Engaging Students in Large, Introductory Courses

The Intro Physics Story

Rebecca L. Trousil
ITeach Symposium
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Intro Physics Lectures

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Large Classroom

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100-150 Students

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Large Classroom

One Captivating Instructor

100-150 Students

Despite our best intentions...

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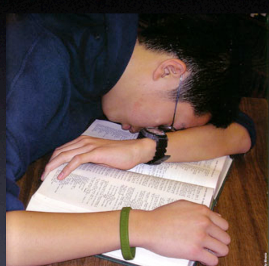

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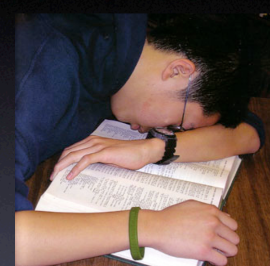

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The Experiment

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- Develop a new introductory physics course that *actively* engages students in and out of class

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- Develop a new introductory physics course that *actively* engages students in and out of class
- Constraints:
  - ✓ Large class size
  - ✓ Classroom is a large lecture hall
  - ✓ Cover sufficient content in a two semester sequence

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- Curriculum perceived as interesting and relevant to students
- Hone conceptual understanding as well as quantitative problem solving skills
- Develop approximation and estimation skills necessary for “real world” problem solving
- Integrate modern physics into the curriculum

How to engage students?

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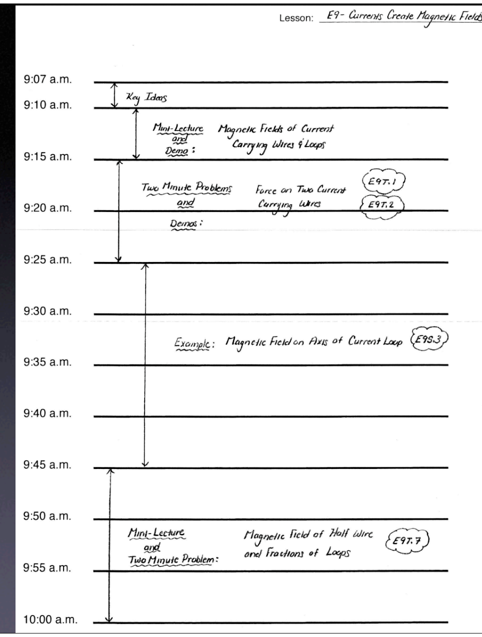
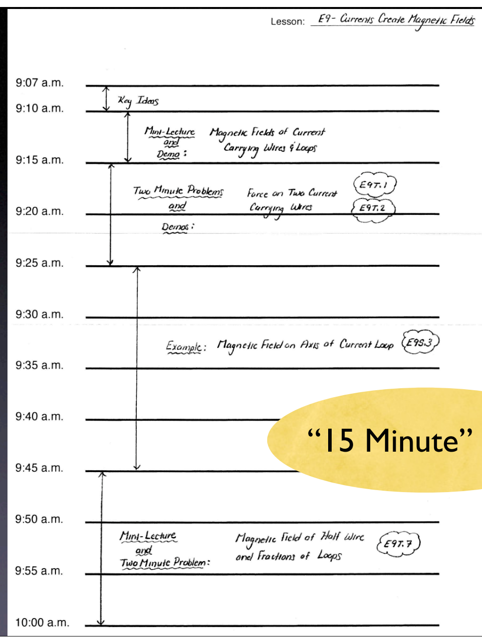




"15 Minute" Rule

A Typical Class Period

- Mini-Lectures
- Two Minute Problems
- Interactive Problem Solving
- Demonstrations

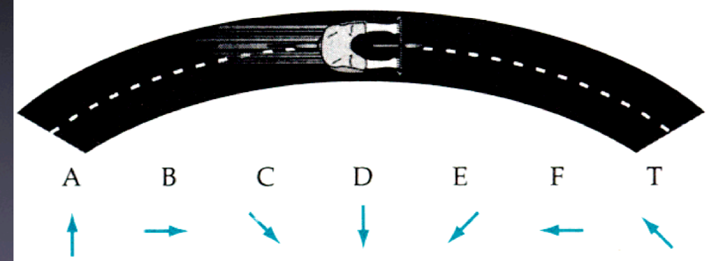
Two Minute Problems

- Multiple choice or True/False conceptual questions posed to entire class
- Students discuss the problems with nearest neighbors and build a group consensus

Two Minute Problem N2T.11

A bike (shown in a top view in the diagram) travels around a curve with its brakes on, so that it is constantly slowing down.

Which of the arrows shown below most closely approximates the direction of its acceleration at the instant that it is at the position shown? (Hint: Draw a motion diagram).



Student Response Systems

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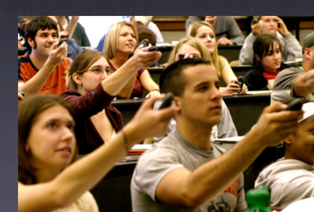

Student Response Systems

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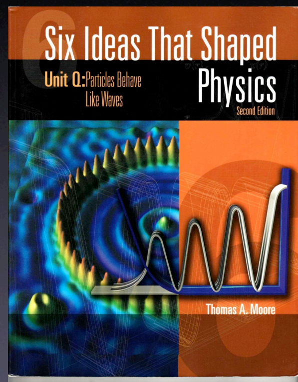
Old School



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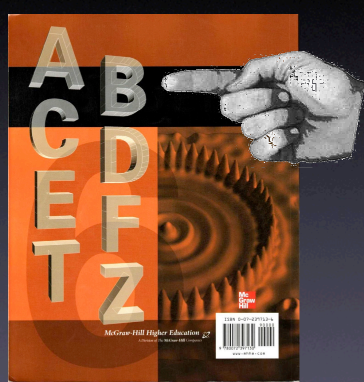

Interactive Examples

- Sophisticated quantitative and conceptual reasoning problems that illustrate key principles and applications of fundamental ideas
- Problems are broken into digestible pieces, so that students can formulate a problem solving framework in a few minutes
- Small and large group discussion elements

Example: How much does it cost to make popsicles?

Freezers and refrigerators have electric compressors and motors which transport heat from the cold compartments to the outside environment. Thus, electrical energy is required to maintain your freezer or refrigerator at a constant temperature. Consider, for example, the cost of making popsicles...

As kids we made popsicles in molds similar to the ones shown in the figure to the right. Let's figure out how much it would cost to make one tray of 6 popsicles out of fruit juice...

a) Each popsicle is about 4" long with a round cross-section that is about 1.5" in diameter. What is the total mass of our six popsicles?

b) Using energy conservation, determine how much electrical energy will be needed to make these popsicles if the fruit juice is initially at 22° C. My freezer's ambient temperature is 6.5° F (-14.2 °C). State any assumptions you make.

c) If electrical energy costs ~ $1/25 MJ of electricity, how much will it cost us to make our popsicles?

Crucial Elements for Successful Engagement

- A non-threatening environment
- Reward desired behavior
  - ✓ Class participation is 5% of grade
  - ✓ Exams contain qualitative and quantitative reasoning elements like those practiced in class

How to engage students?

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- Keep it "real" and/or make it fun.

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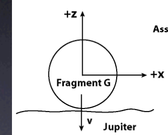
- Encouraging students to grapple with non-idealized problems...
  - ... develops high level problem solving skills (approximation, estimation, synthesis)
  - ... gives students confidence that they are capable of analyzing the world around them
  - ... maintains student interest despite a demanding homework schedule

Example: Shoemaker-Levy Comet Crashing into Jupiter

In July 1994, about 20 fragments of comet Shoemaker-Levy struck the planet Jupiter, each traveling at a final speed of roughly 60 km/s. These impacts were closely studied because they promised to be the most cataclysmic impacts ever witnessed. No one knew exactly how cataclysmic, though, because the fragments' sizes (and thus masses) were too small to measure. One estimate of the total energy released by fragment G's impact was 4×10^{22} J (equivalent to the detonation of roughly 100 million typical atomic bombs). Use this to estimate fragment G's size, first assuming that is was solid rock and then that is was solid ice, which have densities of about 3000 kg/m^3 and 920 kg/m^3, respectively. Don't worry about being excessively precise. This illustrates how even a little knowledge about kinetic energy can help answer questions about objects that can barely be seen by the best telescopes!

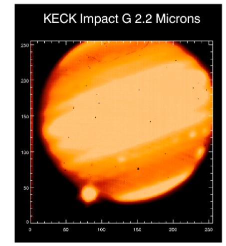
Translation:



Assume: Fragment is spherical
Gravitational potential energy is zero just before impact

Knowns:
Speed just before impact = v = 60 km/s
Energy released upon impact = $\Delta U = 4 \times 10^{22}$ J

Density of comet = ρ
Mass of fragment = m
Volume of fragment = V



Earth-based telescope image from Keck observatory in Hawaii after Fragment G of comet Shoemaker-Levy struck Jupiter.

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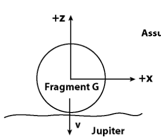

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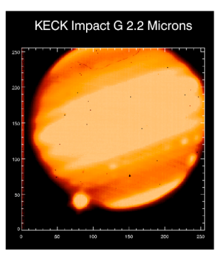

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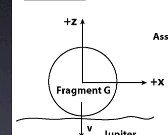

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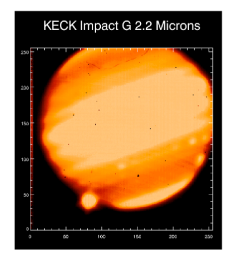

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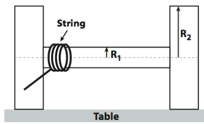
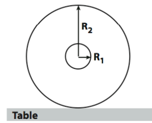
Physics 197 - Section 01 (Trousil) Name: ______________________
Exam #2 - November 1, 2007

2. [28 Points] Knowing that you are taking physics, a friend of yours brings you a toy that was given to him as a gift, because he cannot figure out how it works. It is a dumbbell shaped object with a string wrapped around the central axis. It is similar to a yo-yo, but when you pull on the string, the toy begins to rotate and translate on a horizontal surface rather than in the vertical direction. Your friend is perplexed, because the resulting motion of the toy depends on how you pull the string.

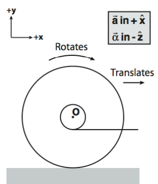


Front View



Side View Cross Section

(a) [8 Points] Curious, you begin to play with the toy. If you pull the string to the right from underneath the central axis as shown in the figure, the toy begins to translate slowly to the right and begins to rotate clockwise without slipping. Draw a free body diagram on the figure below, and label all the forces acting on the toy. Place the tails of the force vectors at the location on the toy where the forces act. Make sure your free body diagram is consistent with the translational and rotational motion that you observed.



Side View

Physics 197 - Section 01 (Trousil) Name: ______________________
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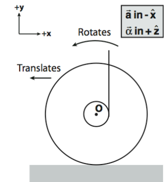
(d) [4 Points] Feeling quite proud of yourself for understanding the motion of the toy when you pull the string to the right, your buddy tells you to try pulling upward on the string from the right side of the central axis as shown in the figure below. The ensuing motion is indeed different. This time the toy begins to translate slowly to the left and begins to rotate counterclockwise without slipping. Your friend, looking smug, thinks he has stumped you, but you are up to the challenge. To get yourself started, draw a free body diagram for the toy on the figure below, and label all the forces acting on the toy. Again place the tail of each force vector at the point on the toy where the force acts.



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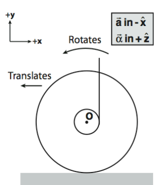


Side View

Wow! I can do this!

Example: BBQ Ribs Anyone?

When Dr. Trousil was in college she waitressed during the summers at Billy's Bar & Grill in her home town of Anoka, MN. On Friday nights, the dinner special was a rack of baby back bbq ribs. On one particularly busy Friday, she learned a memorable lesson about static and kinetic friction. As she walked out of the kitchen carrying a large tray of food, including a platter of ribs, she remembered that she had forgot to bring a dinner sald to another customer, so she quickly stopped to grab a salad before heading out to the dining room. The sudden deceleration caused the platter of ribs to slide off the tray and launched them into the air, where they proceeded to crash loudly to the floor in the middle of a packed dining room. Mortification ensued...

a) To help Dr. Trousil understand what went awry, consider a tray supporting a plate of ribs. Her hand provides a contact force on the bottom of the tray to support the tray and food. Dr. Trousil is initially moving to the right when she suddenly stops. Draw free body and free particle diagrams for the tray and the ribs for the case when the platter does not slide relative to the tray. Circle any third law force pairs.

b) Identify the forces responsible for the following actions:

Force responsible for bringing the tray to rest:

Force responsible for bringing the ribs to rest:

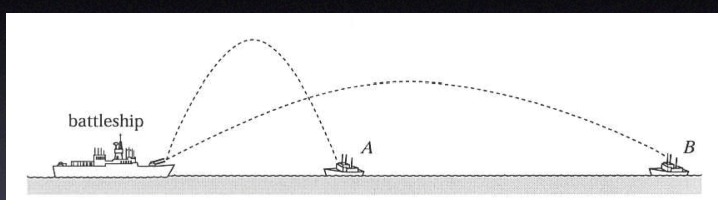
c) Determine the maximum horizontal force that Dr. Trousil's hand can exert on the tray so that the plate of ribs does not slide relative to the tray. The plate of ribs has a mass of 1.0 kg, and the tray is approximately twice the mass of the platter of ribs. The coefficients of friction between the plate of ribs and the tray are $\mu_s = 0.4$ and $\mu_k = 0.25$. You may assume that the tray does not slip with respect to her hand.

d) If the horiztonal force exerted by her hand on the tray exceeds this maximum value, the platter of ribs will move relative to the tray. Will the magnitude of the acceleration for the platter of ribs be less than, greater than, or equal to the magnitude of the tray's acceleration? Which was does the kinetic friction force on the ribs (due to the tray) act? Relative to the tray, which way does the plate of ribs move?

How to engage students?

- Instructor talks less. Students talk more.
- Keep it "real" and/or make it fun.
- Pose counterintuitive questions and problems that will generate debate.

A battleship simultaneously fires two shells with the same muzzle speed at enemy ships. If the shells follow the parabolic trajectories shown, which ship gets hit first?



A) Ship A
B) Both ships get hit at the same time.
C) Ship B
D) Need more information
Z) ???

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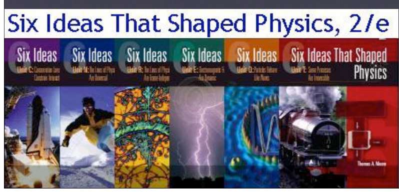
Six Ideas That Shaped Physics

- Novel introductory physics text that organizes curriculum around six underlying themes in physics
- Seamlessly integrates modern physics into curriculum



Six Ideas Text

Unit C:	Conservation laws constrain interactions
Unit N:	The laws of physics are universal
Unit R:	The laws of physics are frame independent
Unit E:	Electric and magnetic fields are unified
Unit Q:	Particles behave like waves
Unit T:	Some processes are irreversible

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- Let them know you are watching!

Keep them on their toes!

- Learn names and use them with reckless abandon!
- Solicit participation from all parts of the classroom.
- Ensure all students have an opportunity to contribute.

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- Unpredictable class sessions!

A Paradigm Shift

<u>Traditional Lecture</u>

- Instructor is gatekeeper of information.
- Goal of students is to acquire information.

<u>Active Learning Classroom</u>

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<u>Active Learning Classroom</u>

- Instructor is a coach, facilitator, traffic cop...
- Goal of students is to wrestle with new ideas, practice conceptual and quantitative problem solving, and give their own voice to the topics being studied

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- Students perceive this course to be easier than the traditional lecture-based class.
- Interesting and effective approach for a broad audience.

Acknowledgements

Thanks to...

Tom Moore, author of the Six Ideas text, who makes this all possible.

Tom Bernatowicz, the trail blazer for active learning in introductory physics at WU.