

Promoting Incremental Research-based Instructional Innovation

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Work supported in part by the National Science Foundation through a sequence of grants, for which we are quite thankful since the work could not have been done otherwise.

Problem we wanted to help instructors address:

I'm a straight-A electrical engineering student but I have almost no understanding of basic theory and principles. Will I get a job or into grad school? I never pay attention in lectures, read my textbook, or study at all - at the most an hour or so before an exam. I know the definitions of most things, but have no real understanding of them or what the definitions actually mean. I treat everything as some kind of special puzzle or game without understanding the basic theory behind it.

For example, I don't really know what Laplace transforms are. I can do them (because that's just matching things up in a chart), and they pop up in my work all the time, but I have no clue what it really means. Come to think of it, I don't have a very good understanding of what voltage actually is, although I understand perfectly how it relates to current and impedance. I got an A in the required statistics class, but I still have no idea what a standard deviation means (although I could calculate it if you gave me the formula).

I'm just going through the motions in all my classes: I know how to calculate all sorts of different values and make a bunch of nice plots, but don't ask me what they mean, let alone to actually use it to make something. I only learn the bare minimum to complete assignments and get A's on exams. I usually forget everything once I finish a course and relearn things when necessary.

This approach has been enough to get me straight A's in almost every course I've ever taken since high school, but as I near graduation, I begin to worry. I don't have anything more than a slight familiarity with the content of the courses I've already taken. About the same as if I had never taken them and instead just read a Wikipedia article on the topic. In other words, I feel like I haven't learned anything and have been spending the last three years doing meaningless calculations (which I have since forgotten).

... So here are my questions:

1. Is this typical?
4. Does this stuff "all make sense" after a while, or are there any working EEs/grad students who still don't really understand what this stuff actually means?
5. Do you need to have this kind of understanding of theory to get into grad school or get a job in EE?

Thanks for reading through this post!

We have been guided by results from Physics Education Research

Three areas of the research provide insight:

Students' Initial Knowledge State

Student Epistemologies

Problem Solving

Students bring a “common sense” knowledge base to the study of physics.

This knowledge base contains accurate elements, but it also contains alternative ideas that can interfere with learning the correct physics.

This knowledge base is organized in idiosyncratic ways that often have little relation to the proper physics.

Student epistemologies also have a strong effect on learning.

Do the students believe, as the student above, that learning physics is a matter of making answers, or

Do they believe that physics is actually supposed to make sense and help explain how the natural world works?

Students' ideas and approaches to problem solving also affect how they approach learning

Students commonly use “plug and chug” (means-ends analysis) and think of problem solving as finding numerical answers to word problems.

There is evidence that the majority of students learn little about the concepts, principles and relations of physics from solving typical end-of-the-chapter problems.

We cannot do the students thinking for them, they must think the issues through for themselves.

We need to set up a context where they think about the issues in a variety of ways and in ways that confront their “common-sense” ideas.

Hake (1998) presented evidence that a pedagogical approach called interactive engagement (IE) is an effective learning context for helping students change conceptions to more physically correct ideas.

But what is interactive engagement?

We describe interactive engagement as a learning context in which students work on tasks that elicit their natural ideas while discussing those tasks with their peers in pairs or small groups, and with the class as a whole then considering the matter to try to develop a consensus.

There are two critical aspects of an effective IE session:

tasks that effectively engage students and elicit their natural ideas,

and vigorous discussion of the various ideas elicited by the tasks.

Goal in Conceptual Exercises workshops was to provide resources and experiences to instructors interested in changing their approaches to IE.

Since there is truth in the old adage that: “We teach as we were taught”, we had the participants engage with the tasks in the same manner we advocated they have their students work on them.

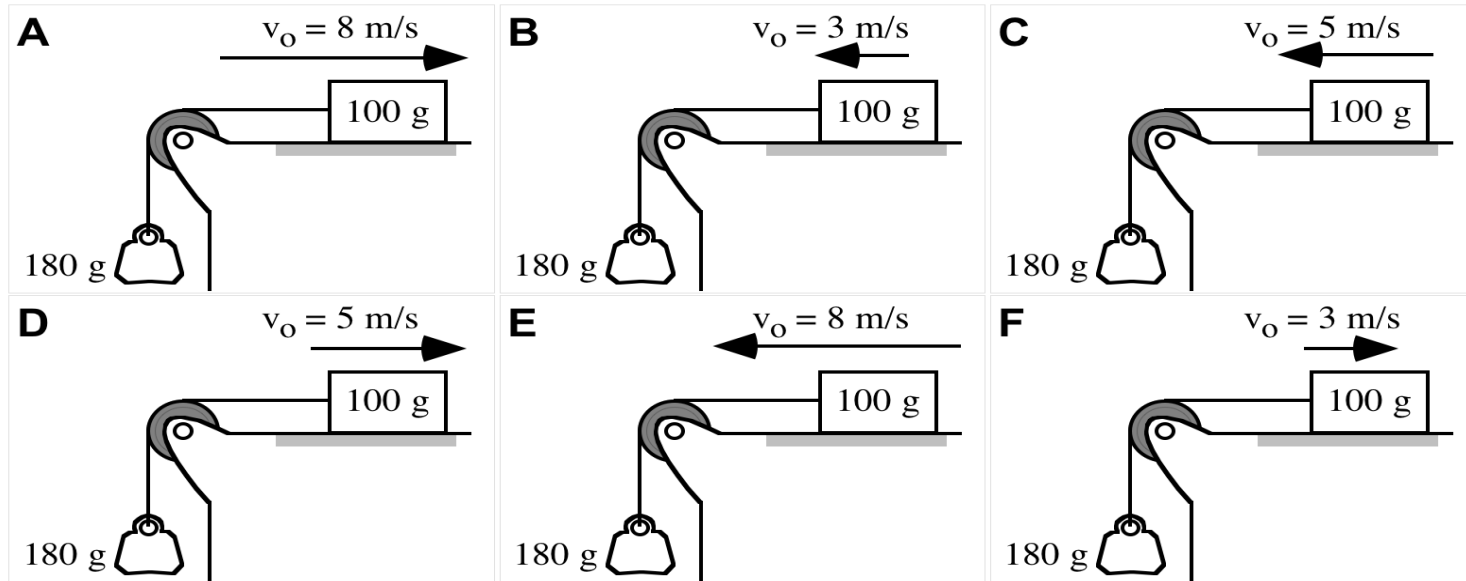
This gave the participants an experience of an alternative learning context and developed some understanding of how their students would feel when working on the materials.

Workshop participants have broad range of backgrounds from those with a Ph.D. in physics, astronomy, or engineering to BS biology majors who are being required to teach H S physics.

This mix results in discussions similar to those students generate.

For example consider the following ranking task that participants explored in groups of four in one of our workshops.

In the six cases shown below, a box is sliding along a horizontal surface at different velocities. There is friction between the box and the horizontal surface. The box is tied to a hanging stone by a massless rope running over a massless, frictionless pulley. All six cases are identical except for the differing initial velocities of the boxes.



Rank the accelerations of these boxes at the instant shown.

Greatest 1 _____ 2 _____ 3 _____ 4 _____ 5 _____ 6 _____ Least

OR, The acceleration of these boxes is the same but not zero. _____

OR, The acceleration of these boxes is zero. _____

OR, We cannot determine the ranking for the acceleration of these boxes. _____

Please carefully explain your reasoning.

One group presented their consensus that all of the situations had the same acceleration since the speed of the systems didn't matter.

All of the other participants agreed with this “solution”.

When the presenter was asked for the direction of the frictional force in cases A and B he quickly realized that their “solution” was in error.

TIPER Projects

Initial project was in the domain of magnetism because there were essentially no materials available at the time.

This was followed by our electrostatic project, when Steve Kanim from NMSU joined the team.

Resulted in E & M TIPERs book.

Participants in workshops kept asking for materials in Newtonian dynamics, so we are currently working on materials in this domain.

What are TIPERs?

Paper and pencil tasks in a variety of formats that require thinking about physics in a variety of ways. Task types are:

Conflicting Contentions Tasks

Changing Representation Tasks

Qualitative Reasoning Tasks

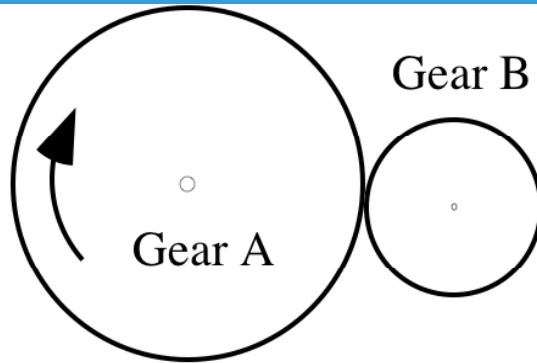
Working Backwards Tasks

What, if anything, is wrong Tasks

Troubleshooting Tasks Bar Chart Tasks

Ranking Tasks Comparison Tasks

A gear A rotates clockwise driving a second smaller gear B without slipping. The radius r_A for gear A is larger than the radius r_B for gear B by a factor of two.



Gear A rotating at ω_A driving smaller Gear B
(gear teeth not shown)

(1) Is the magnitude of the angular velocity of gear A (a) *greater than*, (b) *less than*, or (c) *equal to* the magnitude of the angular velocity of gear B? _____

Explain.

(2) Is the magnitude of the linear velocity of a point on the edge of gear A (a) *greater than*, (b) *less than*, or (c) *equal to* the magnitude of the linear velocity of a point on the edge of gear B? _____

Explain.

(3) Are the gear teeth for gear A (a) *closer together*, (b) *farther apart*, or (c) *the same distance apart* as the gear teeth for gear B? _____

Explain.

The equation below results from the application of the conservation of energy to a physical system:

$$(0.5)(12 \text{ kg})(4 \text{ m/s})^2 + (12 \text{ kg})(9.8 \text{ m/s}^2)(5 \text{ m}) \\ = (12 \text{ kg})(9.8 \text{ m/s}^2)(3.5 \text{ m}) + (0.5)(k)(1.4 \text{ m})^2$$

**Draw a physical situation that would result in this equation.
Explain how your drawing is consistent with the equation.**

A student is analyzing a situation where a block slides 8 m along a frictionless horizontal surface, 4 m along a rough 30° incline and then along another frictionless horizontal surface. The block, which has a mass of 9 kg, is initially moving at 6 m/s. The student writes the following conservation of energy equation.

$$\begin{aligned} (1/2)(9 \text{ kg})(6 \text{ m/s})^2 - (0.2)(9 \text{ kg})(9.8 \text{ m/s}^2)(\cos 30^\circ) \\ = (1/2)(9 \text{ kg})v_f^2 + (9 \text{ kg})(9.8 \text{ m/s}^2)(2 \text{ m}) \end{aligned}$$

What, if anything, is wrong with this equation? If something is wrong, explain the error and how to correct it. If the equation is valid explain why.

These tasks are designed so that students believe they understand them and they have an answer for them. They elicit multiple answers from different students who can then engage in resolving their disagreements and making sense of the situation.

As we mentioned we are currently engaged in developing TIPERs for Newtonian mechanics. Some of these materials are ready for field testing so if you are interested in using them for a course please contact Curt at

Thank you for your attention and
thanks again for the recognition of
our work.