Implementing and Assessing a New Introductory Physics Course at Georgia Tech

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Intro Physics at Georgia Tech

• Large enrollment (>1700 students per semester, total)
• Large lectures (150-200 students, 3 hr/wk)
• Lab sections (20 students, 3 hr/wk)
• Problems:
  – GPA significantly lower than other intro courses
  – High D/F/W rate (as high as 25%)
  – Unpopular with students
  – External review committee criticized structure, outcomes of intro courses
Issues with traditional intro physics

• Lack of modern content
  – No 20\textsuperscript{th} century physics
  – Macroscopic systems—no atoms!

• Incomplete or ineffective approach to problem-solving
  – Equation-hunting & problem-matching
  – No computer modeling

• Inadequate for preparing future scientists and engineers
  – Nanotechnology, materials science, bioengineering
  – ABET curriculum criteria, 2008-09:
    • Analytic, experimental, and \textit{computational} methods emphasized by several programs
New physics course

- GT School of Physics using *Matter & Interactions* (M&I) curriculum
  - Modernize course content
  - Help improve course outcomes
Matter & Interactions
(R. Chabay & B. Sherwood, Wiley, 2007)

- Fundamental principles
- Microscopic structure of matter
- Coherent framework (including 20th century physics)
- Computer modeling
  - VPython: Programming language that easily allows for 3D graphics
  - Students model a wide variety of different systems
Implementation

- Gradual ramp up
- Summer 06:
  - 1 pilot section of 1st semester mechanics, 40 students
- Fall 08:
  - 2 sections of M&I mech. (300 students total)
  - 3 sections of M&I E&M (450 students total)
  - *Nearly half* of the total intro enrollment
- Increase in faculty adoption
  - Apprenticeship, co-teaching
- M&I popular with students
  - Courses well-subscribed, fill quickly
Assessment

- Compare student performance: M&I vs. traditional course
- Focused mostly on overlap of content between M&I and traditional
- Methods:
  - Standardized tests
  - Common exam problems
  - Interview study

Focus on E&M
Assessing E&M courses

• Brief E&M Assessment (BEMA)
  – Standardized test
  – Multiple choice
  – Qualitative and short quantitative questions
  – Covers topics common to both M&I and traditional course

• Administer “pre-test” at beginning of course, “post-test” at end, measure gains
BEMA Pre-test results
Multiple lecture sections from Fall 06 to Fall 07

M&I mean=26%
Trad. mean=25%
BEMA Post-test results
Multiple lecture sections from Fall 06 to Fall 07

Trad. mean=46.2%
N=1246

M&I mean=58.2%
N=612
BEMA: Post-test results by section

- 11 sections 5 different instructors
- 5 sections 4 different instructors
**BEMA: Post-test results by section**

- **Traditional**: Two very good instructors

  - Means: “Good” trad.=51.6%  
  M&I=58.2%

  - Difference is still statistically significant (p<<0.01)
Assessing mechanics

• More complex task
  – Less overlap between M&I and traditional course content than E&M: what is a fair comparison?

• M&I: lower gains on standardized assessment
  – Assessment emphasizes more traditional problem types
  – M&I students may need more practice applying fundamental principles to these systems

• Assessing M&I specific content
  – Substantial gains on M&I specific energy assessment
  – Complex problems
Summary

• E&M
  – M&I outperforming traditional course in student understanding of basic E&M topics

• Mechanics
  – Complexity in making direct comparisons
  – More work is needed to shore up M&I students’ understanding of more traditional topics

• Future assessment
  – “Think aloud” protocol study: examine in more detail student reasoning on
  – Broader impact: effect on future coursework, complex problem-solving skills
Acknowledgments

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Common exam problems

• Several common final exam problems have been given to both M&I and traditional courses

• Mechanics: M&I and traditional classes perform on par
  – Note that common questions have been biased toward more traditional material to be fair to traditional course

• E&M: M&I shows better performance on complex problems (e.g. Faraday’s Law of Induction problem)
  – Note M&I and trad. E&M have more overlap in classes of problems covered
Force Concept Inventory

• FCI gains for M&I course are worse than for traditional course
  – Normalized gain: Fraction of possible gain from pre to post:
    \[ g = \frac{\text{post}\% - \text{pre}\%}{(100\% - \text{pre}\%)} \]
  – Traditional course at Georgia Tech: \(<g>\) ranges from 0.35 to 0.5
  – M&I course: \(<g>\) about 0.2

• Possible reasons
  – FCI: places emphasis on 2-D constant acceleration kinematics
  – M&I: more emphasis on impulse and momentum, less on acceleration

• Possible solution—implication for instruction
  – Include more examples of applying fundamental principles in more traditional problems
Implementation

• Faculty adoption
  – Different course content and structure: potential barrier
  – Apprenticeship model
    • Several new faculty members were convinced to try M&I
    • Worked closely with veterans
    • Summer 07: Co-taught M&I E&M with veteran faculty member
  – Reactions from faculty new to M&I have been very positive
  – By the end of Fall 2008, the GT School of Physics will have 6 faculty experienced in \textit{M&I}
A uniform magnetic field is present in a circular region of radius 6 cm. In this region at any given time, the magnetic field may be pointing directly out of the page (in the $+z$ direction), directly into the page (in the $-z$ direction), or it may be zero. The $z$-component of the magnetic field in this region changes with time according to the function $B_z = Kt^2 - P$, where $t$ is time, $K = 0.12 \text{T/s}^2$, and $P = 3.0 \text{T}$. Outside of the 6 cm radius, the magnetic field is always zero. A thin metal ring of radius 11 cm is concentric with the region of magnetic field. The ring has a resistance of $1.3 \times 10^{-3} \Omega$.

(a) At time $t = 3 \text{s}$, find the magnitude of the induced current in the metal ring.

(b) At time $t = 3 \text{s}$, find the direction of the induced current in the metal ring (clockwise, counter-clockwise, or zero), and briefly explain your reasoning.
<table>
<thead>
<tr>
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<tbody>
<tr>
<td>Completely correct (magnitude &amp; direction)</td>
<td>17%</td>
<td>28%</td>
</tr>
<tr>
<td>Used <strong>correct approach</strong> to find magnitude (w/ possible minor errors)</td>
<td>32%</td>
<td>51%</td>
</tr>
<tr>
<td>Used <strong>wrong principle</strong> to find magnitude</td>
<td>43%</td>
<td>15%</td>
</tr>
<tr>
<td><strong>Correct direction</strong> w/ correct reasoning</td>
<td>36%</td>
<td>57%</td>
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3D graphics

Create objects, give initial pos.

Constants

Initial momentum

Timestep

Reset time

from visual import *

planet=sphere(pos=(0,0,0),radius=3e7,
              color=color.green)

moon=sphere(pos=(3.84e8,0,0),radius=2e7,
            color=color.blue)

moon.trail=curve(color=moon.color)

planet.m=6e24
moon.m=7.4e22
G=6.67e-11

speed=2*pi*4e8/(29*24*3600)
moon.p=moon.m*vector(0,speed,0)

deltat=2.5e3

i=0
Physics loop

while $t < 28 \times 24 \times 60 \times 60$:

$r = \text{planet.pos} - \text{moon.pos}$

$rmag = \sqrt{r.x^2 + r.y^2 + r.z^2}$

$rhat = r / rmag$

$Fmag = G \times \text{moon.m} \times \text{planet.m} / rmag^2$

$F = Fmag \times rhat$

$\text{moon.p} = \text{moon.p} + F \times \text{deltat}$

$\text{moon.pos} = \text{moon.pos} + \text{moon.p} / \text{moon.m} \times \text{deltat}$

$\text{moon.trail}.append(pos = \text{moon.pos})$

$t = t + \text{deltat}$
“Think-aloud” protocol study

- Ongoing project: to examine in more detail why M&I students have difficulty with FCI
- Volunteers from M&I and traditional courses work on FCI problems in an individual interview setting while saying out loud what comes to mind
- Data collected, currently being analyzed