The Force Inside the Object

Start with this question.

Three identical balls are at the same height. One is going up. One is at the peak, momentarily at rest. One is coming down. Ignore air resistance.

Are the forces on the three balls the same?

They are. Each ball has the same force on it: its weight, downward. The motions differ, but the forces don't.

In Viennot's samples, between 30 and 55 percent of students got this wrong. The pattern held from secondary school through third-year university, across France, Britain, and Belgium. Most common reasons given: "The forces are different because the motions are." Or: "The force is zero because the velocity is zero."

These aren't careless mistakes. They're systematic.

Why the second law is hard

Newton's second law relates quantities at the same instant. $F_{net}(t) = ma(t)$. Net force right now equals mass times acceleration right now. Not because of something that happened earlier. Right now.

This is routine for physicists. For students, it isn't obvious.

Their natural way of explaining motion is narrative. First a cause — a throw, a push. Then, later, the effect — the object moves. Cause first, effect later. That's how ordinary explanation works. That's not how the second law works.

Laurence Viennot put it this way: a law relating simultaneous quantities is a law, not a story. Students want a story. When the story doesn't match the physics, they don't drop the story. They modify the physics.

What's happening in their heads

A ball thrown upward. The student's version: the thrower gave the ball force. The ball carries this force upward. The force runs out. The ball falls.

Physically wrong. Force isn't something you give to an object. Objects don't carry force. Force doesn't get used up. At the top of the trajectory, gravity is still acting — the force is not zero.

But the reasoning is psychologically coherent. Listen to the language students use, across cohorts:

- "The force of the thrower's movement is still at work at the top."
- "The mass has a force."
- "A supply of upward force."
- "The force the fellow gave it."

Three things are happening at once.

One. Force is being treated as something the object has. In physics, force describes an interaction between two objects — force of A on B. The student says "the force of the mass," as if force were an intrinsic property of the object. Once force is something an object possesses, it can be stored, carried, used up.

Two. Quantities that belong to the present are being pulled in from the past. The thrower released the ball seconds ago. But "the force of the thrower" is invoked at the peak. The student takes a past event and installs it in a present explanation.

Three. The boundaries between distinct quantities collapse. Students use "force," "energy," "velocity," "inertia," and "impetus" almost interchangeably. Sometimes they draw diagrams adding a force vector to a velocity vector. That violates dimensional homogeneity. Within the student's framework, these aren't separate things. They're all versions of one idea: the object's capacity to keep doing what it's doing.

Viennot calls this "dynamism" — not because students have a clean rival theory by that name, but because they keep reaching for the same vague causal resource whenever motion needs explaining.

The error is selective

If force–velocity confusion were just ignorance, it would show up uniformly across problems. It doesn't.

Viennot found that the error spikes under two specific conditions. First, the motion must be vivid — easy to picture. Second, the motion must appear incompatible with the known forces.

The pendulum makes this clear. Same device, same two forces — weight and string tension. Two situations show the contrast sharpest.

Mass at the top of a full circular loop — weight and tension both point downward, but the object continues through the loop. Highest error rate. Two forces pull down, nothing visible pushes up, and the object does not drop straight down. Students invent what they need: a centrifugal force outward, or a tension that has reversed direction. They construct forces on the spot to make sense of the situation on their terms.

Mass at the highest point of a simple swing — momentarily at rest, with a nonzero resultant force. Lowest error rate. Zero velocity with nonzero force should be just as troubling. It isn't, because common reasoning tolerates a slight delay between cause and effect. The force is there; it will produce motion soon.

What common reasoning can't tolerate is sustained motion with no visible cause.

This selectivity matters. The errors aren't failures of memory. They're products of a reasoning system that deploys its resources — invented forces, stored dynamism, imported past causes — wherever the physics feels causally inadequate.

Same logic in waves

If this pattern were confined to thrown balls and pendulums, you could treat it as a narrow mechanics problem. It isn't.

Ask students whether the speed of a bump on an idealised rope depends on how hard you flick the rope. Many say yes — harder flick, more force in the bump, faster motion. Ask if a bigger bump overtakes a smaller one. Many say yes — it "has more force." Ask what happens as the bump flattens. They say: "It has less and less force, so it moves more and more slowly... because of friction."

The student has invented an object. A bump on a rope isn't a material body — it's a propagating disturbance. But common reasoning needs an object to carry force, so the bump becomes one. It gets loaded with stored dynamism from the initial cause. Then it wears out.

The narrative is identical to the thrown ball.

Sound does the same thing. Students predict that a louder shout makes sound travel faster — the sound "will have more force." Some think sound can propagate in a vacuum — with nothing in the way, why would it stop?

Teaching implication: it's not enough to state the rule "for this idealised rope, pulse speed is set by tension and linear mass density, not by how hard you flick it." Students can recite that and still hold the underlying intuition. The rule has to be set explicitly against the intuition it overrides: "The speed of the bump does not depend on the initial hand motion — in this idealised linear case — and that is the surprising part. Here's why."

Why the Third Law is hard

Once force has been attributed to objects and explanation organised around stories of stored cause, Newton's Third Law becomes structurally difficult to accept.

A stronger student and a weaker student push against each other on low-friction carts. Common sense says the stronger student exerts the larger force. Newton says the force of A on B and the force of B on A are equal in magnitude and opposite in direction. If their accelerations differ, the difference comes from differences in mass or other external forces — not from an unequal interaction pair.

If each person "has a force" — their own dynamism, proportional to strength — equal forces are absurd. The stronger one must push harder. That's what "stronger" means.

This isn't just intuition resistance. It's structural. If force belongs to objects, the Third Law makes no sense. Force-as-interaction is the only framework where equal-and-opposite reciprocal forces are even coherent. But force-as-interaction requires abandoning the causal architecture that makes mechanics feel intuitive.

Two things get conflated, and separating them is half the battle:

- Forces acting on a single object, which sum to determine its acceleration.
- The pair of forces in a single interaction, which act on two different objects and are always equal and opposite.

These are different operations. Students collapse them into one. Standard force diagrams often let them.

Viennot's fix: fragmented diagrams. Draw interacting objects separated, even when they're in contact. For each interaction, one arrow on each object — same colour, same length, opposite directions. Then separately, draw the force balance on each object by summing all its interactions. The procedure makes the confusion much harder to sustain.

Situations involving acceleration are better for teaching this than equilibrium situations. In a book-on-table diagram, the weight on the book and the normal force on the book are equal in magnitude — so students may call them an action-reaction pair, even though both act on the same object. Acceleration cases break that ambiguity.

For this specific distinction, forces at a distance are easier than contact forces. When there's no contact, you're forced to decide which object each force acts on. Contact creates an ambiguity that distance eliminates.

The spring problem

A problem in Viennot's appendices puts the whole argument in one place.

A mass sits on a spring — not attached, just resting. You push the mass down, compressing the spring, and release. How far down must you push for the mass to fly off the spring?

Students say: the spring force at maximum compression must exceed the weight.

At the instant the mass lifts off, the spring is at its natural length. The spring force is zero. The only force acting is gravity, pointing down. The mass rises with no upward force on it. The initial compression must be large enough that the mass still has upward kinetic energy when the spring reaches its natural length. The spring force at maximum compression merely exceeding the weight isn't enough.

Students can't accept this. They reach into the past. They compare the spring force from a moment ago with the weight from right now — as if Newton's law allowed a cross-temporal balance. When the comparison doesn't work, some conclude "the law of action and reaction no longer applies."

The student's reasoning demands a presently available cause whenever the visible motion seems otherwise unexplained. When physics says the explanation lies in the object's state at that instant — not in a still-acting cause imported from the past — the student's framework breaks. Rather than accept that, they import a cause from the past, violate the time structure of the law, and when the analysis fails, they throw out the Third Law.

The thesis in one problem.

What to do about it

The point is not to collect errors. The point is to see the system behind them.

Students arrive with a coherent way of making motion intelligible — one that extends across dynamics, wave propagation, support forces, and interaction analysis — and stating the right formulas doesn't take it apart. The system has its own logic. Objects possess dynamism. Dynamism explains motion. It comes from past causes. It dissipates over time. This logic works for much of everyday experience. People do get tired. Batteries do run out. Cars do slow down when you stop pressing the accelerator.

Newtonian physics works differently. Force is an interaction, not a possession. Laws relate simultaneous quantities, not sequential causes and effects. The past matters only insofar as it has brought the system to its present state.

Viennot's pedagogical principle is simple to state and hard to execute: whenever a correct result contradicts what natural reasoning expects, say so explicitly. Don't state the rule and assume the student sees why it's surprising. Name the surprise.

- "The speed of the bump does not depend on the initial hand motion — and that is strange."
- "On the way up, after release, the only force on the ball is gravity — even though the ball is still moving upward."
- "The force the hammer exerts on the nail equals the force the nail exerts on the hammer — even though the nail goes in."

This requires the teacher to understand, at every point, what the student's alternative reasoning predicts. A teacher who doesn't understand the student's reasoning can't make the conflict visible. A conflict that isn't visible won't be resolved.

This article draws on Laurence Viennot, Reasoning in Physics: The Part of Common Sense (Kluwer, 2001), especially Chapter 4, "The essential: laws for quantities at time t," and on Viennot's and Laurence Maurines' earlier studies of spontaneous reasoning in dynamics and wave propagation.