



NEWSLETTER

ONTARIO ASSOCIATION OF PHYSICS TEACHERS
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 April, 2006

PHYSICS and COGNITION

Teaching Grade 10 Students Physics



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Last issue, we examined the difficulties that beginning physics students face as they attempt to learn both *vector operations* and *physics concepts* at the same time. The biggest problem appeared to be that students would choose to add vectors they should subtract, and vice versa. Beginning students would lack the ability to recognize that certain sums or differences were physically meaningless quantities. When we looked at the *sequential* vectors, we found that we should expect our students to get a wrong answer over 60% of the time.

Now let's consider the case of two vectors which occur *simultaneously*. Meaningless quantities are indicated with a \emptyset . The set of physically meaningful sums and differences is surprisingly small.

The top left box would then mean "the sum of two simultaneous position vectors of a bowling ball." The first thing we notice is that this operation results in a physically meaningless vector. It is not possible for a bowling ball to have two simultaneous positions that can be added or subtracted. Likewise, it is not possible to have two different displacements at the same instant.

Simultaneous velocities are next. Students first encounter them in navigation problems: a boat motors North while the river flows East,

or an airplane flies Southeast while the wind blows West. These are frame-of-reference calculations, not kinematics calculations. Suddenly, the vectors mean "velocity of the water with respect to the earth" and "velocity of boat w.r.t. the water."

Sums and differences of simultaneous acceleration vectors... Do they have a proper application?

Simultaneous force vectors are used in free body diagrams! I agree that FB diagrams are an indispensable tool, and students must learn how to construct them. I'm betting that you have got a student to draw FB diagrams, only to find that he or she makes a miserable showing on the kinematics questions on the final exam. Why? Well, if they can add simultaneous forces, why not simultaneous positions?

In the traditional physics curriculum, we expect students to become competent at vector math at the same time as acquiring competency in the concepts. But as we proceed from \mathbf{x} to \mathbf{d} to \mathbf{v} to \mathbf{a} to \mathbf{F} to \mathbf{p} and \mathbf{j} through the traditional physics curriculum, we switch physics concepts, vector methods, and time-related grounds approximately once every three days or so. Sum or difference? Position or displacement? Simultaneous or sequential? The changes are so frequent and abrupt that students are confused.

	Position \mathbf{x}	Displacement $\Delta\mathbf{x} = \mathbf{d}$	Velocity $\mathbf{v} = \Delta\mathbf{x} / \Delta t$	Acceleration $\mathbf{a} = \Delta\mathbf{v} / \Delta t$	Force $\mathbf{F} = m\mathbf{a} = \mathbf{j} / \Delta t$	Momentum $\mathbf{p} = m\mathbf{v}$	Impulse $\mathbf{j} = \Delta\mathbf{p}$
Sum	\emptyset	\emptyset	$\Sigma\mathbf{v}$ is meaningful in relative velocity and frame-of-reference analysis	?	$\Sigma\mathbf{F} = \mathbf{F}_T$ Total force, Newton's 2 ^o Law Free Body Diagrams	\emptyset	$\Sigma\mathbf{j}$ Two simultaneous impulses on the ball will act as one impulse
Difference	\emptyset	\emptyset	$\Delta\mathbf{v}$ is meaningful in relative velocity and frame-of-reference	\emptyset	$\Delta\mathbf{F} = \mathbf{F}_?$ Infer "missing" force by subtraction in FB diagrams	\emptyset	\emptyset

Teachers want students to succeed, so we provide only problems that can be solved by application of limited procedural knowledge to limited situations. Students are unable to understand those limits, and therefore cannot successfully apply their learning outside the most limited kinds of problems.

So... what are we to do? I would propose the following:

Begin in grade 10 with position and displacement. Provide students with plenty of experiences of measuring real two-dimensional position and displacement vectors. Emphasize the fundamental relationship that unites \mathbf{x}_1 , \mathbf{x}_2 and $\Delta\mathbf{d}$. Provide lots of exercise in making representations, and solving problems with this relationship. This would provide the student with a familiar reference point with which to organize all vector sums and differences. Ideally, the vector operations Δ and Σ would become as familiar as their scalar counterparts.

Continue grade 10 with velocity. Do not spend time on sums and differences with velocity vectors! Provide only enough instruction in velocity to support the student moving to an understanding of momentum and impulse. Minimize the mathematical treatment of acceleration. Leave it for one year, as it is a subtle concept, and difficult for a young person to learn correctly.

Spend considerable time on momentum and impulse. Students have a profound intuitive understanding of momentum and impulse, far deeper and more certain than any of their personal knowledge of velocity, acceleration or force. We should use that knowledge, formalize it, and reinforce it through many applications in the students' world. Students experience many hundreds of these every day, all of them much more accessible to young people via a simple set of representations.

The momentum / impulse vector set behaves exactly as the position / displacement vector set. The operations in both vector sets can be directly and easily confirmed by students' experience. This is simply not possible with velocity, acceleration or force.

Think how much time you spend telling kids that they have it wrong! In fact, telling kids that "you have it wrong" is so much a part of the physics teaching culture that we actually include whole sections of "you probably have it wrong" in physics text books! Why not start with what they can get very right?

Next issue, I will fill in some ideas for the rest of the secondary syllabus. I'll stop here, and invite more responses. To those who have written, my deepest thanks. To those who have felt an urge to respond, please do.

Digital Physics

Exploring the Impulse-Momentum Theorem



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G'day everyone, and welcome to this year's final installment of Digital Physics! Last issue, we investigated a way of communicating to our students the subtle difference between the law of conservation of energy and the work-energy theorem. In this issue, we'll help our students draw an analogy between the work-energy theorem and the principle of impulse and momentum. The analogy that I wish my students to pick up from this activity is the following: just as kinetic energy is transferred as work done by the net force (W_{net}), momentum is transferred as impulse ($\vec{J}_{i \rightarrow f}$) delivered by the net force. Making such a comparison helps students gain a deeper understanding of physics in general, and impulse-momentum in particular.

My approach in drawing this comparison involves the use of IP2000, and the script that was discussed in the previous issue (block moving up a ramp). I begin by recalling with my students the work-energy theorem, namely: $E_{ki} + W_{net} = E_{kf}$. That is, the total kinetic energy of an object in its initial position plus the kinetic energy that has been added to it as work done by the net force is equal to the total kinetic energy of the object in its final position. With this review in place, we proceed to explore the principle of impulse and momentum (taught in the previous

lesson): $\vec{p}_i + \vec{J}_{i \rightarrow f} = \vec{p}_f$. In words, this equation expresses that the total momentum of an object in its initial position plus the momentum that has been transferred to it as impulse by the net force as it moves from its initial to final position is equal to the total momentum of the object in its final position.

Now, here's where the simulation comes in. Students are given the initial conditions (or state) of the block, and then manually calculate the block's initial momentum. The simulation is then run and stopped some arbitrary time later as the block is moving up the ramp. Using the net force acting on the block as it moves, and the time over which that net force is applied, students can determine the momentum transferred to the block as impulse. Adding \vec{p}_i to $\vec{J}_{i \rightarrow f}$ gives students what should be the final momentum of the block. Students can calculate, using data obtained from the simulation, the momentum of the block in its final position – thus verifying the principle of impulse and momentum and completing the analogy.

I have found this approach to be successful so long as the delivery is slow and methodical, but this is key.

As always, those interested in trying the simulation and worksheets are welcome to contact me at the above address.

Comments are welcome, too, and many thanks to those that have! Happy teaching and see you at the conference in May!

The Demonstration Corner

A Versatile and Inexpensive Physics Demonstration

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A versatile and inexpensive demonstration tool for every physics teacher is the "sound tube," also known as the whirly, Hummer and corrugahorn. Its puzzling properties span many different physics topics.

What is a sound tube? The sound tube is a corrugated plastic tube that is about 75 cm long and 3.5 cm in diameter. The most amazing property of the sound tube is its ability to "sing." By holding one end of the tube and swinging the other end around in a circle, you will hear a loud clear sound. As it is twirled faster, different frequencies are heard. The toy's packaging indicates that five frequencies are possible although this seems to be from only the most skilled "twirlers," as we could produce only four.

How do you investigate the sound tube? You can ask students to play with the tube and determine some physical principles associated with it. You could even ask them to take it home for continued experiments, but this might require a sound tube for each student. Our investigations determined the following properties.

1. If you close either the stationary or the twirled end of the tube there is no sound produced. To produce singing, the tube must be open at both ends.
2. A smooth tube of similar length and diameter does not sing when twirled.
3. The frequency of the lowest resonance does not correspond to a smooth open tube's fundamental frequency. In fact, the sound tube's fundamental is closer to the second harmonic of a smooth tube.
4. As the spin rate of the tube is increased, there are sudden upward jumps in the frequency. Intermediate frequencies are not heard.
5. Driving a car with the sound tube out the window will produce no sound if the tube is held perpendicular to the airflow, but will produce sounds if the tube is held parallel to the wind. Therefore, airflow is necessary for the singing sound but it is not produced by Bernoulli's effect. Frequency jumps are produced at the same driving speed as the tangential component of the velocity of the twirled end (Crawford, 1974).



Figure 1 One of the authors demonstrating use of sound tube. Inset: Close-up of sound tube.

Why does the sound tube sing? The singing is caused by turbulent air driven over the tube's crenulations by centrifugal pumping. The speed of the air flow through the tube is equal to the tangential component of the velocity of the spinning end (Crawford 1974). Laminar (low speed) flow produces no sound. The amplification of only particular frequencies is associated with the standing wave resonance produced by the tube open at both ends.

Where can you use this demonstration in the curriculum?

Obvious places would be waves and sound. However, the sound tube demonstration can be used for topics such as centrifugal force, Bernoulli's principle, turbulence and Reynolds' number. The quantized sound tube frequencies also make for interesting demonstrations in quantum mechanics (Griffiths and Steinke, 2001). What more could you ask for \$2.99?

References:

Crawford, F.S. (1974) Singing Corrugated Pipes. *Am. J. Phys.* 42:278-288

Griffiths, D.J. and Steinke, C.A. (2001) Waves in locally periodic media. *Am. J. Phys.* , 69(2):137-154

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Highschool Teaching Strategies

Roller Coasters in the Classroom



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Roller coasters provide wonderful examples of physics in action. Roller coasters link classroom concepts with the "real world". They are the "hooks" that grab the interest of our students and can fuel animated discussions. A trip to Canada's Wonderland is a school trip that is both educational and entertaining. Unfortunately for students taking physics in the first semester such a trip is not possible. Designing and building a classroom roller coaster is a viable alternative.

To introduce my students (I do this with both my grade 11 university physics and grade 12 college physics students) I use the Internet to show them this year's latest thrill machines. This year it was the monstrous Kingda Ka coaster at Six Flags in Ohio. This beast reaches a maximum height of 139 m (45 stories) and attains a maximum speed of 204 km/h. An onboard video¹ gives the students a taste of what it would be like to ride the actual coaster. Next year the park will be opening the world's steepest (76 degree) wooden coaster called El Toro and has a simulation² available for viewing. The students then use the Internet (and any other resources) to help them design their coasters.

For the actual construction I have found that 6 ft long hot water pipe insulation (split in half) to be ideally suited to the task. It is both economical and reuseable. Duct tape seems to do a good job of joining the lengths together. One inch thick sheets of foam insulation provide an economical base. Retort stands, furniture

(desks, stools) and walls provide good vertical supports. Marbles can be used as coasters, but metal bearings do a better job. As part of the evaluation students must log their progress (successes and failures). In addition the students are evaluated for **safety** (the coaster cannot leave the track) **efficiency** (a ratio of the height gained to the height lost) **thrills** (features like loops, corkscrews, "negative g" hills etc).

The advent of economical digital cameras with video capability has meant that this project can be taken one step further. Students can then take a short video of their coaster in action (this often works better if the bearing or marble is painted white or yellow). This can then be imported into any number of video analysis programs like Logger Pro³ or Physics Toolkit⁴. This allows students to track the coaster's position, speed and ultimately gravitational, kinetic and total energy. The depth of the analysis will depend on both the students and the time available. Regardless of the depth of the project the students benefit from this hands-on relevant project.

1. <http://themeparks.about.com/od/photoandvideogallery/v/kingkavideo.htm>
2. <http://www.sixflags.com/video/shared/eltorohs.mov>
3. <http://www.vernier.com/soft/lp.html>
4. <http://www.physicstoolkit.com/index.html>

What's New at OAPT?

The New Physics Funding Formula



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OAPT CONFERENCE MAY 26, 27, AND 28 OF 2006

LOCATION: Perimeter institute for theoretical physics. **On the Web:** perimeterinstitute.ca

THEMES:

1. Innovative Teaching Strategies for Modern Physics

Quantum theory and relativity form the bedrock of much of physics research done today. They are also immensely practical. These two theories were crucial to the development of numerous advanced technologies such as modern electronics, nuclear medicine and the GPS. In addition, Nobel prize winner Leon Lederman has estimated that 70% of the US's gross domestic product depends on quantum theory. In Ontario, quantum and relativistic physics occupy 20% - 40% of the prescribed syllabus, but rarely receive more than 10% of the time. Given their critical importance, how can we change high school physics education so as to ensure that they do justice to them?

2. Authentic Inquiry

For the past 150 years, physics teaching has been dominated by content. We are now gradually realizing that this is not very effective in achieving our goals, and we are beginning to explore the Process Model. Real scientists don't do science by sitting in a classroom listening to lectures. Rather, they hive off a bit of the universe, poke it, and observe what happens. How do we allow our students the opportunity to model what real scientists do? This second theme of the conference will involve critically analyzing the merits and drawbacks of a number of innovative approaches to teaching physics. We know that members of OAPT are doing exciting work in the classroom. We invite you to share it.

DETAILS AND REG. AT: OAPT.CA. DON'T MISS THIS STELLAR CONFERENCE!