Tutorial – Newton's Third Law
Instructor's Guide

Overview

In our experience, this tutorial is perhaps the most jarring and memorable one of the set. Newton's Third Law is a very counterintuitive piece of physics when placed in the context of common collisions. We've set this up so that students start off making incorrect predictions about the forces between objects in a collision. They then see an experiment showing (provided your setup works) that N3 holds when a large object collides with a smaller one. Finally, we get them to make another common sense prediction that leads to the right N3 answer as well as that gasp of realization we all know and love.

I.

A.
Just about every student here predicts that the truck's force is larger. If one of your students has seen Newton 3 in a previous course, make sure to stress that we're looking for an intuitive answer.

B.
This question cements the response we hope to hear in part A. It also establishes the common way of discussing the collision as "car reacts more."

D.
Before you let the groups go up and look at the demo, get their opinion on this question. Students will have a lot of different things to say. Some will figure there's some way N3 works out in the end. Others figure that N3 doesn't apply here. Perhaps, after all, only the truck exerts force on the car.

The Experiment

We set this experiment up with force probes. You may know from experience that electronic probes hooked to computers can be fickle things. Force probes have to be carefully calibrated, and we typically calibrate them before each class. Even so, equal forces may not show up as equal.

The students need to see what it means for a force to be equal. We set up our force probes to take data over a few seconds. You can get one of your students to come up and take two force carts (equal mass). Tell him or her to push them together equally. Your students should expect THOSE forces to be equal. Check out what the computer gives, and indicate that this is "what equal looks like" on the computer.

The collision is done by weighting one of the carts so it's about twice the mass of the other. For the collision, we set up the program to take triggered data, that is, to make a very quick graph (less than a second) that starts upon sensation of a force. That way, you're not comparing two digital spikes that may look different.

Even with these precautions, the graphs of $F_{1->2}$ and $F_{2->1}$ may not look the same. You might ask the students what *factor* difference they'd expect. The graphs will be equal well within that tolerance. Also, you might switch which cart has the weights on it. That way, you can see if one probe or the other is systematically different.

II.

A.

Although this should be asked about at the checkpoint, wander around and see what students say in response to this question. This will give you a feel for where your groups are when it is time to check them out.

B.

The students can say whatever they want here, but again, if there's even a slight difference in reasoning between even one of your students and the rest, make sure to talk about it at the checkpoint.

III.

The point of this section is to get them making a common sense prediction (that is usually correct), then following through with some simple arithmetic to see that N3 really does hold in the case of one collision.

A.

Given the instruction to "apply the intuition that the car reacts more," all of your students will either immediately say the car gains 10 m/s or be fully sympathetic to that idea.

Some students are willing to "play the game" of guessing 10 m/s even though they're convinced at this point that 5 m/s is the real gain.

Checkpoint 1

There are two main objectives for this checkpoint. First, find out what your students said to the question in II.A and talk out any disagreements. Early in the semester, you need to keep stressing that these questions aren't disposable and worthless of attention.

Next, check their answers to III.A. Make sure that the 10 m/s idea is out there on the table, and see that all the students are at least sympathetic to it. That's the number you need to use in the next part to get the desired "final conceptual payoff."

B.
The truck accelerates half as much as the car, and if they know the basic definition for acceleration, your students should get this right. Then, all they need to do is apply F=ma to get the forces. Hopefully, they'll see that their intuitive guess agrees with N3

At the end, students will discuss the questions at the end of B a lot. They can either do this in your presence as the start of the checkout or on their own

Checkpoint 2
This checkpoint is to ensure that the calculations are correct and that the students see agreement between N3 and their intuition.

IV.
A.
The goal is for them to see that *car-reacts-more* isn't wrong or right in itself, but depends on context. If you say the car feels more force, that's wrong. If you associate "acceleration" with "reaction," you're now correct. Some students will recognize this as a bit of trickiness arising from our use of language.

B.
The answer to this question is that a car's smaller mass will accelerate more than a heavier mass given equal forces. It's not a complicated answer, but it's important that all of your students get this.

C.
We call this the "most important question," but the students often see it as the least important question since it doesn't contain any new physics. *NOTE: Do not let your students leave tutorial until you've seen their answers to B and C here.* If they are allowed to run off without discussing these questions, you will have great difficulty focusing their attention on questions like this in future weeks. In preparing to teach this lesson, it might help to think about what responses would be good to C. here. One would be to use the *implications game*: get the students to make an intuitive guess about an important bit of physics and investigate the implications. The implications of their intuitive "change-in-velocity" guess lead to correct answers about forces.