I. SUV vs. car

On a test track, a sports utility vehicle (SUV) of mass 2000 kg, traveling at 12 m/s, hits a stationary car of mass 1000 kg. The car crumples and stays in contact with the SUV; they move together as a unit.

A. Answer this without doing calculations: Which vehicle, if either, undergoes a greater change in velocity during the collision? How do you know?

B. Without using formulas, see if you can intuitively guess the post-collision speed of the two vehicles. Briefly explain your common-sense reasoning. If you get totally stuck, move on.

C. Now calculate the post-collision speed using momentum.

D. If you got stuck in part B, do you now see a way that you could have "guessed" the post-collision speed? Explain.

II. Common sense and formulas

Now that you've heard hypothetical and real students (in tutorial and ILD) debate the relationship between equations and common sense, what's your verdict? Specifically, which of the following best expresses your (not necessarily your professor's!) view:

i. Many physics *concepts* make a lot of sense and connect to everyday experience; but *formulas* are more of a problem-solving tool than a sense-making tool.

ii. It really depends on the formula. Some of them make sense, but you shouldn't expect them to make sense as a general rule.

iii. In general, physics formulas express some kind of common-sense ideas.

Explain why you chose what you chose, giving specific examples if they help express your thinking. Since we want to hear what you really think, grading will be based only on the completeness, not the content, of your response.

III. Bowling ball vs. pin

A bowling ball rolls into a stationary bowling pin, which is much lighter than the ball.

A. During the collision, is the force exerted by the ball on the pin greater than, less than, or equal to the force exerted by the pin on the ball? Briefly explain.

B. During the collision, is the bowling ball's change in *speed* greater than, less than, or equal to the pin's change in speed? Briefly explain.

C. During the collision, is the bowling ball's change in *momentum* greater than, less than, or equal to the pin's change in momentum? Briefly explain.

D. A student makes the following argument about part C:

> In the collision, the pin's momentum changes more than the ball's momentum, because the ball's motion hardly changes, while the pin's motion changes a lot; it bounces off the ball really fast.
>
> How could you help this student reconcile his intuitive ideas abut the "changes in motion" with the fact that the ball's momentum and the pin's momentum change by the same amount?

IV. Momentum conservation and Newton's 3rd law

(Note: This problem depends on the class having completed the ILD about momentum conservation.)

According to conservation of momentum, when two objects collide, the momentum lost by one object equals the momentum gained by the other. In an ILD, you derived momentum conservation from Newton's 3rd law and other assumptions. Here, we want you to give a common-sense, non-mathematical explanation of the connection between Newton's 3rd law and momentum conservation. In other words, make an argument that Newton's 3rd law and momentum conservation, though they seem different on the surface, actually "say" similar things. A good answer would help your roommate understand why those two seemingly-disconnected laws are closely connected. Again, we're looking for conceptual, common-sense reasoning, not formal mathematical reasoning. Continue on the back.

