NEWSLETTER

ONTARIO ASSOCIATION OF PHYSICS TEACHERS (An Affiliate of the A.A.P.T., and a charitable organization) November 2007

The Demonstration Corner

Newton's Third Law and Water Rockets

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Having students construct and launch a water rocket is an entertaining way to investigate Newton's Third Law of motion. Students can construct the rockets at home for an in-class launching session.

Apparatus: two-litre pop bottle, range enhancers (see below), launching pad, bicycle pump with basketball-inflator "needle," rubber stopper.

Procedure for Students:

1. Find an empty two-litre pop bottle. You may glue on a "nose cone", some "fins" and anything else that you think might help your "rocket" fly farther. However, you may not use a set of "wings" or other form of lifting airfoil, like an airplane.
2. Decide how much water you want to place in the rocket. Put this much in.
3. Attach the rubber stopper firmly, and place your rocket in the launcher. Pump air into the rocket until it "fires."
4. Your "score" is the distance flown horizontally, in metres.

Notes to the teacher:

1. The launcher can be as simple as two boards, angled at 45º, with guide rails on the launch board (Fig. 1).

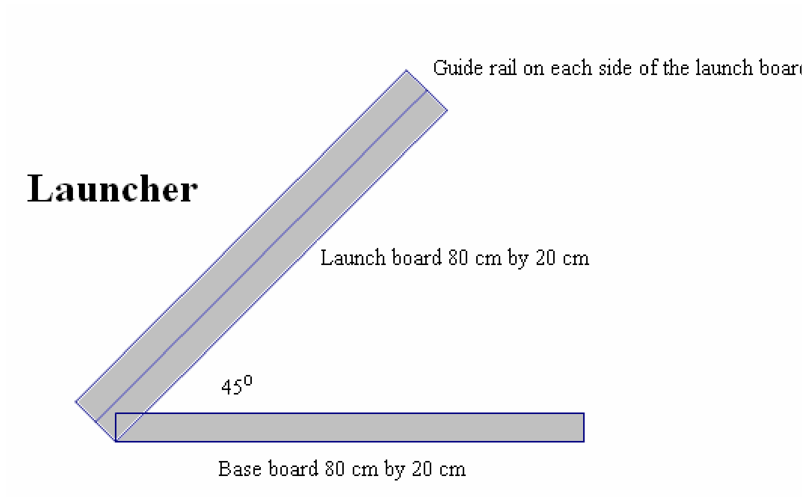

Figure 1 *A typical launcher.*

2. Ensure that the firing range is clear. A good water rocket can fly over 100 m horizontally.
3. Use a basketball inflator pushed through a rubber stopper to attach the bicycle pump to the rocket (Fig. 2).

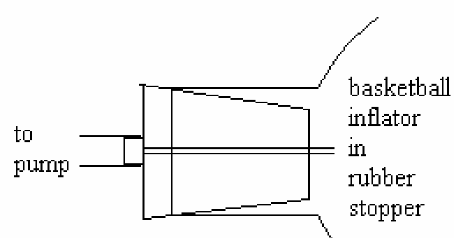

Figure 2 *Connection between the pump and the rocket.*

4. I usually do not warn students not to stand directly behind the rocket while pumping. A little water won't hurt them, and will reinforce the workings of Newton's Third Law.

Possible Follow-up or Report Questions:

1. Explain how the rocket works in terms of Newton's third law.
2. Why doesn't the rocket work well if there isn't much water in it?
3. Why doesn't the rocket work well if there isn't much air in it?
4. Which mixture seems to work the best?
5. A real rocket for use in space must carry both fuel and oxygen. Why is this?

Other Notes:

1. Just after launch, a "cloud" will often form inside the bottle, and persist for several seconds. Why this cloud forms makes for an interesting discussion or research question.
2. A more sophisticated launcher can include a way of changing the angle of the two boards, allowing an investigation of range versus angle of launch.

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Submissions describing demonstrations will be gladly received by the column editor.

The PhET WebSite

A Gold Mine of Physics Simulations

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I avoided using computer simulations in physics for many years because I felt that they were just a way to avoid the hassle of setting up a real hand-on experience. However, two years ago, Carl Weiman's brilliant summary of Physics Education Research in Physics Today* put me straight on that misconception. Simulations are a critical complement to real experiments for two key reasons. First, a simulation can remove the many irrelevant pieces of information that can distract the student from the key concepts. For example, many students think that the colour of the wires in a circuit is significant. Secondly, the simulations help them build the abstract mental models that are needed to analyse a real experiment. The concepts of current and potential difference are very difficult for students to grasp. A simulation that shows charges moving in a circuit can really help.

Having grasped the importance of simulations I went hunting around for useful examples - googling applets, simulations or physlets is a good way to start. However, this takes a lot of time and many of these are really just simple animations with very little opportunities for interaction. Furthermore, when you do find one that is good and work a regular place for it in your course, you often find that the website has disappeared. Once again, Carl Weiman's article had a great suggestion – the PhET (Physics Education Technology) website** of the University of Colorado. This one site is full of interactive simulations ranging from university level quantum mechanics to an elementary level John Travoltage.

I use these simulations in a variety of ways. The electric circuit simulation is great to use before working with real circuits. The students get to fry batteries and blow up light bulbs and generally experiment freely with no risk to equipment or life. I like to demonstrate things qualitatively with a ripple tank and then have the students collect data with the wave simulation. In other areas, I use the simulation in a full-class format to explore the concepts using the Predict Explain Observe Explain technique. Finally, the simulations can be great motivators when used as open-ended physics games. My students' favourites so far are the Lunar Lander and Electric Field Hockey. I get dozens of students hanging around at lunch and after school trying to win and incidentally building their understanding of physics.

* **Weiman, C., & Perkins, K.** 2005, "Transforming Physics Education," *Physics Today*, 58(11), 36.
** http://phet.colorado.edu/new/index.php

Dave Doucette's PER Corner

'Bridging Research into Practice'

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This is the 4th in an series of articles using physics education research (P.E.R.) to modify instructional practice, ie, 'Bridging Research into Practice'.

Having a Ball With Physics

(gr. 11 university physics)

As experienced physics teachers, we are fully aware of the difficulty students have in applying equations to simple phenomenon. Students select values for time intervals, displacements, mass and so on that are puzzlingly inappropriate. In the 3rd article of this series I discussed challenges in selecting the correct Δt in concrete applications and suggested adaptations to help students explicitly identify correct and incorrect time intervals. This article examines similar difficulties selecting appropriate Δd values while throwing a tennis ball.

Throwing a tennis ball seems a direct and relatively simple application of an external force (your hand) doing work on an object (the ball) to produce a change in kinetic energy. Where students commonly err is in selecting the correct 'Δd' to apply in '$F \cdot \Delta d$'. The majority choose the displacement of the ball after the ball is released from the hand, and not the displacement of the hand while throwing the ball. To combat this misconception I developed a sequence of scaffolded questions.

The activity was preceded by a discussion of the difficulties students have in applying formulae to phenomena, with examples. They were instructed to throw the ball, measuring the distance the ball moved while the force was applied by the hand. They measure time and the horizontal distance the ball travels to determine the average velocity. Neglecting friction, this allows them a reasonable approximation for the ball's kinetic energy.

The 1-page worksheet was as follows:

EW1.02 identify conditions required for work to be done, and apply quantitatively the relationships among work, force, and displacement along the line of the force

m_{ball} = ____ g = ____ kg Δd_{arm} = ____ m
Δd_{tossed} = ____ m Δt = ___ s V_{av} = ___ m/s

*1. You do **work** when you throw a ball, $F \cdot \Delta d$. In this formula:*
i) what does F refer to? acting on what? by what?
ii) what does Δd refer to?
iii) what changed about the ball as a result of the work you did on it?
2. To measure the V_{av} above, you used '$\Delta d/\Delta t$'. How is this 'Δd' different from the 'Δd' you used to measure the work done? Does it matter which 'Δd' you use to determine the work done on the ball? Explain.
i) calculate the change in kinetic energy of the ball: $\Delta KE = KE_f - KE_i$
ii) assume the ΔKE was a result of the work done by you on the ball. Use this relationship to determine the $F_{average}$ you applied to the ball.
iii) Why do we call it the average force, $F_{average}$, instead of a 'constant force'?
3. Imagine you did the same amount of work on the ball, but threw it straight upwards. What would happen to the kinetic energy of the ball? How high would it rise?

The results were encouraging and illuminating. During the activity phase in our hallway students peppered me with clarifying questions, such as: '*Is F the force the ball exerts on my hand or my hand exerts on the ball?*' '*Is F the force of my hand when I'm holding the ball or when I throw the ball? Aren't they the same thing*?' '*Is the delta d when I am throwing the ball different from the delta d to where the ball lands on the ground*?' '*Doesn't the force of your throw continue until gravity takes over*?' Sobering questions, reinforcing the need to provide myriad opportunities to apply seemingly simple concepts.

The worksheet results were mixed, with a small percentage of students correctly applying both work and kinetic energy change formulae. The majority of students demonstrated inconsistencies – or worse – in their responses. Some incorrect examples were:

Question *You do* ***work*** *when you throw a ball, F·Δd. In this formula: i) what does F refer to? acting on what? by what?*
Answer*: F refers to the force applied on the hand, from your arm*.
Question: *ii) what does Δd refer to?*
Answer: *The displacement is how far the ball traveled. From when it was tossed to where it landed.*

More encouraging were responses such as: *'ΔD refers to the displacement of how far my arm extended, when the ball was in contact with my hand, not when the ball flew away from my hand.*' '*The Δd_{tossed} is the distance the ball traveled. The other Δd_{arm} is the distance measured while the force is being applied. In order to determine the work done you would need to use the Δd_{arm} because that is where the force is being applied*.' The latter was written by a student who to date was failing in the course.

Misconceptions of force and kinetic energy were also revealed. A common phrase was, '*The ball gained kinetic energy which caused it to accelerate forward*', which reveals a failure to discriminate between force as a cause and kinetic energy increases as an effect. However the worksheet provides an opportunity for a formative dialoque between teacher and student, moving the student towards a deeper understanding of fundamental concepts.

Sometimes you have to read responses carefully to recognize a misconception! In answer to the question *Why do we call it the average force, $F_{average}$, instead of a 'constant force',* one student wrote, '*You call average force, F_{av}, instead of constant force because you want the total force you applied on the ball. Constant force would mean that you are referring to the force applied through the whole traveled time*.'

The reference to a force *applied through the whole traveled time* suggests the persistent notion of the force of your hand traveling along with the hand until it 'dissipates', much as 'heat dissipates from a heated object' - to use layman's logic. Until Newton's time this was the prevailing orthodoxy and continues to this day among naïve learners. Only a deep appreciation of the Newtonian concept of forces causing accelerations that tends to put this misconception to rest.

What was truly surprising was a significant number of students correctly identifying the Δd to use in F·Δd, explaining why it was incorrect to use Δd_{tossed}, yet using the incorrect Δd in the subsequent calculation for $F_{av=}$ ΔKE/Δd!

The results overall are encouraging. The challenge will not be overcome by any single application. A progressive emphasis on distinguishing correct values for time, force, mass, displacement is demanded. This includes word problems in which multiple values are provided and differentiation is necessary. A colleague, Gord Ridout, has already included this in a recent quiz by asking "To throw a 145 g baseball a pitcher applies a force of 35 N for a distance of 1.8 m. If the ball travels 30m, find the amount of work done by the pitcher on the baseball." One could add, 'Identify a value for Δd which does not belong in the formula W= F·Δd.'

The hope is that, by directed attention to the problem students have in mapping formulae onto real-world phenomenon, we will produce graduates with richer insight and who more readily perceive physics in the world around them.

Who thought throwing a tennis ball could be so enriching? It certainly was – for me!

If you wish a 'Word' copy of the worksheet, or would like to exchange similar efforts, contact the author at the email enclosed.

Please direct questions or comments to the editor James Ball james.ball@ugdsb.on.ca