Computational exercises in introductory mechanics

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February 16, 2010

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Supported by NSF DUE-0942076

Mechanics at GT

Two Courses

- A course based on Knight
- The Matter and Interactions course (M&I)

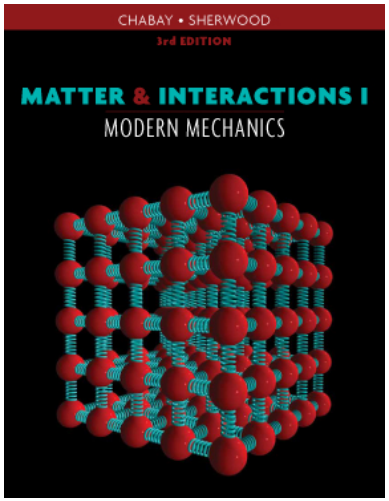
Boundary Conditions for Intro Mechanics (M&I)

- $\sim$ 800 students per semester take introductory mechanics
- 83% engineering, 17% science majors
- Large classroom setting (150-250 students)
  - 3 hours of lecture (with "clicker" questions)
  - Online homework system (for M&I - WebAssign)
- Labs/Recitations (25-40 students)
  - 3 hour lab/recitation
    - Experimental labs
    - Computer modeling labs
    - Group problems

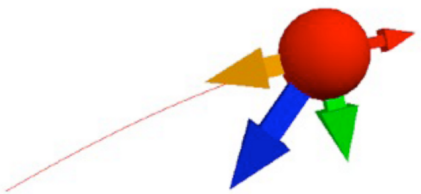
The Matter and Interactions Course

How does M&I differ from the "typical" physics course?

- Emphasizes a principles based approach (Impulse-Momentum Theorem, Energy Principle, Angular Momentum Principle)
- Introduces the ball and spring model of matter and connects microscopic to macroscopic (speed of sound, temperature)
- Uses modern tools (simulation and visualization)
  - Iterative view of motion (Non-constant forces)
  - Computer modeling laboratories



Projectile with Drag



www.matterandinteractions.org

Why Computer Modeling Homework?

Why Computer Modeling?

- Third pillar of modern science and engineering
  - theory, experiment, computation
- Explore systems that are too difficult to solve in closed-form
  - Effects of air resistance
- Simulate experiments that are impossible to perform in a lab
  - Elliptical orbit, 3 body problem
- Visualization of the problem
  - observing the motion, physical vectors; plotting of energy-time series

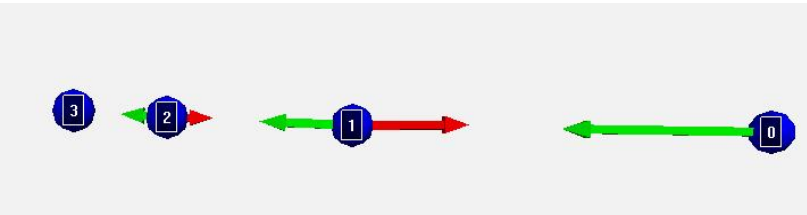
On Homework Assignments?

- Homework is generally "end-of-chapter" work, online
- Randomization does not deter "short-cuts" (Google)
- Significant fraction of students never write programs
- Not a novelty of the lab

Nuts and Bolts

Method of Implementation

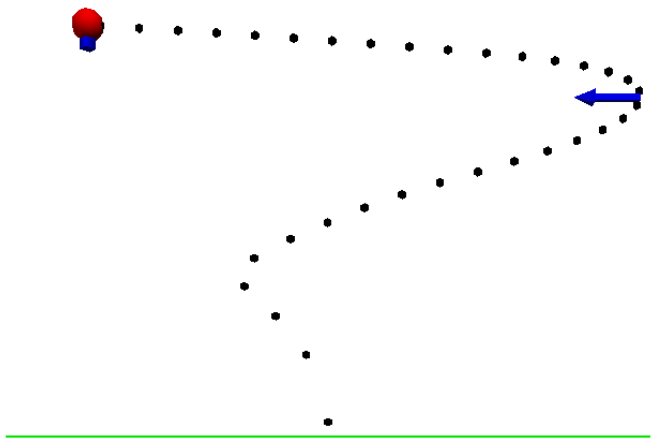
- Homework based on Computer Modeling Labs
  - Numerical Integration: interactions known $\longrightarrow$ reconstruct motion
  - Numerical Differentiation: motion known $\longrightarrow$ reconstruct interactions
- Implement via WebAssign
  - Generate $\sim$ 500–1000 realizations
    - store initial conditions and solutions
  - Randomize realization per student
    - problem is solved numerically
- Types of Homework Questions
  - Numeric Questions
    - change initial conditions; randomized for each student
    - graded for accuracy
  - Visualization Questions
    - qualitative questions (e.g., directions of forces/kinematic quantities)
    - confront misconceptions



A Typical Week

An Example - Forces on a Weather Balloon

- Initial program written during lab
  - Read position data to determine $\vec{F}_{\text{net}}$
  - Reproduce trajectory
  - Using arrows, visualize $\vec{p}$, $\Delta\vec{p}$, and $\vec{F}_{\text{net}}$
  - Print $\vec{r}$, $\vec{v}$
- Homework gives students new position data
  - Reproduce work done in lab
  - Decompose net force, $\vec{F}_{\text{net},\parallel}$ and $\vec{F}_{\text{net},\perp}$ and visualize with arrows
  - Quantitative questions, $\vec{r}$, $\vec{v}$
  - Qualitative questions, directions of $\vec{p}$, $\Delta\vec{p}$, $\vec{F}_{\text{net}}$, $\vec{F}_{\text{net},\parallel}$ and $\vec{F}_{\text{net},\perp}$



Weather Balloon Trajectory
blue arrow represents $\vec{F}_{\text{net}}$

So...how are students doing?

Instructor Perspective

- Minimal changes to programs thus far
- Minor hiccups caught early on
  - installation issues, give students sample sets
- Students were slipping by without writing programs
  - i.e., before Spring 2010

Student Perspective

- Students score slightly lower on average
  - Computational Questions: 84.4 ± 0.1 %
  - Analytic Questions: 90.6 ± 0.1%
- Group of students (~ 5%) with consistent low scores
  - difficulty with programming?
  - ignoring questions?

Assessment

Where are the measurements?

- Attitudinal
  - Colorado Learning Attitudes about Science Survey
  - GT designed Attitudes/Impressions of Programming
- Qualitative Understanding
  - Force Concept Inventory
  - Exam Questions
- Computational Abilities
  - Exam Questions
  - Final Exam programming assignment

Closing Remarks

Future Work

- Compare attitudes about science to M&I without computational exercises
- Detailed comparison of qualitative understanding to other courses
- Novel problem study based on Kohlmyer

Thanks

- Dr. Ed Greco
- Daniel Borrero, Huseyin Kurtuldu
- Juan-Jose Lietor-Santos, Adam Perkins