Tutorial 3: Name _____ Section _____

Counterintuitive ideas: Newton's third law

The main point of this tutorial is helping you learn more strategies for learning physics concepts that seem to defy common sense.

I. Newton's third law and common sense

According to Newton's third law, when two objects interact,

> *The force exerted by object A on object B is equal in strength (but opposite in direction) to the force exerted by object B on object A.*

Often, this law makes perfect sense. But in some cases, it seems not to.

Consider a heavy truck ramming into a parked, unoccupied car.

A. (*Work together*) According to *common sense*, which force (if either) is larger during the collision: the force exerted by the truck on the car, or the force exerted by the car on the truck? Explain the intuitive reasoning.

B. (*Work together*) We've asked this question of many students, and a typical response goes like this:

> Intuitively, the car reacts more during the collision. (You'd rather be riding in the truck!) So the car feels the bigger force.

Is your group's explanation in part A similar to or different from this? Explain.

C. (*Work together*) According to Newton's third law, which of those forces (if either) is bigger?

D. *Experiment.* Is this a case where Newton's third law doesn't apply? At the front of the room, the TA has set up an experiment that simulates a truck ramming a car. Go do the experiment and record the results here. You can also test whether Newton's third law holds for other collisions.

II. What to do with the contradiction between common sense and Newton's third law?

Before moving on to the next part of our Newton's third law lesson, let's consider the contradiction we just found between physics and common sense.

A. (*Work individually*) In summary, for most people, Newton's third law contradicts the common-sense intuition that the car reacts more during the collision. Which one of the following best expresses your attitude toward this contradiction?

   i. We shouldn't dwell on these kinds of contradictions and should instead focus on learning exactly when Newton's third law does and doesn't apply.

   ii. There's probably some way to reconcile common sense with Newton's third law, though I don't see how.

   iii. Although physics usually can be reconciled with common sense, here the contradiction between physics and common sense is so blatant that we have to accept it.

   Briefly explain why you chose the answer you chose.

B. Discuss your answer with your group. Is there a consensus or do people disagree?

III. A new strategy: Refining intuition

Before accepting that there's an irreconcilable contradiction between Newton's third law and the intuition that the car reacts more during the collision, let's try a reconciliation strategy called *refining your intuitions.*

A. (*Work together*) We'll start with a new question. Suppose the truck's mass is 2000 kg while the car's mass is 1000 kg. And suppose the truck slows down by 5 m/s during the collision. Intuitively, how much speed does the car gain during the collision? (Apply the intuition that the car reacts more during the collision, keeping in mind that the truck is twice as heavy.) Explain your intuitive reasoning.

☆ *Consult an instructor before you proceed.*

B. Does your answer to part A agree with Newton's third law? To find out, we'll lead you through some quick calculations.

1. Suppose the car and truck remain in contact for 0.50 seconds before bouncing off each other. Calculate:

   i. the truck's acceleration during the collision.

   ii. the car's acceleration during the collision (assuming your guess about its change in speed is correct).

2. To good approximation, the forces that the car and truck exert on each other are the *net* horizontal forces they feel during the collision. Starting with the accelerations you just calculated, use Newton's second law (the one relating net force to acceleration) to find:

   i. the force felt by the truck during the collision.

   ii. the force felt by the car during the collision.

3. The accelerations and forces you just calculated were all based on your guess about the car's gain in speed – a guess based on the intuition that the car reacts more during the collision. Does that intuitive guess agree or disagree with Newton's third law? How do you know?

☆ *Consult an instructor before you proceed.*

IV. What just happened?

A. (*Work together*) We need to sort out what to do with the *car-reacts-more* intuition, *i.e.,* the idea that the car reacts more than the truck during the collision. At the beginning of this tutorial, when you answered a question about the forces acting on the car vs. the truck, that intuition led to a wrong answer that disagreed with Newton's third law. But in section III above, when you answered a question about changes in velocity, that same intuition led to a right answer that agrees with Newton's third law. So, what's up with the *car-reacts-more* intuition? Is it wrong? Is it right? Is it something else? Explain.

B. (*Work together*) We now see that the car "reacts" more during the collision in the sense that it undergoes a greater change in velocity, *i.e.,* it experiences a larger acceleration. Give a common-sense explanation for why the car reacts (accelerates) more during the collision even though it feels a force no bigger than the truck feels. Ask your TA for a hint, if needed. This is the second most important question in the tutorial.

C. (*Work together*) We intended this tutorial as a lesson not just about Newton's third law, but also about strategies for learning physics concepts that seem to contradict common sense. What general strategies are suggested by this tutorial—strategies you might be able to use with counterintuitive concepts appearing later in the course? This is the most important question in the tutorial.

