11. Using your answers to #8 and #10, explain whether W_1 is *greater than*, *less than*, or *equal to* W_2. [Refer to definitions, page 3.] Is there also a way to answer this question using an "area" argument?

12. Is Q_1 *greater than*, *less than*, or *equal to* Q_2? Explain. *Hint:* Compare the magnitude of ΔU_1 and ΔU_2, and make use of the answer to #6.

Classroom Testing

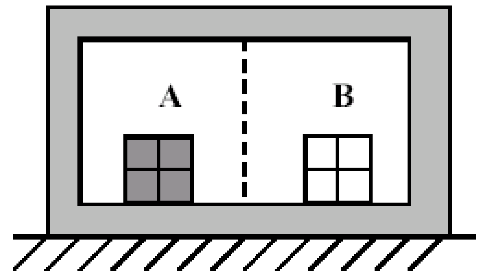
- Use worksheets in randomly chosen recitation sections (assisted by PERG graduate students).
- Compare exam performance of students in experimental sections to those in control sections.
- Modify worksheets based on input from recitation instructors and PERG graduate students.

Related Work on Calorimetry

- Probe understanding of students in physics courses
  - N.-L. Nguyen and Warren Christensen
- Investigate students' understanding of chemical calorimetry
  - with T. J. Greenbowe, ISU Chemistry Dep't., and post-doc Irene Grimberg
  - paper in press at *International Journal of Science Education*
- Develop and test worksheets for both physics and chemistry

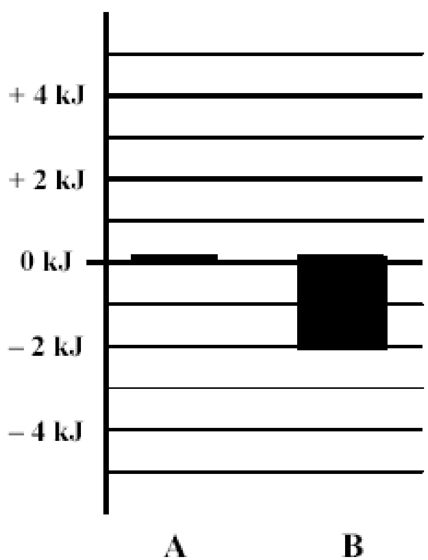
Calorimetry Worksheet

1. Suppose we have two samples, *A* and *B*, of **different** materials, placed in a partitioned insulated container which neither absorbs energy nor allows it to pass in or out. Sample *A* has the **same** mass as sample *B***.** Energy but no material can pass through the conducting partition. (Assume specific heat is independent of temperature.) **The specific heat of material *A* is twice that of material *B*.**

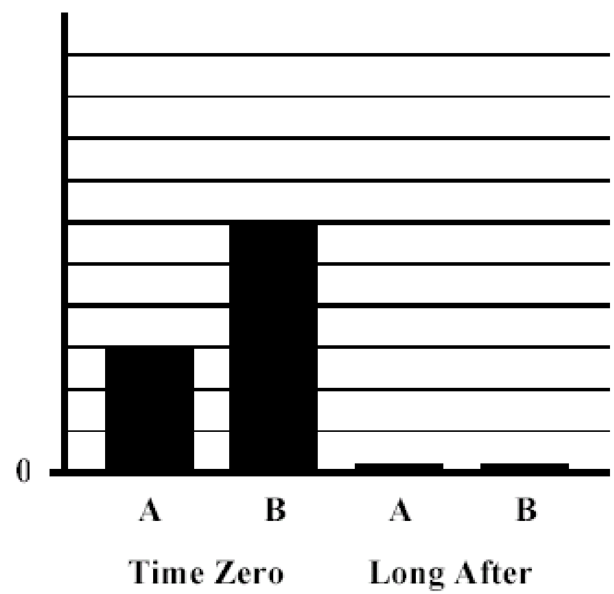


Complete the bar charts below for temperature and energy transfer. If any quantity is zero, label that quantity as zero on the bar chart. Explain your reasoning below.

Energy Transfer <u>to</u> Sample:



Absolute Temperature



[Poster at Physics Education Research Conference]

Project Description: Student volunteers (N=8) from a calculus-based physics course were interviewed on their understanding of calorimetry concepts in audio-taped sessions lasting 45-60 minutes. Based on their responses, a series of worksheet questions were developed. During the next offering of the same course (Summer 2002), a pretest on calorimetry concepts was administered to the entire class. The worksheets were then used in one of the recitation sections of the class, and later a related exam question was administered to the entire class.

Summary of Interview Questions:

- A piece of hot metal is placed in colder water (mass of metal = mass of water) and left in thermal isolation. Describe the transfer of energy between the metal and the water, and their relative amounts of temperature change.
- Draw a graph of temperature vs. time for the metal and water when the mass of the metal is (1) the *same* as the water, and (2) *twice* that of the water.
- Draw a temperature vs time graph for two different liquids heated at the same rate, when the liquids have the same mass but *different* specific heats.

Observation from the Interviews: The requirement for the students to draw and justify temperature-time graphs was very helpful in getting them to thoroughly explain their reasoning

Example interview item A

3. A calorimeter is made of very good insulating material and it has a lid. We can assume that no energy transfer occurs between the walls of the calorimeter and any material contained within it, and also that there is no energy transfer between the calorimeter and the room where it is located.

A piece of copper metal is put into a calorimeter which is partly filled with water. The mass of the copper is the ***same*** as the mass of the water, but the temperature of the copper is ***higher*** than the temperature of the water. The calorimeter is left alone for several hours.

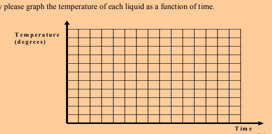
a) Does energy transfer occur? If yes, please explain and compare the ***quantities*** or amounts of energy that are transferred and where they are transferred to.

b) Is there a temperature change in either the copper or the water? If so compare the ***amount*** of temperature change or lack of such in the copper and water. If one changes temperature more, then which one changes temperature more and why?

Example interview item B

5. Suppose we have two ***separate*** containers each containing ***different*** liquids with different ***specific heats*** but with the same mass and initial temperature. Each container is placed on an heating plate that delivers the ***same rate of heating*** in joules per second to each liquid.

i) Below please graph the temperature of each liquid as a function of time.

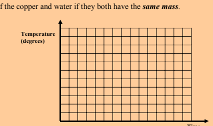


ii) Please explain the reasoning that you used to determine how you chose to draw the graph as you did.

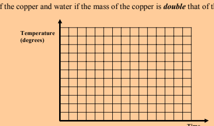
Example interview item C

6. Suppose that a mass of copper is heated to a high initial temperature. Suppose then that is placed in a insulated container of water that is at a lower initial temperature.

a) Graph the temperature of the copper and water if they both have the ***same mass***.



b) Graph the temperature of the copper and water if the mass of the copper is ***double*** that of the water.



Major findings from interviews:

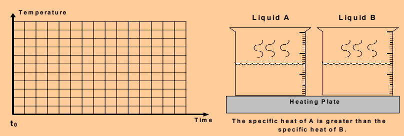
- Students were able to use the concept of thermal equilibrium in their explanations.
- Students were often unable to distinguish among heat, internal energy, and work.
- In the case of copper and water of equal mass, some students (3 out of 8) incorrectly stated that the copper would have the smaller temperature change. Their reasons were (1) higher thermal conductivity of the copper; (2) higher melting point of the copper, and (3) the idea that water could change temperature "more easily" than the copper.
- Almost all students (7 out of 8) were able to state correctly that doubling the mass of the copper would lead to a smaller net temperature change for the copper.

Pretest: Items similar to the interview questions were administered as in-class quizzes during the summer-session course

Sample pretest item:

2. Suppose we have two ***separate*** containers: One container holds Liquid A, and another contains Liquid B. The mass and initial temperature of the two liquids are the same, but the ***specific heat*** of Liquid A is ***greater than*** Liquid B. Each container is placed on a heating plate that delivers the ***same rate of heating*** in joules per second to each liquid beginning at initial time t_0.

a) On the grid below, graph the temperature as a function of time for *each* liquid, A and B. Use a separate line for each liquid, even if they overlap. Make sure to clearly label your lines, and use proper graphing techniques.



b) Please **explain** the reasoning that you used in drawing your graph. (Please continue on the back of the page.)

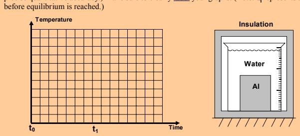
Pretest Results: For the most part, students were able to correctly draw two lines with the line representing liquid B having the greater slope. However, a significant minority (22%) drew the liquid-A line as having the greater slope, and many were unable to give acceptable explanations. 9% of students showed the lines sloping down (i.e., cooling)

Post-test: A post-test question was given to the class as part of their next exam, after using the worksheets. Analysis of these results is not yet complete

Exam Question

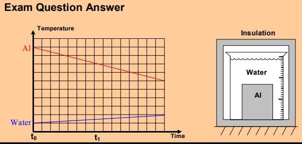
2. Suppose that a mass of aluminum (**Al**) is heated to a high initial temperature. At time t_0 it is placed in an insulated container of water that is at a lower initial temperature. The mass of the aluminum is the ***same*** as the mass of the water. (Note: The specific heat of water is higher than that of aluminum.)

a) On the grid below, graph the temperature as a function of time of the aluminum and water separately. (Don't worry about precise quantitative accuracy.) Make sure to clearly label your graphs. (Note: t_1 represents a time shortly after the initial time, before equilibrium is reached.)



b) Please explain the reasoning that you used in drawing your graph.

Exam Question Answer



Common errors in exam responses:

- Slope of water line having greater absolute value than that of the aluminum line.
- Indicating that the net temperature change of the aluminum was less than that of the water, or that water's temperature change would be "faster."
- Stating that the time until equilibrium was reached for one material or the other would be "longer," or would require "more time" or "less time."
- Saying that temperature changes occur "more easily" or "less easily" for one of the materials.
- Stating that for aluminum, "***heat***" absorption/change/increase is faster
- Explaining that the faster temperature change of aluminum was due to its higher initial temperature.

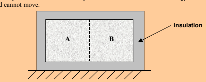
Ideas for curriculum development:

- **Increased precision:** Many times student explanations were vague or imprecise. We developed questions that required more exact understanding or manipulation of specific quantities.
- **Proportional reasoning:** By using ratios or other tasks that required students to compare specific numbers, they would be led to develop more precise judgments and descriptions.
- **Guided development:** The poor explanations given by many students suggested that it would be helpful to guide them through the concepts in a step-by-step manner.
- **Targeting confusion among fundamental quantities:** The worksheets were designed to focus students' thinking on the distinctions among basic thermodynamic quantities such as temperature, heat, and internal energy.

Sample worksheet page A

The *internal energy* [symbol: *U*] of an ideal gas is equal to the total kinetic energy of all of the molecules in the gas. According to the kinetic theory of gases, the absolute *temperature* of an ideal gas is proportional to the average kinetic energy of the molecules contained within the gas.

1. Suppose we have two samples, **A** and **B**, of an **ideal gas** placed in a partitioned insulated container of negligible heat capacity. Sample **A** has the **same mass** as sample **B** and each side of the partition has the same volume. Energy but no material can pass through the conducting partition; the partition is rigid and cannot move.



On the bar chart on the next page, the values of the samples' internal energy are shown at some initial time ("Time Zero"); "Long After" refers to a time long after that initial time. Refer to the set of three bar charts to answer the following questions.

a. Find the absolute temperature of sample A at time zero (the initial time), and plot it on the chart. *Hint:* If two equal masses of ideal gas have the same internal energy, will their temperature be the same, or different? If the ratio of internal energies is $\frac{U_A}{U_B}$, what can you say about $\frac{T_A}{T_B}$?

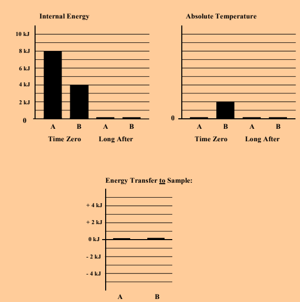
b. After the initial time, would you expect to see any changes in the temperatures of samples A and B? If yes, describe the changes (i.e., increases or decreases). If you don't expect to observe any changes, explain why.

c. A long time after time zero, what ratio do you expect for the temperatures of the two samples? $\frac{T_A}{T_B}$ = ____?

d. A long time after time zero, what ratio do you expect for the internal energies of the two samples? $\frac{U_A}{U_B}$ = ____? Explain.

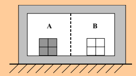
e. Complete the bar charts by finding the "Long After" values for temperature and internal energy, and also the amounts of energy transferred to the two samples. (This is the net transfer that occurs between time zero and the time "long after.") If any quantity is zero, label that quantity as zero. Explain your reasoning below.

Example worksheet page B



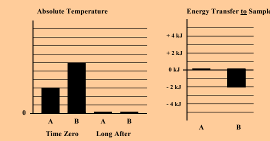
Example worksheet page C

5. Suppose we have two samples, **A** and **B**, of **different** materials, placed in a partitioned insulated container of negligible heat capacity. Sample **A** has the **same** mass as sample **B.** Energy but no material can pass through the conducting partition. The atmosphere in the container can transfer energy but has a negligible heat capacity. Assume specific heat is independent of temperature. **The specific heat of material A is twice that of material B.**



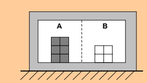
a. If the temperature of sample A changes by ΔT_A, what would be the corresponding change in the temperature of sample B? ΔT_B = ________?

b. Complete the bar charts below for temperature and energy transfer. If any quantity is zero, label that quantity as zero. Explain your reasoning below.



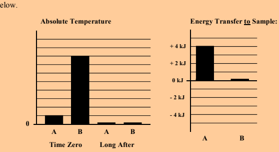
Example worksheet page D

6. Suppose we have two samples, **A** and **B**, of **different** materials, placed in a partitioned insulated container of negligible heat capacity. Sample **A** has **1.5 times the mass** of sample **B.** Energy but no material can pass through the conducting partition. The atmosphere in the container can transfer energy but has a negligible heat capacity. Assume specific heat is independent of temperature. **The specific heat of material B is twice that of material A.**



a. If the temperature of sample A changes by ΔT_A, what would be the corresponding change in sample B? ΔT_B = ________?

b. Complete the bar charts below for temperature and energy transfer. If any quantity is zero, label that quantity as zero. Explain your reasoning below.



Student Response to Worksheets:

- **Appropriate Difficulty Level:** Students took the entire time given to them (forty minutes) to work on the sheets. No students finished the entire 8-page worksheet.
- **Accessibility:** Most students were able to go through the worksheets based on discussions among themselves, but instructor intervention was required for some students on several questions.
- **Supplements standard instruction:** By the time the students had been given the worksheets they had already had a traditional lecture and completed a homework assignment on calorimetry. However, this did not seem to make the worksheets redundant. Even the more advanced students needed to pause, think, and reason out several of the problems.

Thermochemistry Tutorial

The textbook (p. 161) describes an experiment in which Silver Nitrate ($AgNO_3$) solution is mixed with hydrochloric acid (HCl) solution in a constant-pressure calorimeter. (We assume that the calorimeter loses only a negligible quantity of heat.) The temperature of the resulting solution is observed to increase, due to the following reaction:

$$AgNO_3(aq) + HCl(aq) \rightarrow AgCl(s) + HNO_3(aq)$$

2. Three students are discussing this experiment. Here is part of their discussion:

Mary: The silver nitrate was originally a solid. When it's put into solution along with the HCl, I think that heat flows out from the $AgNO_3$ and into the HCl solution, and that's why the temperature increases.

Bob: Well, the hydrochloric acid is the more powerful reactant; it's a strong acid, so it must be the one that reacts most strongly. I think that the heat must come out of the HCl.

Lisa: I don't really think that the heat flows into either of those two. I think heat flows out of both the silver nitrate *and* the hydrochloric acid solution, and that's why the temperature rises.

Mary: But how could heat flow out of *both* of the reactants? Where is it coming from then? Doesn't that violate conservation of energy?

Comment on the students' statements. Do you agree with one of them more than the others? If so, explain why. If you don't think that any of them are completely correct, give your own opinion.

INT. J. SCI. EDUC., 2003, VOL. 25, NO. 1, 1–22

Taylor & Francis
Taylor & Francis Group

Student learning of thermochemical concepts in the context of solution calorimetry

Thomas J. Greenbowe, Department of Chemistry, Iowa State University of Science and Technology, Ames, IA 50011, USA; e-mail: tgreenbo@iastate.edu; and David E. Meltzer, Department of Physics and Astronomy, Iowa State University of Science and Technology, Ames, IA 50011, USA; e-mail: dem@iastate.edu

Student understanding of heat and thermal phenomena has been the subject of considerable investigation in the science education literature. Published studies have reported student conceptions on a variety of advanced topics, but calorimetry – one of the more elementary applications of thermochemical concepts – has apparently received little attention from science education researchers. Here we report a detailed analysis of student performance on solution calorimetry problems in an introductory university chemistry class. We include data both from written classroom exams for 207 students, and from an extensive longitudinal interview series with a single subject who was herself part of that larger class. Our findings reveal a number of learning difficulties, most of which appear to originate from failure to understand that net increases and decreases in bond energies during aqueous chemical reactions result in energy transfers out of and into, respectively, the total mass of the resultant solution.

ISU PERG Major Projects

- **Basic Research**
  - students' reasoning in thermodynamics
  - role of diverse representational modes in learning
    - student understanding of vectors
- **Curriculum Development**
  - interactive lecture
    - (*Workbook for Introductory Physics)*
  - curricular materials for thermodynamics
- **Instructional Methods**
  - methods for large-enrollment classes:
    - "Fully Interactive Lecture"

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AWSFL008-DS3

NSF Award Abstract - #0206683

Investigation of Diverse Representational Modes in the Learning of Physics and Chemistry

NSF Org	REC
Latest Amendment Date	June 26, 2002
Award Number	0206683
Award Instrument	Standard Grant
Program Manager	Walter C. Ermler REC DIV OF RSCH, EVALUATION AND COMMUNICATIO EHR DIRECT FOR EDUCATION AND HUMAN RESOURCES
Start Date	July 1, 2002
Expires	June 30, 2003 (Estimated)
Expected Total Amount	$99949 (Estimated)
Investigator	David E. Meltzer dem@iastate.edu (Principal Investigator current) Thomas J. Greenbowe (Co-Principal Investigator current)
Sponsor	Iowa State University 2207 Pearson Hall, Room 15 Ames, IA 500112207 515/294-5225
NSF Program	1666 RESEARCH ON LEARNING & EDUCATI
Field Application	0116000 Human Subjects
Program Reference Code	9177,9237,SMET,

Investigation of Diverse Representational Modes in the Learning of Physics and Chemistry

- Probe students' reasoning with widely used representations
  - e.g., free-body diagrams
- Compare student reasoning with different forms of representation of same concept
  - e.g., verbal, diagrammatic, mathematical/symbolic, graphical
- ***Preliminary work:*** student understanding of vector concepts
  - central to instruction in general physics curriculum

Physics Students' Understanding of Vector Concepts

N. Nguyen and DEM, Am. J. Phys. (June 2003)

- Seven-item quiz administered in all ISU general physics courses during 2000-2001
- Quiz items focus on basic vector concepts posed in graphical form
- Given during first week of class; 2031 responses received

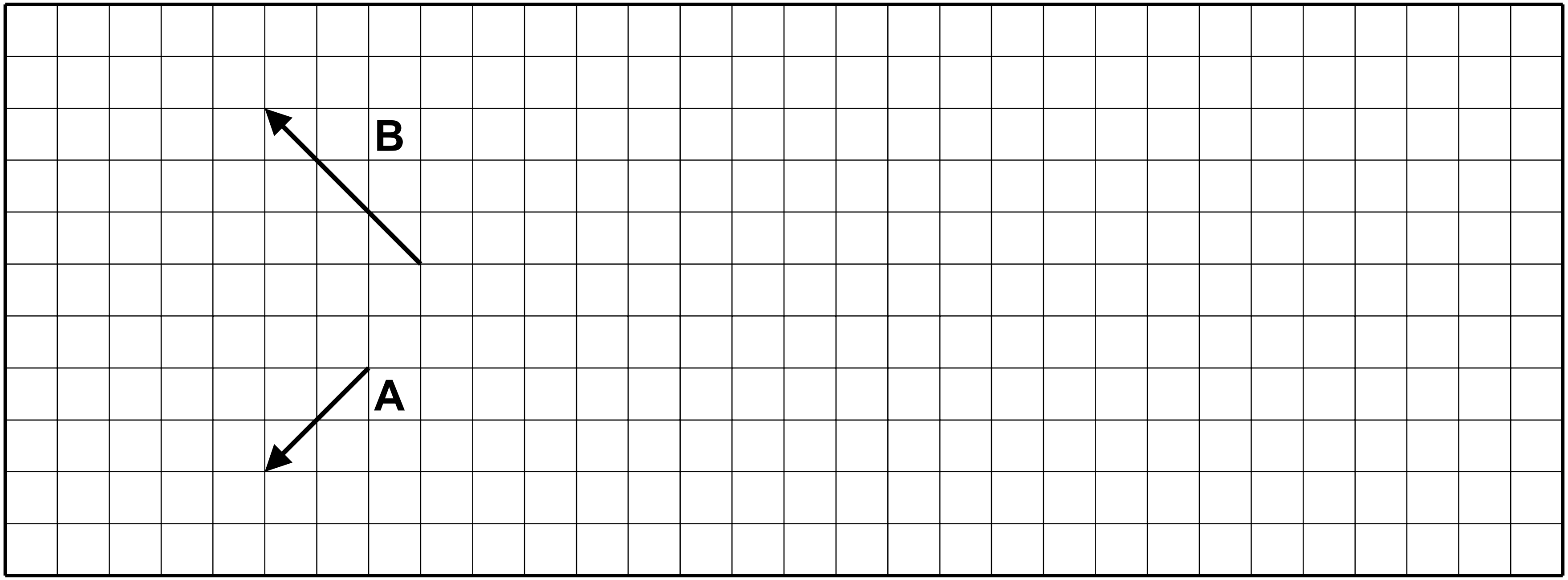
Two Key Items

- **Question #2:** Choose vector with same direction as given vector
- **Question #5:** Two-dimensional vector addition

Two Key Items

- **Question #2:** Choose vector with same direction as given vector
- **Question #5:** Two-dimensional vector addition

5. In the figure below there are two vectors $\vec{\mathbf{A}}$ and $\vec{\mathbf{B}}$. Draw a vector $\vec{\mathbf{R}}$ that is the sum of the two, (i.e. $\vec{\mathbf{R}} = \vec{\mathbf{A}} + \vec{\mathbf{B}}$). Clearly label the resultant vector as $\vec{\mathbf{R}}$.



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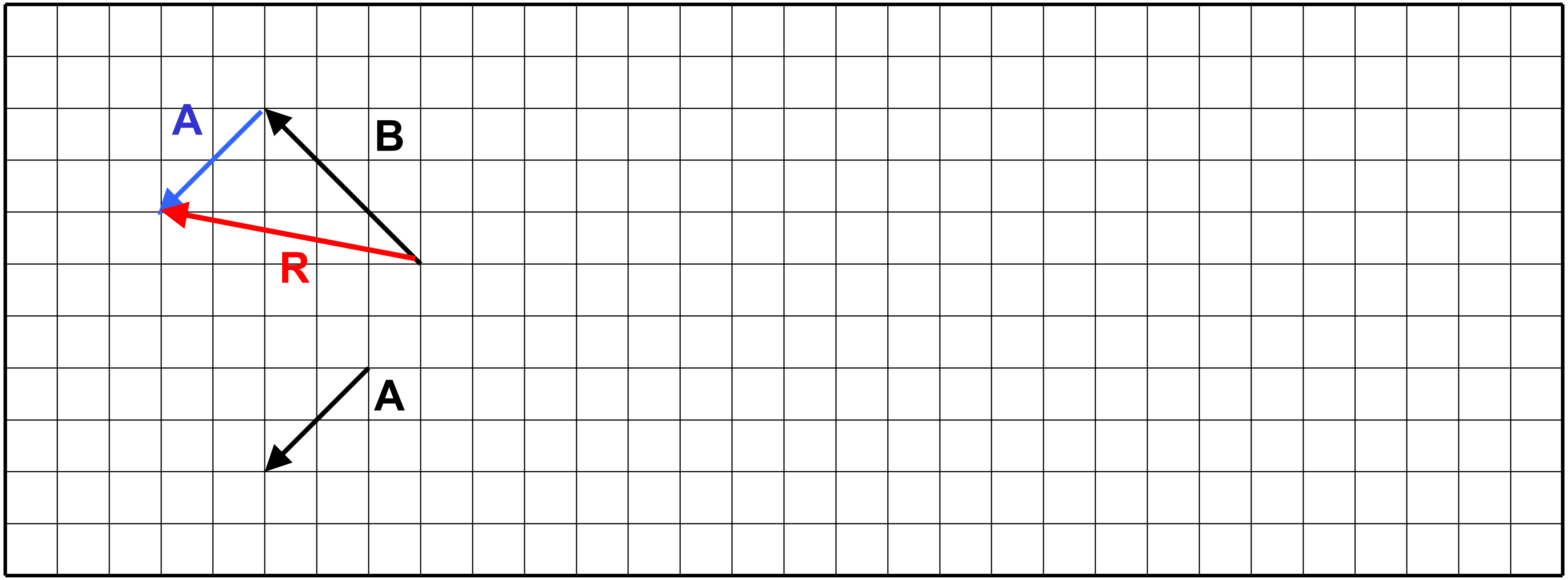

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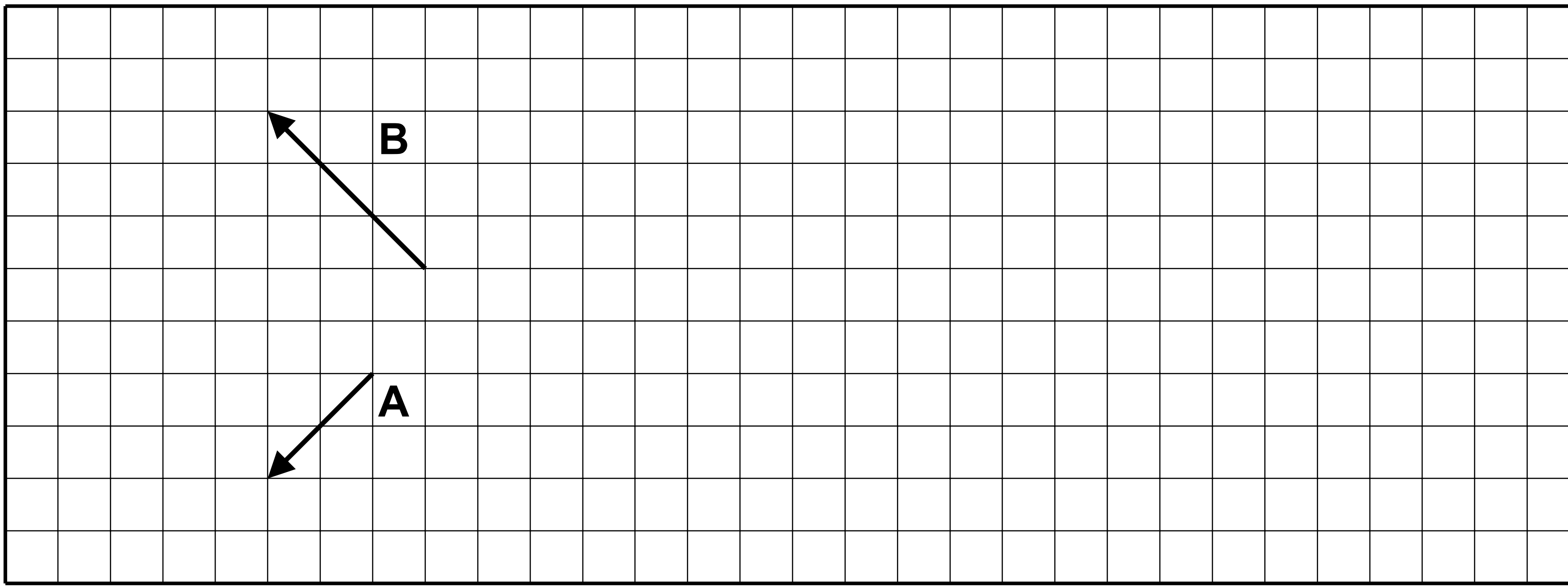
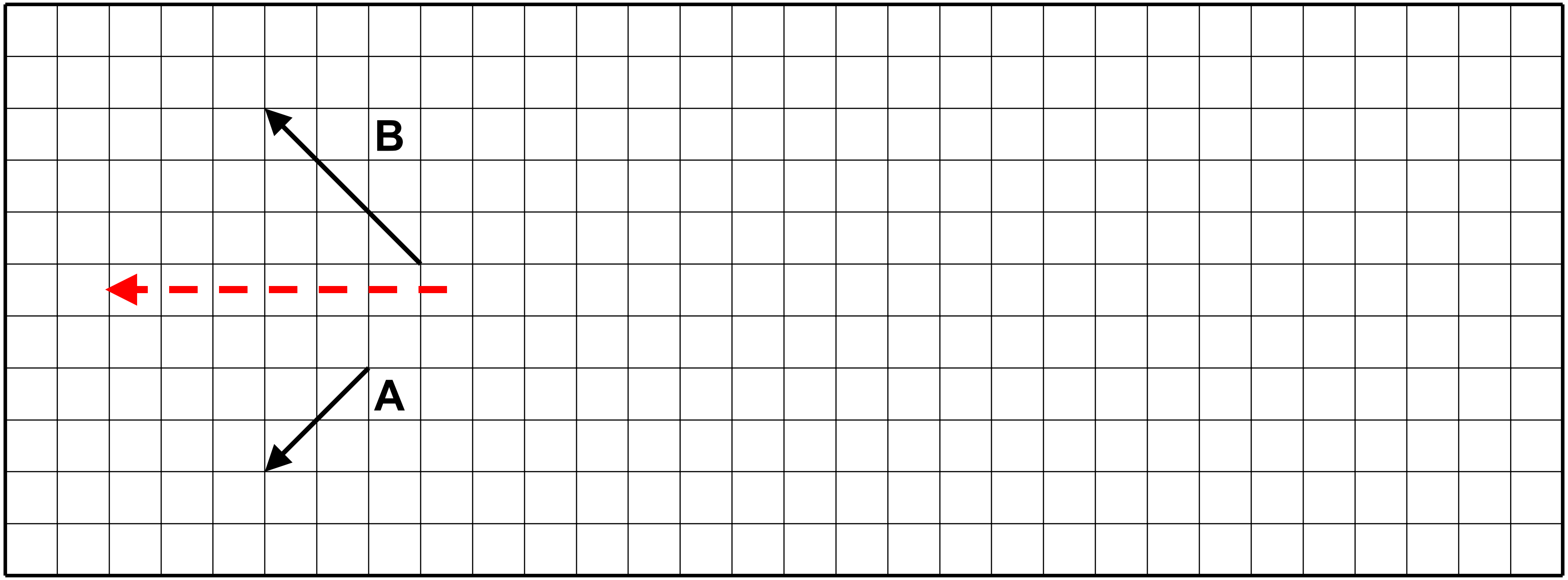


Error Rates:

Calculus-based course: ***27% - 42%***

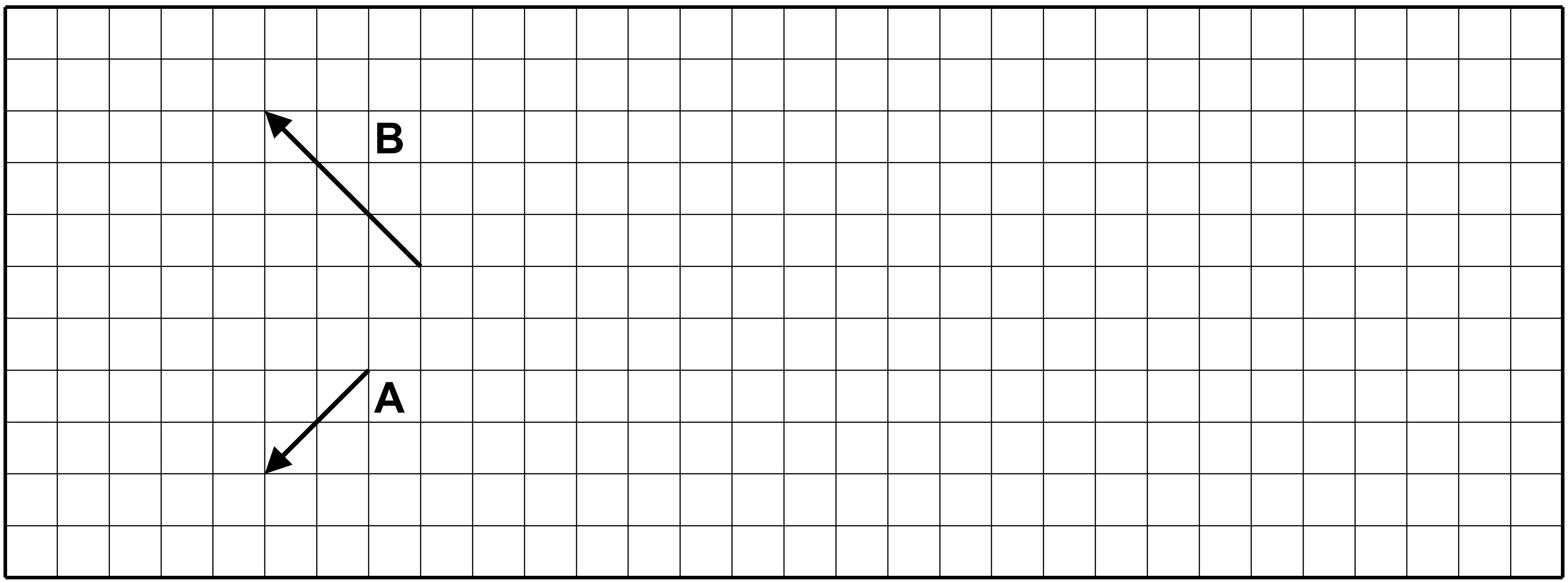
Algebra-based course: ***56% -78%***

5. In the figure below there are two vectors $\vec{\mathbf{A}}$ and $\vec{\mathbf{B}}$. Draw a vector $\vec{\mathbf{R}}$ that is the sum of the two, (i.e. $\vec{\mathbf{R}} = \vec{\mathbf{A}} + \vec{\mathbf{B}}$). Clearly label the resultant vector as $\vec{\mathbf{R}}$.



Common Error

5. In the figure below there are two vectors $\vec{\mathbf{A}}$ and $\vec{\mathbf{B}}$. Draw a vector $\vec{\mathbf{R}}$ that is the sum of the two, (i.e. $\vec{\mathbf{R}} = \vec{\mathbf{A}} + \vec{\mathbf{B}}$). Clearly label the resultant vector as $\vec{\mathbf{R}}$.



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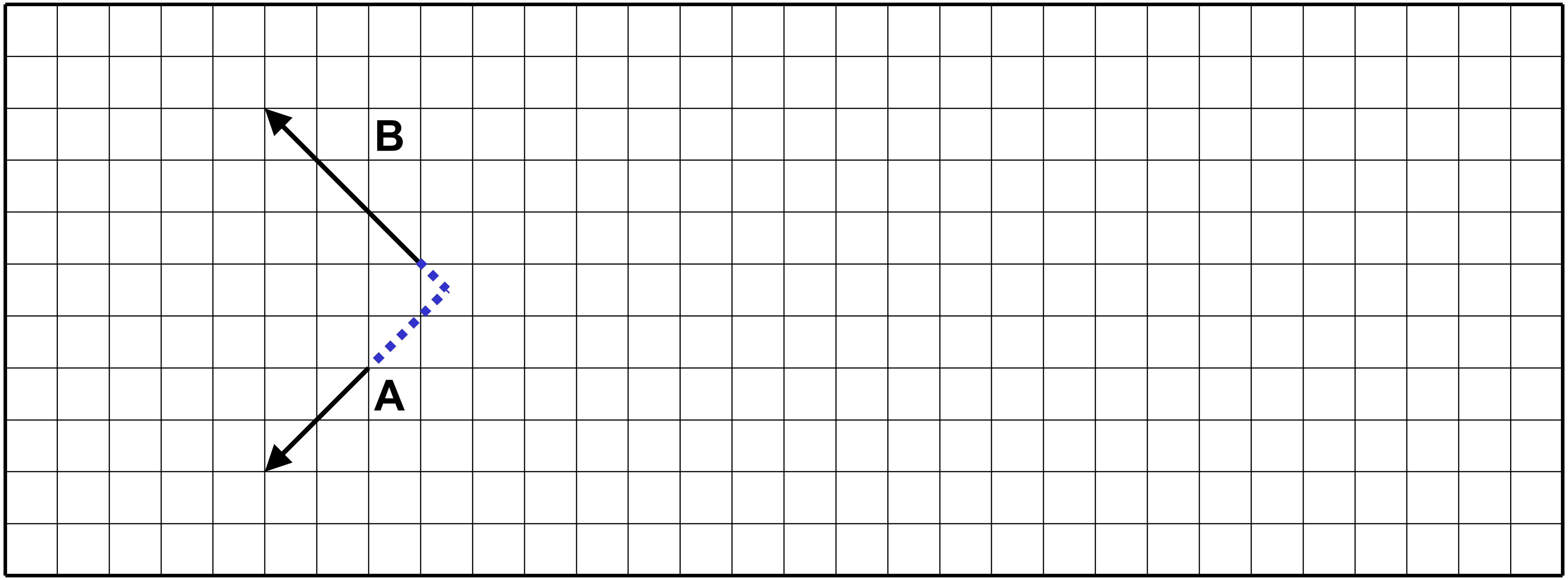
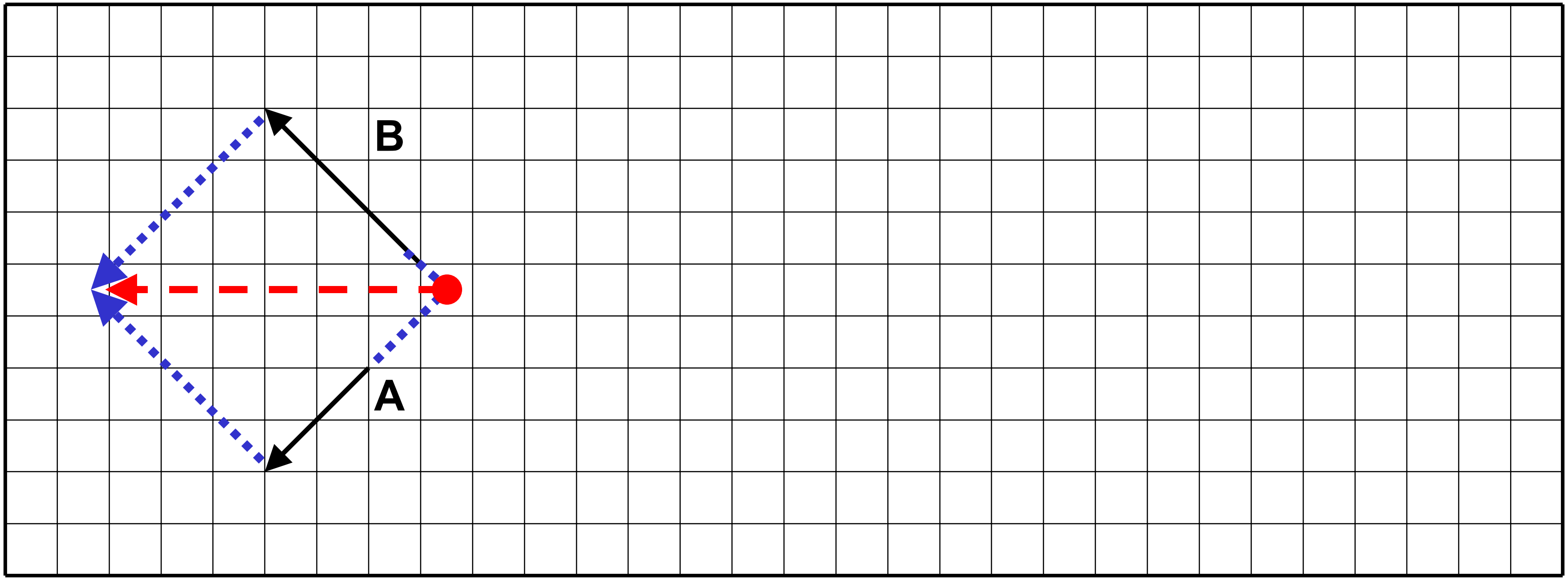


5. In the figure below there are two vectors $\vec{\mathbf{A}}$ and $\vec{\mathbf{B}}$. Draw a vector $\vec{\mathbf{R}}$ that is the sum of the two, (i.e. $\vec{\mathbf{R}} = \vec{\mathbf{A}} + \vec{\mathbf{B}}$). Clearly label the resultant vector as $\vec{\mathbf{R}}$.



Common Incorrect Method

Difficulties with Vector Concepts

- Imprecise understanding of vector direction
- Vague notion of vector addition

  “***R*** should be a combination of ***A*** and ***B*** so I tried to put it between ***A*** and ***B***”

- Confusion regarding parallel transport

  (must maintain magnitude ***and*** direction as vector “slides”)

Initial understanding of vector concepts among students in introductory physics courses

Ngoc-Loan Nguyen[a)] and David E. Meltzer[b)]
Department of Physics and Astronomy, Iowa State University, Ames, Iowa 50011

(Received 8 February 2002; accepted 12 March 2003)

We report the results of an investigation into physics students' understanding of vector addition, magnitude, and direction for problems presented in graphical form. A seven-item quiz, including free-response problems, was administered in all introductory general physics courses during the 2000/2001 academic year at Iowa State. Responses were obtained from 2031 students during the first week of class. We found that more than one quarter of students beginning their second semester of study in the calculus-based physics course, and more than half of those beginning the second semester of the algebra-based sequence, were unable to carry out two-dimensional vector addition. Although the total scores on the seven-item quiz were somewhat better for students in their second semester of physics in comparison to students in their first semester, many students retained significant conceptual difficulties regarding vector methods that are heavily employed throughout the physics curriculum.
[DOI: 10.1119/1.1571831]

I. INTRODUCTION

Vector concepts and calculation methods lie at the heart of the physics curriculum, underlying most topics covered in introductory courses at the university level. As Knight[1] has emphasized, the vector nature of forces, fields, and kinematical quantities requires that students have a good grasp of basic vector concepts if they are to be successful in mastering even introductory-level physics. Knight has alluded to the surprising lack of published research regarding student

veyed students in both the first- and second-semester courses of the two-semester general physics sequence, both in algebra-based and calculus-based courses.

II. METHODS

We constructed a quiz containing seven vector problems posed in graphical form (see the Appendix). The problems assess whether students can correctly identify vectors with identical magnitudes and directions, and whether they can

Investigation of Physics and Chemistry Learning with Diverse Representations

(with T. Greenbowe and L. Allen)

- Probe student understanding of standard physics and chemistry representations
- Compare student reasoning with different forms of representation

“Multiple-Representation” Quiz

- Same or similar question asked in more than one form of representation
  - e.g., verbal [words only], diagrammatic, mathematical, etc.
- Comparison of responses yields information on students’ reasoning patterns with diverse representations

Coulomb's Law Quiz in Multiple Representations

IF YOU WANT A QUESTION GRADED OUT OF THREE POINTS (–1 [MINUS ONE] FOR WRONG ANSWER!!) WRITE "3" IN SPACE PROVIDED ON EACH QUESTION.

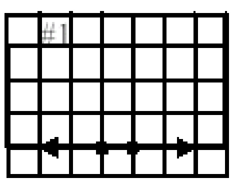
1. When two identical, isolated charges are separated by two centimeters, the magnitude of the force exerted by each charge on the other is eight newtons. If the charges are moved to a separation of eight centimeters, what will be the magnitude of that force now?

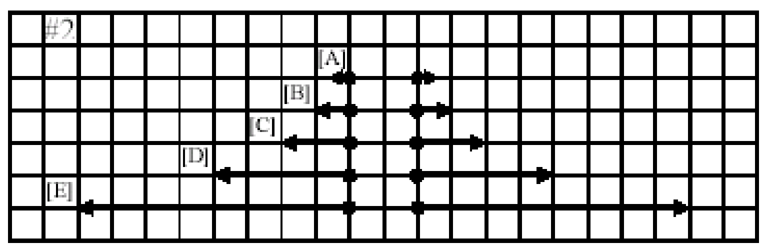
A. one-half of a newton
B. two newtons
C. eight newtons
D. thirty-two newtons
E. one hundred twenty-eight newtons

verbal

Grade out of three? Write "3" here: ______

2. Figure #1 shows two identical, isolated charges separated by a certain distance. The arrows indicate the forces exerted by each charge on the other. The same charges are shown in Figure #2. Which diagram in Figure #2 would be correct?





A.
B.
C.
D.
E.

Grade out of three? Write "3" here: ______

diagrammatic

3. Isolated charges q_1 and q_2 are separated by distance r, and each exerts force F on the other. $q_1^{initial} = q_1^{final}$ and $q_2^{initial} = q_2^{final}$; $r^{initial} = 10m$; $r^{final} = 2m$. $F^{initial} = 25N$; $F^{final} = ?$

A. 1 N
B. 5 N
C. 25 N
D. 125 N
E. 625 N

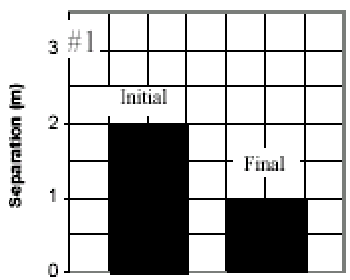
Grade out of three? Write "3" here: ______

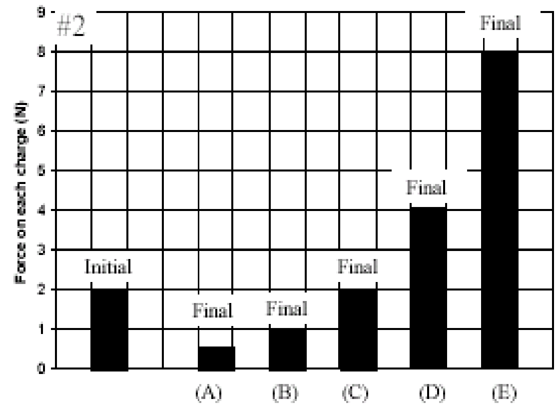
mathematical/symbolic

4. Graph #1 refers to the initial and final separation between two identical, isolated charges. Graph #2 refers to the initial and final forces exerted by each charge on the other. Which bar is correct?

Grade out of three? Write "3" here: ______

A.
B.
C.
D.
E.





graphical

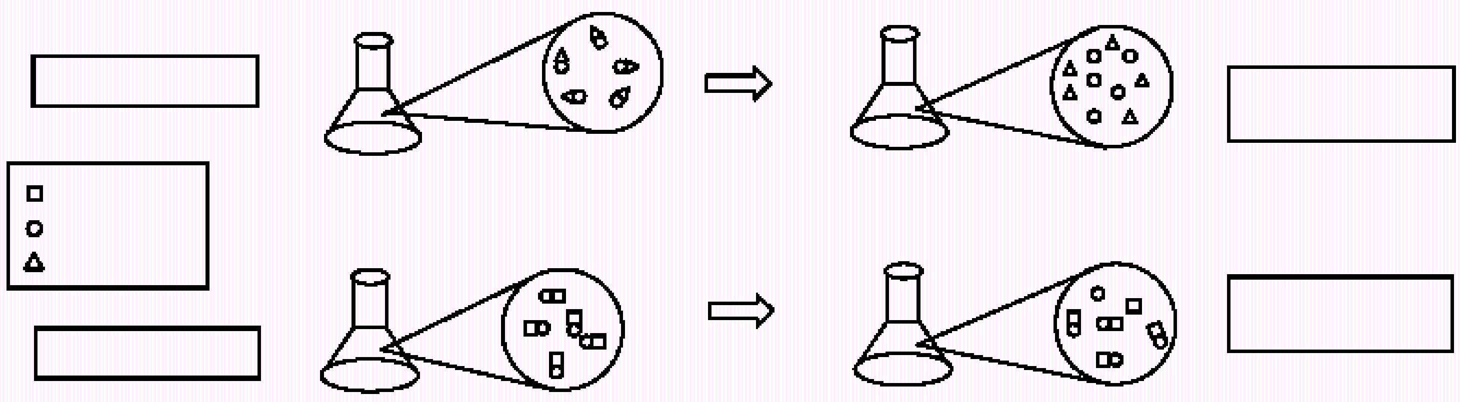
1. Hydrogen chloride gas is bubbled into water, resulting in a one-tenth molar hydrochloric acid solution. In that solution, after dissociation, all of the chlorine atoms become chloride ions, and all of the hydrogen atoms become hydronium ions. In a separate container, HA acid is added to water creating an initial concentration of one-tenth molar HA-acid solution. In that solution (at equilibrium), twenty percent of the H atoms becomes hydronium ions, and twenty percent of the A atoms become A^- ions.

(a) Find the pH of the hydrochloric acid solution and explain your reasoning.

(b) Find the pH of the HA-acid solution and explain your reasoning

[Chemistry Multi-representation Quiz]

2. (a) Given these two samples below, find the pH of each solution



(b) Explain the reasoning you used to come to this conclusion.

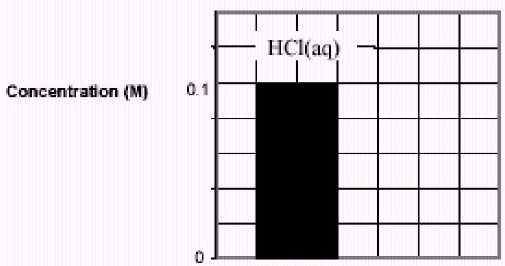
3. (a) Given these two solutions below, find the pH of each solution.

$HA(s) + H_2O(l) \Leftrightarrow H_3O^+(aq) + A^-(aq)$ ionization = 20% initial concentration = 0.1 M pH = ?	$HCl(aq) + H_2O(l) \rightarrow H_3O^+(aq) + Cl^-(aq)$ ionization = 100% initial concentration = 0.1 M pH = ?

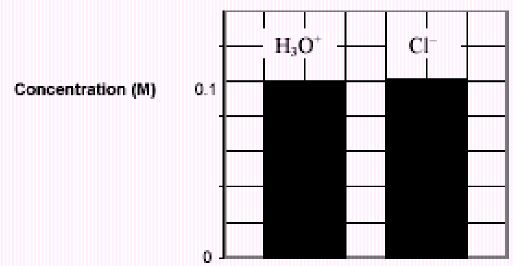
(b) Explain your reasoning.

4. (a) Given the solutions below, find the pH of each solution.

Before dissociation

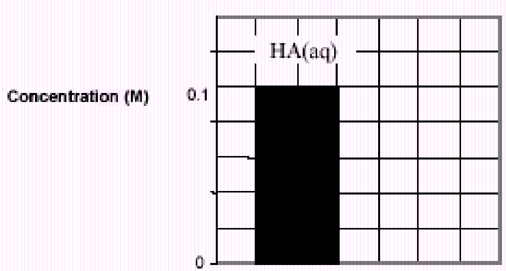


After dissociation

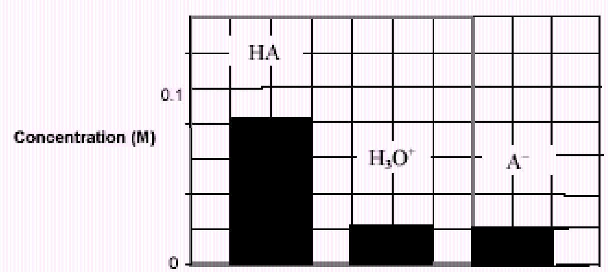


pH = ?

Before dissociation



At equilibrium



pH = ?

Issues Related to Data Analysis and Quantitative Methods in PER

David E. Meltzer
Department of Physics & Astronomy, Iowa State University, Ames, IA 50011

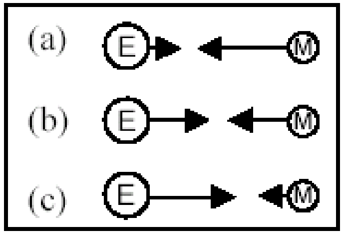
A variety of issues are always relevant (either explicitly or implicitly) in analysis of quantitative data in Physics Education Research. Some specific examples are discussed.

There are a number of issues that always arise, implicitly or explicitly, when conducting quantitative research and carrying out data analysis in Physics Education Research. (Most are relevant for qualitative research as well.)

I. Validity. Broadly speaking, validity refers to the degree to which the conclusions of an investigation truthfully and accurately respond to some specific research questions. Among the particular issues that may arise is: Does your instrument provide data that could actually answer your research question? A common flaw is that the instrument (or test item) is not sufficiently focused, in this sense: To try to answer the question, "Do students understand concept *A*?" the test item (or test instrument) requires knowledge of concepts *A*, *B*, and *C*. Here, *B* and/or *C* might correspond to specific mathematical tools or formal representations. A related question that might arise is: Is your interpretation of the data an accurate representation of students' knowledge?

For example, consider how one might assess students' knowledge of Newton's third law in the context of gravitational forces. At Iowa State I

On the very same quiz, Question #8 asks the students to choose a vector diagram that most closely represents the gravitational forces that the earth and moon exert on each other. The three most popular choices are shown in the figure below.



The correct answer "*b*" was given by 6-12% of students. In each of the five independent administrations of the quiz, the proportion of correct responses on Question #8 was about half that on Question #1 (0.43, 0.60, 0.59, 0.50, and 0.50). The implication seems to be that Question #8 was measuring not only students' knowledge of Newton's third law of motion and law of gravitation, but also (in part) students' understanding of vector diagrams. This conclusion is considerably strengthened by the fact that 34-47% of students gave answer "*c*" on Question #8 [answer "*a*": 43-55%]. The "*c*" response corresponds to the force exerted by the more massive

Topical Strands and Abstracts: Papers and Posters

Foundations for Language and Science Literacy Research: Philosophical, Psychological, Linguistic, and Cultural

This conference theme focuses on the nature and purpose of science discourse, cognitive and metacognitive processes involved in the derived and fundamental senses of science literacy, and the theoretical models of cognition, reading, writing, and argumentation, the socio-cultural dimensions of science instruction, and gender perspectives of language and science literacy.

III-K

Meltzer, David E., Assistant Professor, Iowa State University, USA

Student Learning of Physics Concepts Employing Verbal and Written Forms of Expression in Comparison to Other Representational Modes

Physics instruction includes a variety of representational modes including diagrammatic, mathematical/symbolic, and "verbal" (written passages employing ordinary language). Instructors attempt to assess students' understanding by observing their problem-solving performance employing this same variety of representational modes. An important issue investigated is possible discrepancies in student learning abilities when using verbal and written forms of expression in comparison to diagrammatic and mathematical forms. Another issue being explored is the accuracy of assessment of student learning via students' written descriptions of their reasoning, in comparison to their mathematical/ symbolic problem-solving performance.

ISU PERG Major Projects

- **Basic Research**
  - students' reasoning in thermodynamics
  - role of diverse representational modes in learning
    - student understanding of vectors
- **Curriculum Development**
  - interactive lecture
    - (*Workbook for Introductory Physics)*
  - curricular materials for thermodynamics
- **Instructional Methods**
  - methods for large-enrollment classes:
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Keystones of Research-Based Pedagogy

- problem-solving activities during class time
- deliberately elicit and address common learning difficulties
- guide students to “figure things out for themselves” as much as possible

“Fully Interactive” Physics Lecture

*DEM and K. Manivannan, Am. J. Phys. **70,** 639 (June 2002)*

V

Transforming the lecture-hall environment: The fully interactive physics lecture

David E. Meltzer[a)]
Department of Physics and Astronomy, Iowa State University, Ames, Iowa 50011

Kandiah Manivannan
Department of Physics, Astronomy, and Materials Science, Southwest Missouri State University, 901 South National Avenue, Springfield, Missouri 65804

(Received 19 September 2001; accepted 29 January 2002)

Numerous reports suggest that learning gains in introductory university physics courses may be increased by "active-learning" instructional methods. These methods engender greater mental engagement and more extensive student–student and student–instructor interaction than does a typical lecture class. It is particularly challenging to transfer these methodologies to the large-enrollment lecture hall. We report on seven years of development and testing of a variant of Peer Instruction as pioneered by Mazur that aims at achieving virtually continuous instructor–student interaction through a "fully interactive" physics lecture. This method is most clearly distinguished by instructor–student dialogues that closely resemble one-on-one instruction. We present and analyze a detailed example of such classroom dialogues, and describe the format, procedures, and curricular materials required for creating the desired lecture-room environment. We also discuss a variety of assessment data that indicate strong gains in student learning, consistent with other researchers. We conclude that interactive-lecture methods in physics instruction are practical, effective, and amenable to widespread implementation.

[DOI: 10.1119/1.1463739]

I. INTRODUCTION

Numerous investigations in recent years have shown active-learning methods to be effective in increasing student learning of physics concepts. These methods aim at promoting substantially greater engagement of students during in-class activities than occurs, for instance, in a traditional physics lecture. A long-standing problem has been that of

The basic elements of an interactive lecture strategy have been described by Mazur.[1] In this paper we broaden and extend that discussion, explaining in detail how the lecture component in large-classroom instruction may be almost eliminated. Depending on the preferences of the instructor and the specific student population, this strategy may yield worthwhile learning outcomes. To carry out the rapid back-and-forth dialogue observed in one-on-one instruction in large-enrollment classes requires a variety of specific instruc-

“Fully Interactive” Physics Lecture

DEM and K. Manivannan, Am. J. Phys. ***70,*** *639 (June 2002)*

- Very high levels of student-student and student-instructor interaction
- Simulate one-on-one dialogue of instructor’s office
- Use numerous structured question sequences, focused on specific concept: small conceptual “step size”
- Use student response system to obtain instantaneous responses from *all* students simultaneously (e.g., “flash cards”)

v

Curriculum Requirements for Fully Interactive Lecture

- Many question sequences employing multiple representations, covering full range of topics
- Free-response worksheets adaptable for use in lecture hall
- Text reference ("Lecture Notes") with strong focus on conceptual and qualitative questions

➡ *Workbook for Introductory Physics (DEM and K. Manivannan, CD-ROM, 2002)*

Supported by NSF under
"Assessment of Student Achievement" program

AWSFL008-DS3

NSF Award Abstract - #0243258

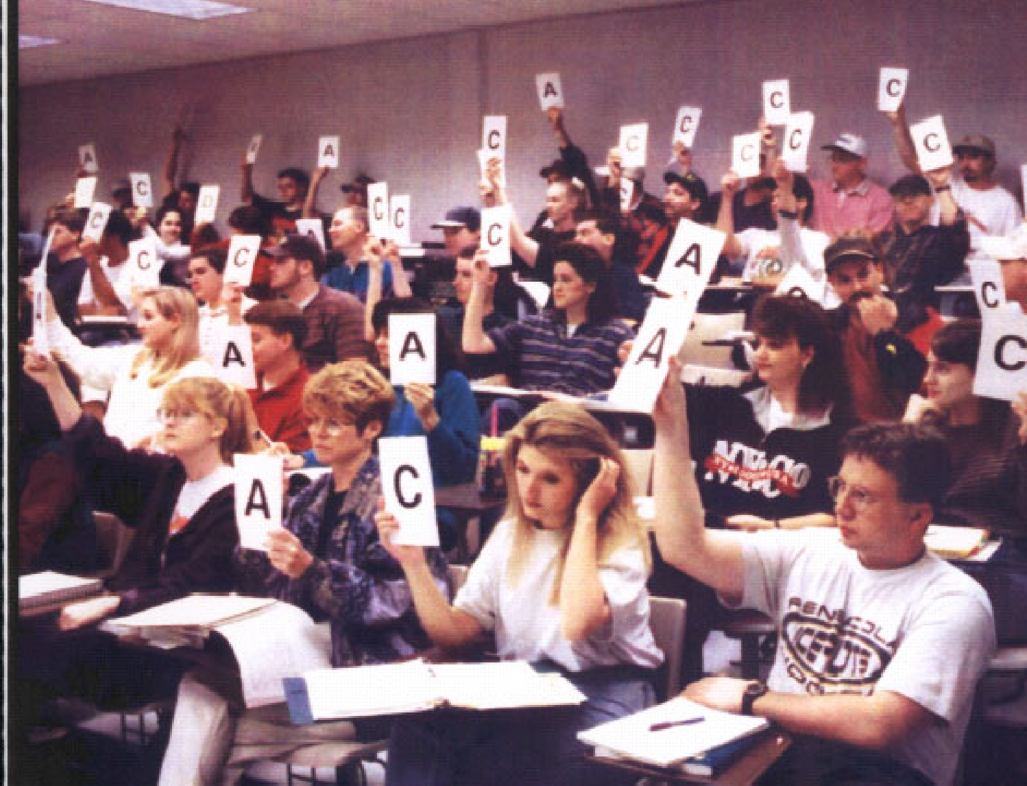
Formative Assessment Materials for Large-Enrollment Physics Lecture Classes

NSF Org	DUE
Latest Amendment Date	February 7, 2003
Award Number	0243258
Award Instrument	Standard Grant
Program Manager	Theodore W. Hodapp DUE DIVISION OF UNDERGRADUATE EDUCATION EHR DIRECT FOR EDUCATION AND HUMAN RESOURCES
Start Date	July 1, 2003
Expires	June 30, 2005 (Estimated)
Expected Total Amount	$104914 (Estimated)
Investigator	David E. Meltzer dem@iastate.edu (Principal Investigator current)
Sponsor	Iowa State University 2207 Pearson Hall, Room 15 Ames, IA 500112207 515/294-5225
NSF Program	7431 CCLI - ASA
Field Application	0000099 Other Applications NEC 0116000 Human Subjects
Program Reference Code	9178,SMET,

Workbook for Introductory Physics

Part II: Electricity and Magnetism, Optics, and Modern Physics

David E. Meltzer and Kandiah Manivannan



Iowa State University Physics Education Research Group

AUTHORS:

David E. Meltzer: Department of Physics and Astronomy, Iowa State University, Ames, IA 50011
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Kandiah Manivannan: Department of Physics, Astronomy, and Materials Science, Southwest Missouri State University, Springfield, MO 65804
kam319f@smsu.edu

Chapter 1 Electrical Forces

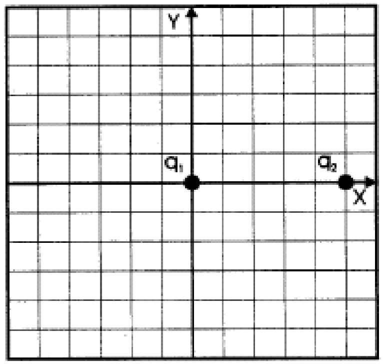
"Flash-Card" Questions

In-Class Questions

Prerequisite Concepts:

- **Positive and negative charges; Coulomb's law: $F = kq_1q_2/r^2$**
- **Protons (+) and electrons (–)**
- **Superposition principle: $F_{net}=F_1+F_2 + \ldots + F_n$**
- **Vector addition: $F_{netx}=F_{1x} + F_{2x} + \ldots F_{nx}$**
- **Newton's second law, $a = F/m$**

Questions #1–2 refer to the figure below. Charge q_1 is located at the origin, and charge q_2 is located on the positive x axis, five meters from the origin. There are no other charges anywhere nearby.



1. If q_1 is positive and q_2 is negative, what is the direction of the electrical force on q_1?

   A. in the positive x direction
   B. in the negative x direction
   C. in the positive y direction
   D. in the negative y direction
   E. the force is not directed precisely along any of the coordinate axes, but at some angle
   F. there is no force in this case

2. If q_1 is positive and q_2 is positive, what is the direction of the electrical force on q_1?

   A. in the positive x direction
   B. in the negative x direction
   C. in the positive y direction
   D. in the negative y direction
   E. the force is not directed precisely along any of the coordinate axes, but at some angle
   F. there is no force in this case

3. In this figure, a proton is located at the origin, and an electron is located at the point (3m, 3m). What is the direction of the electrical force on the proton?

“Flash-Card” Questions

A. 

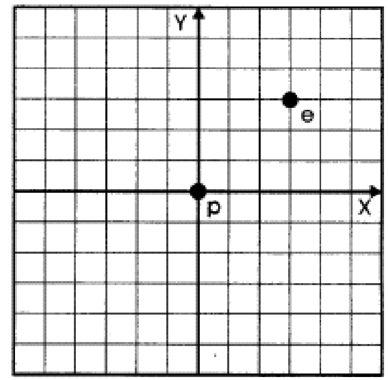
B. 

C. 

D. 

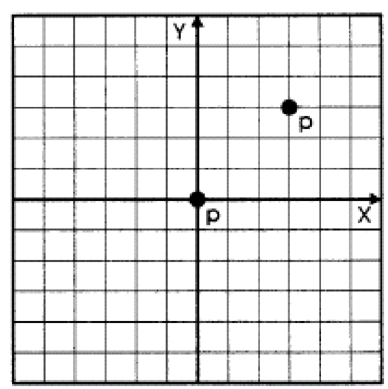
E. 

F. 



4. In this figure, a proton is located at the origin, and a proton is located at the point (3m, 3m). The vector representing the electrical force on the proton *at the origin* makes what angle with respect to the positive x axis?

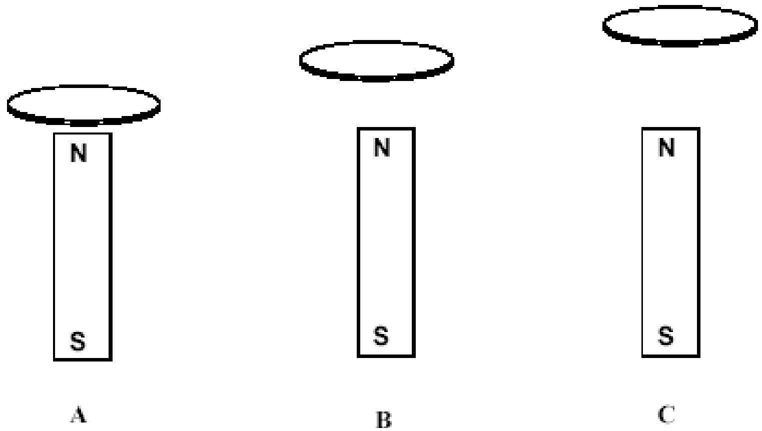
A. 0°
B. 45°
C. 90°
D. 135°
E. 225°
F. 270°



Magnetic Induction Worksheet

Worksheets (free-response)

1. In diagrams A, B, and C, three identical bar magnets and three identical wire loops are shown.
All three loops remain fixed in the positions shown.



a) Is there any magnetic flux in:

Loop A? ________

Loop B? ________

Loop C? ________

b) Rank the magnitude of the magnetic flux in loops A, B, and C. If all three are zero, state that explicitly. Explain your answer.

c) Is there any current flowing in:

Loop A? ________

Loop B? ________

Loop C? ________

d) Rank the magnitude of the current flowing in loops A, B, and C. If all three currents are zero, state that explicitly. Explain your answer.

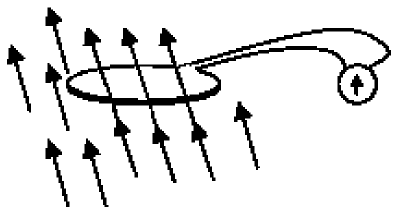
Chapter 10 Notes: Magnetic Induction

Lecture Notes

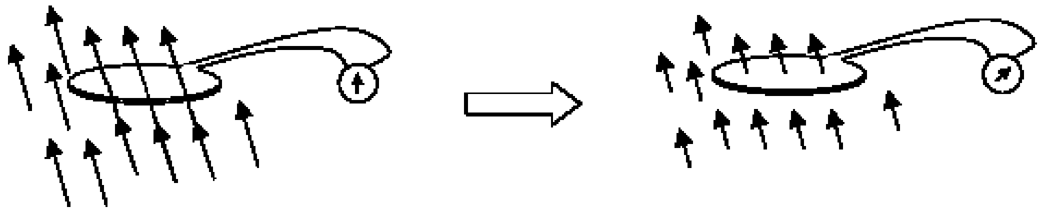
How can a changing magnetic field cause an electric current to flow?

Eleven years after the connection between magnetism and electricity was first reported by Oersted, the British scientist Michael Faraday made one of the most important discoveries in the history of physics. Oersted had found that an electric current could influence the motion of a compass needle; this showed that an electric current produced a magnetic field. Faraday found that, under certain specific circumstance, a magnet (such as a large compass needle) could itself *produce* an electric current (i.e., it could cause charges to begin to move). Although an electric current ***always*** produces a magnetic field, Faraday found that a magnet could only produce an electric current under one or more of three basic conditions: (1) the magnetic field varied in ***magnitude***; (2) the magnetic field varied in ***direction***; (3) the conducting path (which would carry the current) ***varied in shape***.

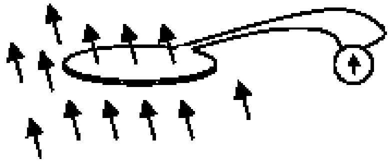
These situations can be illustrated by three different experiments, all involving a magnetic field and a closed loop of conducting material. We could connect a galvanometer (a current-detecting device) to the loop to determine whether or not a current is flowing. We could use a permanent magnet to produce the magnetic field, or instead use the uniform field inside a solenoid. In the diagram below, we have placed a conducting loop in a uniform magnetic field (indicted by the arrows); the loop is connected to a galvanometer. The needle of the galvanometer will deflect (move away from its initial position) if a current if produced in the loop. If the needle is in its initial position (as shown here), there is ***no*** current flowing in the loop.



In the ***initial*** situation shown above, where neither the loop nor the magnetic field is changing in any way, ***no current*** is observed to flow in the loop. However, if we ***change the magnitude*** of the magnetic field – either an increase or a decrease – then a current ***does*** flow in the loop, as shown here:



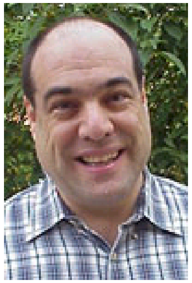
However, if the magnetic field magnitude ***stops changing***, the current will abruptly cease flowing and the galvanometer needle will go back to its initial position (again indicating "zero current"):



Local and National Impact

- Recognition and financial support from Iowa State Univ. “Center for Teaching Excellence”
  - workshops for other faculty
- Invitations to present work nationally
- Continued federal funding

David E. Meltzer



David E. Meltzer, an assistant professor of physics, is the CTE Teaching Scholar for 2002-2003. David received his Ph.D. from SUNY in 1985. His research specialty is physics education, and he has authored or co-authored several papers and journal articles on various aspects of teaching physics. Much of the work of David and his colleagues can be viewed at the Physics Education Research Group Web site.

[CTE "Teaching Scholar" Award]

Workshops

Spring 2003

Learning Through Guided Inquiry
Wednesday, February 19, 3:00 - 4:30 p.m.
David E. Meltzer, Assistant Professor of Physics and CTE Teaching Scholar, 2002-03
Inquiry-based learning is an instructional method in which students are guided to synthesize concepts by investigating and resolving a series of carefully structured problems. Instructors avoid offering answers before students have had a chance to work out solutions and explanations for themselves. Instead, instructors provide guidance through a series of leading questions. In this workshop participants will work in groups, using simple physics laboratory equipment, and be guided to discover some important basic principles of electricity and magnetism.

CENTER FOR TEACHING EXCELLENCE

Workshops

Spring 2003

Large-Class Strategies
Thursday, April 17, 3-5 p.m.
CTE Scholar David Meltzer, assistant professor of physics, will present a "hands-on" workshop in which participants will work together to devise effective techniques for teaching in large classes. After a brief video and discussion, participants will work in small groups to apply the techniques presented to their own disciplines and classrooms.

NEWS

- Bar workers get into the flow of managing work, classes
- Camaraderie essential element for Cycling Club
- Getting job tricky but not impossible in market
- Special graduation ceremony recognizes LGBT students
- Student waitresses serve at late-night feeding ground
- Student-teaching assignments require planning ahead
- Students look beyond Ames for housing
- Tax cut gets passed, but Values Fund in question
- The consequences of a coach's confession

Creative teaching strategies counter large classes

By Michaela Saunders
Daily Staff Writer
April 18, 2003

Large classes are nothing new to the campus environment, but previous and future budget cuts could make the issue even more of a problem at Iowa State.

The problem of overstuffed classrooms has been a major focus of the Center for Teaching Excellence this year, said Associate Director Susan Yager. In accordance with that focus, a faculty-focused workshop was presented Thursday afternoon.

David Meltzer, assistant professor of physics and astronomy, has done extensive research in making large introductory physics lecture courses more interactive. He shared several of his techniques with a group of about 15 faculty members from a wide variety of colleges and departments.

"Large classes are nothing new," Meltzer said. "It is not necessarily that classes have gotten bigger, just that there is more interest in doing something about it."

Meltzer described a technique employing flash cards to engage students in his class.

"The first thing they hear is how these flash cards work," he said.

Students are required to bring them to class and then respond to several multiple choice questions throughout the class period.

"Clean and organized presentation [of material] does not come close to being sufficient," Meltzer said.

May 11, 2003

Search the daily

options

add your feedback or read what others have to say

Poison Ink

CROSSWORD

2002 Summer Meeting Database Search

Author Search Result

The following abstracts matched the criteria which you entered.

Author(s):	Meltzer, David
Session Code:	GF03
Session Date:	Wednesday, Aug. 7
Session Time:	9:00 a.m.
Title:	Observation, Measurement, and Data Analysis in PER: Methodological Issues and Challenges

Abstract:

Just as in other areas of physics, researchers in physics education make use of a variety of observational tools and techniques and of forms of data analysis. In order to probe students' thinking, multiple-choice instruments, students' written explanations, individual interviews, and recordings of group activity are all employed. Each of these methods has both advantages and drawbacks, and it is frequently challenging to extract from this variety of data sources a coherent and consistent model of student thinking. Moreover, a number of challenging methodological issues are always present during data analysis, including uncontrolled "hidden" variables, reliability and validity of diagnostic instruments, multidimensionality of student knowledge states, etc. I will review some of the issues related to observational methods and data analysis, and offer a variety of options for addressing these problems in practical work.

[American Association of Physics Teachers]

Physics Education Research Conference (PERC)

August 7-8, 2002 - Boise, ID

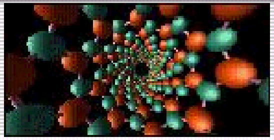
Breakout Session I - Issues related to quantitative methods and data analysis in PER

Location: Hatch Ballroom C&D

David E. Meltzer, Iowa State University and
Richard R. Hake, Indiana University

A number of issues are always present, implicitly or explicitly, when using quantitative methods to carry out PER. A few of these include: identifying targeted outcome variables as well as possible confounding variables, distinguishing among the criteria measured by different diagnostic instruments, validity and reliability of diagnostic instruments, possible biases in sample selection, statistical significance vs. "practical" significance of observed effects, criteria for assessing magnitude of effect (e.g., normalized gain, effect size, etc.). We will present a short introduction based on our experiences in confronting these issues. We will then invite participants to provide written questions based on issues that have arisen in their own experiences, and these will be presented for open discussion among all participants.

DEPARTMENT of Physics



Events

[Ohio State University]

The Process of Physics Education Research: From Investigation of Students' Reasoning to Improved Learning in the Classroom

Who: David E. Meltzer - (Department of Physics and Astronomy, Iowa State University)
Where: Smith Lab, Room 1094
When: Monday, November 25, 2002 at 10:30
Type: Physics Education Seminar

Description: The work of physics instructors can be assisted by Physics Education Research through systematic investigations into students' reasoning, development of new curricular materials, and careful assessment of student learning. As an example, I will describe our investigation of students' reasoning in thermodynamics. Analysis of students' written explanations along with one-on-one interviews has disclosed persistent confusion regarding process-dependent quantities such as heat and work. For instance, most students seem to believe that net heat absorbed and net work done by a system undergoing a cyclic process must be zero. Curricular materials designed to address these difficulties are being developed and tested. In a separate project, initial phases of an investigation into the relationship of representational mode (verbal, mathematical, diagrammatic, etc.) to student learning has identified severe and widespread difficulties with vector concepts expressed in graphical form. In a broader context, we are also engaged in development of a "Workbook for Introductory Physics" comprising curricular materials designed for a full semester of fully interactive lectures in large-enrollment classes. Efforts to assess these materials raise general questions regarding measurement of learning gain and sample selection bias. Methods developed to address these and related problems in physics education have implications and impact behind the confines of departments of physics and astronomy.

[South Dakota State University]

PHYSICS COLLOQUIUM

The Phases of Physics Education Research: Investigation of Student Reasoning, Curriculum Development, and Assessment of Instruction

by

Dr. David E. Meltzer
Dept. of Physics & Astronomy
Iowa State University

Thursday, November 21, 2002

4:00 pm – CEH 324

The goal of Physics Education Research (PER) is to improve the effectiveness of physics instruction. PER comprises systematic investigations into students' reasoning, development of new curricular materials, and careful assessment of student learning. As an example of the "basic research" phase of PER, I will describe our investigation into students' reasoning in thermodynamics. Analysis of students' written explanations along with one-on-one interviews has disclosed persistent confusion regarding process-dependent quantities such as heat and work. Curricular materials designed to address these difficulties are being developed and tested. In a broader context, we are engaged in development of a "Workbook for Introductory Physics" comprising curricular materials for an entire semester of fully interactive lectures in a large-enrollment class. Efforts to assess these materials raise general questions regarding measurement of learning gain and evaluation of instructional methods.

Refreshments will be provided.

Department of Physics

[University at Buffalo, SUNY]

Tuesday, February 25, 2003

Investigating and Improving Student Learning Through Physics Education Research

Professor David E. Meltzer

Department of Physics and Astronomy, Iowa State University

Physics Education Research comprises systematic investigation of the physics-learning process, as well as application of findings to improve the effectiveness of physics instruction. Probes of student understanding lay the basis for development of curricular materials that help students address and resolve common learning difficulties. For example, our investigation of student learning of thermal physics has identified persistent confusion related to process-dependent quantities such as heat and work, and a strong belief that net heat absorbed and net work done by a system undergoing a cyclic process must be zero. A concurrent project has identified specific learning difficulties related to the mode in which physics concepts are represented (e.g., diagrammatic, mathematical, or graphical). Curricular materials designed to address learning difficulties uncovered through our research are being developed and tested. A particular emphasis of our work has been development of materials appropriate for fully interactive lectures in large-enrollment classes, designed to engage students more actively in the learning process. Efforts to assess the effectiveness of instructional innovations raise general issues regarding measurement of learning gain, carrying implications for undergraduate education that transcend departments of physics.

Previous Projects

- Physics course for Elementary Education majors and other non-technical students

AWSFL008-DS3

NSF Award Abstract - #9896264

Elementary Physics Course Based on Guided Inquiry

NSF Org	DUE
Latest Amendment Date	July 2, 1998
Award Number	9896264
Award Instrument	Continuing grant
Program Manager	Duncan E. McBride DUE DIVISION OF UNDERGRADUATE EDUCATION EHR DIRECT FOR EDUCATION AND HUMAN RESOURCES
Start Date	June 1, 1998
Expires	February 28, 1999 (Estimated)
Expected Total Amount	$30700 (Estimated)
Investigator	David E. Meltzer dem@iastate.edu (Principal Investigator current) Kandiah Manivannan (Co-Principal Investigator current)
Sponsor	Iowa State University 2207 Pearson Hall, Room 15 Ames, IA 500112207 515/294-5225
NSF Program	7410 DUE COURSE & CURRICULUM PROG
Field Application	
Program Reference Code	

Previous Projects

- Physics course for Elementary Education majors and other non-technical students

- Investigation of factors underlying individual variability in physics learning

The relationship between mathematics preparation and conceptual learning gains in physics: A possible "hidden variable" in diagnostic pretest scores

David E. Meltzer
Department of Physics and Astronomy, Iowa State University, Ames, Iowa 50011

(Received 27 July 2001; accepted 23 August 2002)

There have been many investigations into the factors that underlie variations in individual student performance in college physics courses. Numerous studies report a positive correlation between students' mathematical skills and their exam grades in college physics. However, few studies have examined students' learning gain resulting from physics instruction, particularly with regard to qualitative, conceptual understanding. We report on the results of our investigation into some of the factors, including mathematical skill, that might be associated with variations in students' ability to achieve conceptual learning gains in a physics course that employs interactive-engagement methods. It was found that students' normalized learning gains are not significantly correlated with their pretest scores on a physics concept test. In contrast, in three of the four sample populations studied it was found that there is a significant correlation between normalized learning gain and students' preinstruction mathematics skill. In two of the samples, both males and females independently exhibited the correlation between learning gain and mathematics skill. These results suggest that students' initial level of physics concept knowledge might be largely unrelated to their ability to make learning gains in an interactive-engagement course; students' preinstruction algebra skills might be associated with their facility at acquiring physics conceptual knowledge in such a course; and between-class differences in normalized learning gain may reflect not only differences in instructional method, but student population differences ("hidden variables") as well.

[DOI: 10.1119/1.1514215]

I. INTRODUCTION

A primary goal of research in physics education is to identify potential and actual obstacles to student learning, and then to address these obstacles in a way that leads to more effective learning. These obstacles include factors that originate during instruction—such as instructional method—as

In Secs. II and III, I review the results and limitations of previous studies on the relation of students' pre-instruction preparation to their performance in physics courses. In Sec. IV I describe a widely adopted measure of student learning called "normalized learning gain" and explain why it is an appropriate measure for the objectives of this study. In Sec. V various factors that may be related to learning gain are

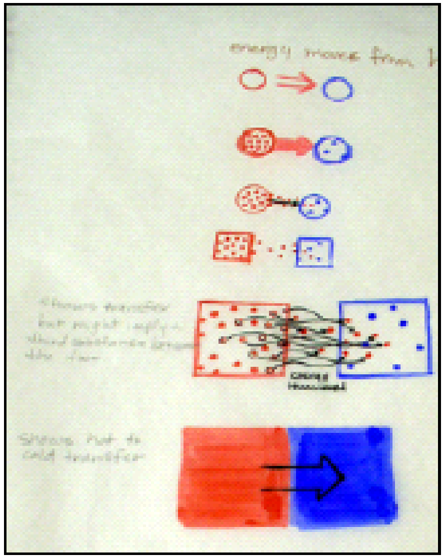
New Projects

- **Instruction and Assessment of Problem-Solving Skills**
  - Collaboration led by Craig Ogilvie, with David Atwood (grant proposal to National Science Foundation)

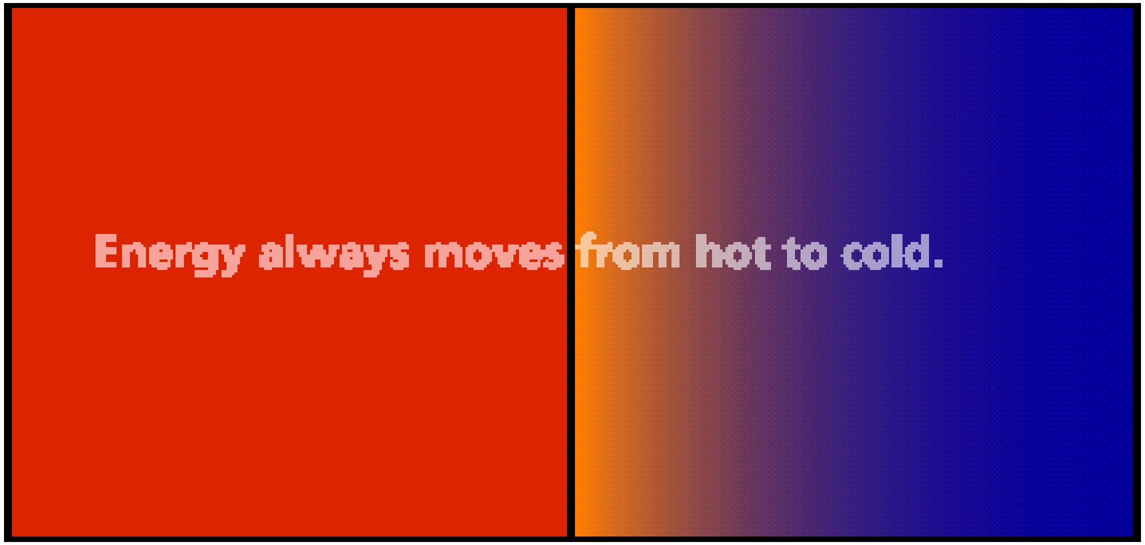
New Projects

- **Instruction and Assessment of Problem-Solving Skills**
  - Collaboration led by Craig Ogilvie, with David Atwood (grant proposal to National Science Foundation)

- **Development of Visually Based Active-Learning Physical Science Course**
  - Collaboration with Departments of Chemistry, Art and Design, and Curriculum and Instruction (grant proposal to Department of Education)



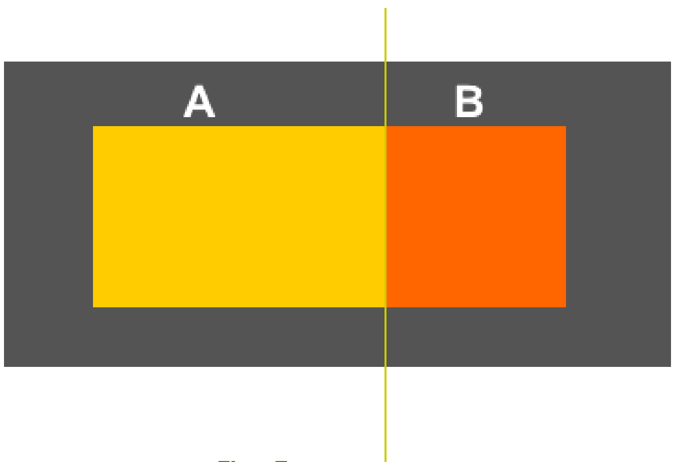
Preliminary Sketches and Notes
Various shapes and notations were explored to communicate the process of energy transfer from hot to cold materials. Color was used to express both hot and cold, as well as the energy itself. The energy was shown as a third color in the form of a gradation. The direction of transfer was also indicated originally with arrows but in the final with the reading direction of the line of type in the center of the illustration.



Heat
The red square represents a warmer object and the blue square represents a cooler object. The orange area represents the transfer of energy in the form of heat. The squares represent objects of equal mass in a closed system where only energy or heat is being transfered. The text is used to further emphasize the direction of the energy movement and to clarify the principle being studied.

Calorimetry Worksheet

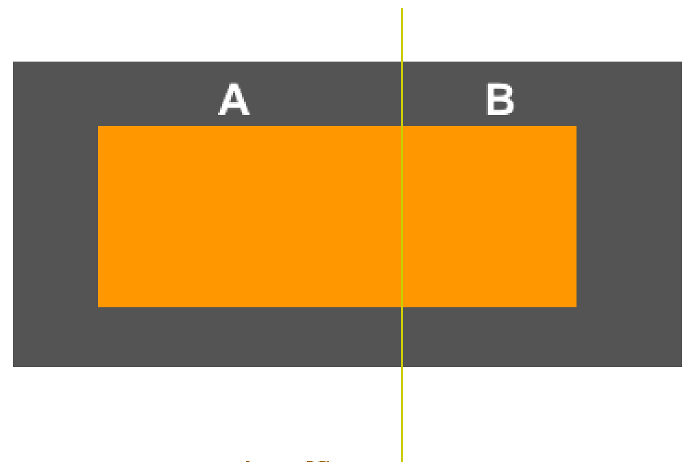
Initial Temperature



Time Zero

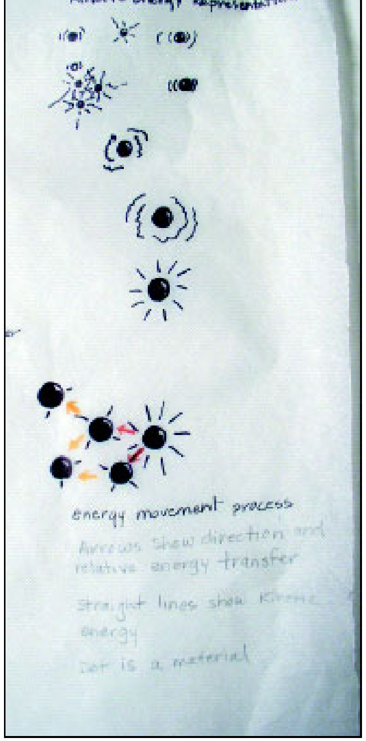
Click here to see Long After

Final Temperature



Long After

Click here to see Time Zero

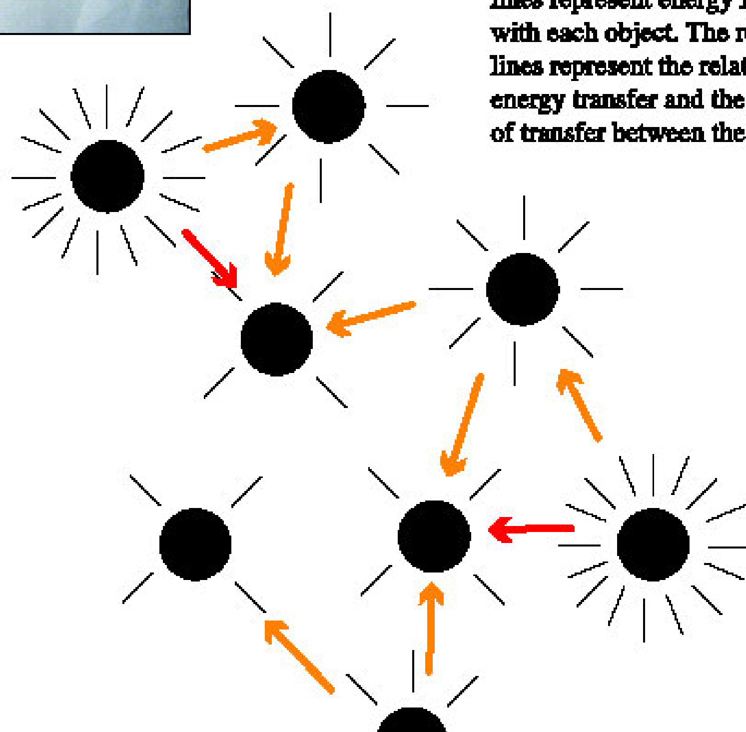


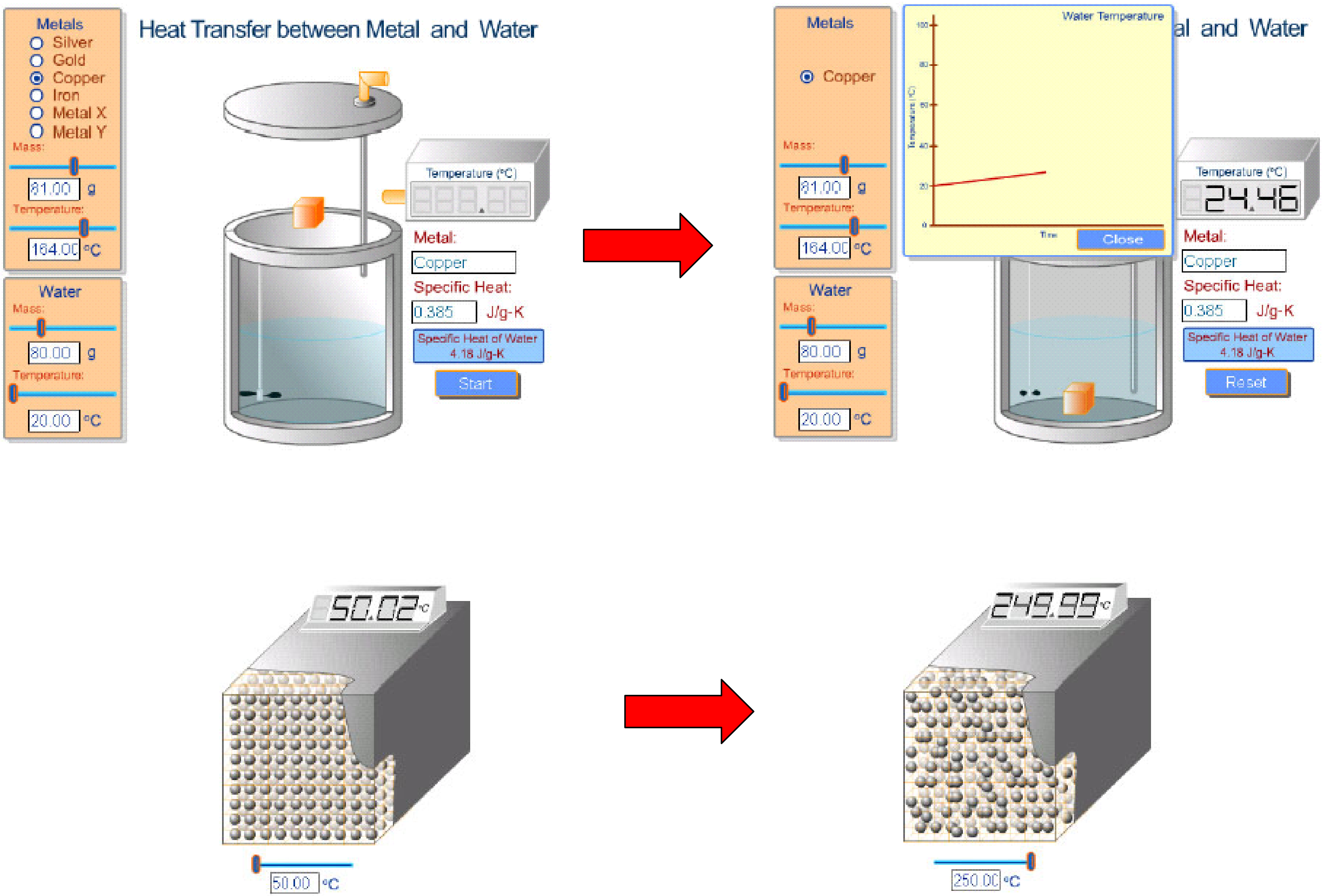
Preliminary sketches and Notes from Study Materials

Energy always moves from hot to cold.
Energy transfered is heat.
Transfered heat becomes internal energy.
Heat flow depends on the amount of material.

Heat

Circles represent objects. The black lines represent energy levels associated with each object. The red and orange lines represent the relative levels of energy transfer and the direction of transfer between the objects.





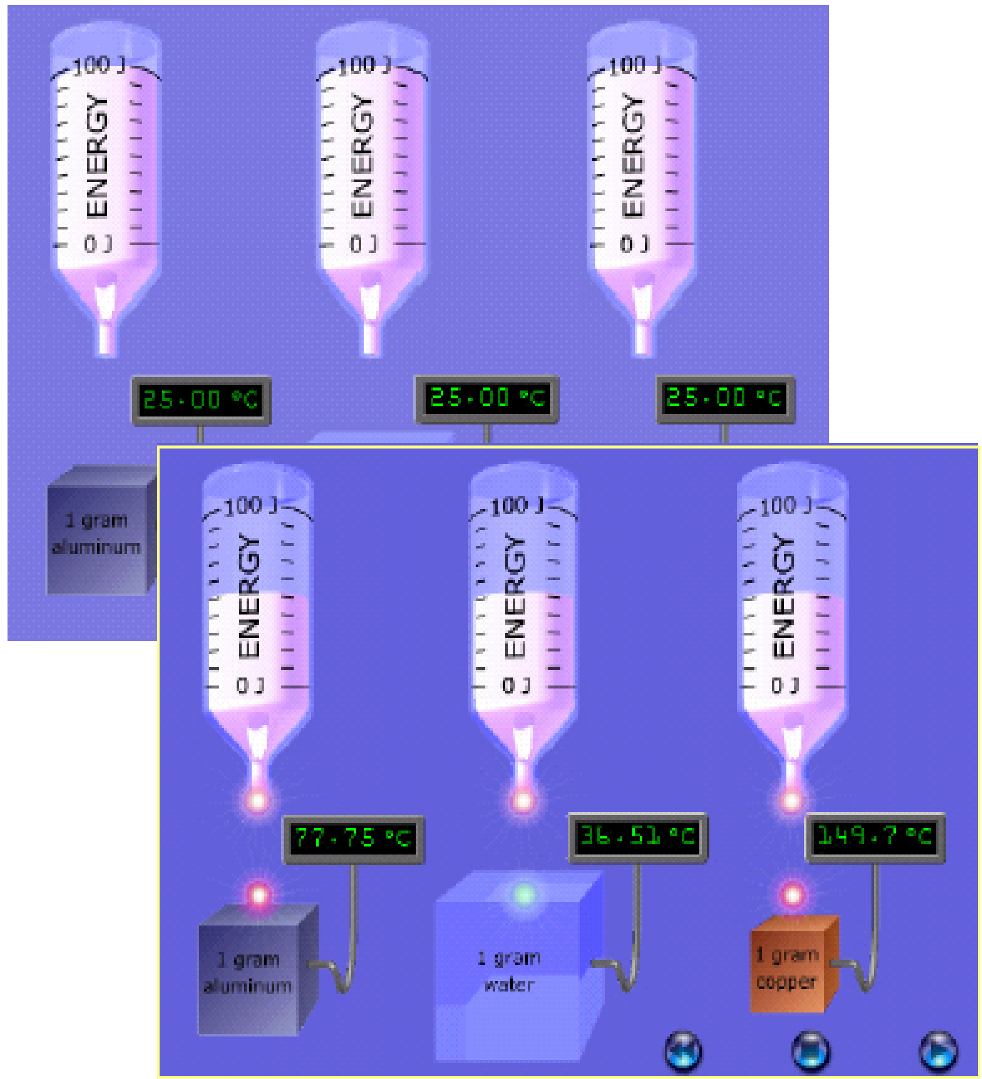
Interactive Simulations of Thermal Phenomena

Specific Heat

Heat Transfer (in J) equals the Specific Heat (in J/(g•° C)) of a material times the mass (in g) times the Temperature Change (in ° C). Below, equal amounts of energy are added to equal masses of Copper, Aluminum, and Water. What is the relationship between Temperature Change and Specific Heat?

Specific Heat of Selected Materials
[Joules / (gram • ° C)]

Aluminum	0.903
Copper	0.385
Iron	0.444
Gold	0.126
Silver	0.233
Water	4.184



The bottom image is a screenshot of the animation after nearly 50 Joules of energy have been added to each of the three materials.

Conclusion: Prospects for Growth of PERG

- Experience suggests that PER is an attractive field for prospective graduate students (but good English-language skills required)
- Recent employment prospects for PER graduates have been extremely favorable
- Small numbers of personnel can have disproportionately large national impact