COMPILATION: Unit 9 - Momentum paradigm lab

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Momentum paradigm lab:

Here is a way of beginning the impulsive force / momentum unit that has worked well for me. It is slightly different from the one in the modeling materials. I like the way this one emphasizes ratio reasoning, and once the students accept the idea of graphing ratios, the definition of momentum develops easily from analyzing the graph.

After completing the energy unit, I show the students a Pasco track with end stops, a plunger cart and a regular cart. (No photogates or computer needed.)

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      [] <---- Xa -----> [  cart a ][ cart b ] <------ Xb ------>[]
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With the plunger between the two carts, I tap the trigger pin with a ruler, shooting the carts away from each other. The situation is discussed, energy storage analyzed, and variables identified. I guide the students to compare the ratio of the cart masses (independent variable) to the ratio of the velocities (dependent variable).

To find the ratio of the velocities, I ask the students to find the starting point for the two carts so that both carts reach the velcro end stops at the same time. Only one "thump" will be heard when both
carts hit the end of the track at the same time. Since v = displacement / time interval, when the time for the two carts to reach the end stops is equal, the ratio of the displacements is equal to the ratio of the velocities.

Students often ask if the force on the two carts is always going to be equal, especially because of the velcro joining the carts. Thankfully, other students are able to remind the class that Newton's third law still applies.

To make the math easier, I suggest that the students separate the end stops 100 cm plus the length of the two carts. Therefore, the sum of Xa plus Xb is always 100 cm. Sometimes the students get confused and measure the displacements from the contact point of the carts rather than from the end of the cart that will hit the end stop. Another common mistake is flipping the ratios around, i.e. 34:66 when they mean 66:34.

Sample Data Table:

Ratio of Masses ma : mb	Ratio of Velocities (displacements) va:vb
1:1	50:50
1:2	66:34
1:3	75:25
1:4	80:20
2:3	60:40

When the students convert their ratios to decimals and graph va/vb vs. ma/mb, an inverse relation results.

Graphing va/vb vs. mb/ma linearizes the graph with a unitless slope of 1. With clean and level tracks, free-rolling carts, slopes are within one percent of the expected 1.00.

Writing the equation for the line:
$y = mx + b$

$va/vb = (1)\ mb/ma + 0$

cross multiplying yields:

$(ma)\ (va) = (mb)\ (vb)$

The product of mass times velocity is equal for both carts in every situation tested, so the useful mv quantity is worthy of a name, momentum.

I later do a lab to relate momentum and impulse using force probes and motion detectors, and then another lab to look at momentum in a variety of collisions using photogates.

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