Breaking a rod: combining impulse and inertia

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Abstract Teaching through discrepant event activities increases student interest in science. In this article, I will introduce a well-known 19th century demonstration, the Tissandier experiment, to stimulate curiosity among students learning the concept of inertia. In this demonstration, a hard object (e.g. a wooden rod) placed on fragile supports is broken into two halves with a hammer. Curiously, the supports stay intact provided the strike was swift enough. The factors involved here are: short impact time, huge peak force and the inertia of the rod.

Newton's first law of motion, also known as the law of inertia, states that an object at rest remains at rest, and an object in motion will continue in motion with a constant velocity (i.e. constant speed in a straight line), unless it experiences a net external force. Striking demonstrations of this law include pulling a tablecloth from under cups of water and pulling a thread attached to the bottom of a mass hanging on an identical thread, such that the upper thread snaps and the lower thread remains intact. I often use these demonstrations before I start teaching Newton's first law to high school students and at in-service teacher-training courses. In addition, I generally utilise the 'wait time' (Ingram and Elliott, 2015), and 'think-pair-share' (Lyman, 1987) instructional techniques together to (a) increase the effectiveness of the demonstration, (b) increase students' understanding, (c) make students more confident in their responses, (d) make students give more extended answers and (e) engage students in discussion.

Breaking a rod demonstration

For this demonstration, I put two identical drinking glasses full of water or juice on two tables of the same height, separated by a distance of about 1 metre. Then, I place a hard wooden rod (like a metre ruler) on top of these glasses so that the glasses support the rod at its ends. For more dramatic effect, I also insert a needle into each end of the rod and place it on the glasses so that it is only supported by the needles (Figure 1). The required materials are often supplied by the students if you explain to them what you are going to do. The rod is then broken by a strong swift blow from, for example, a hammer or a sturdy stick, while the glasses remain intact (watch a video at: www.youtube.com/watch?v=AV5mGKZQlw4).

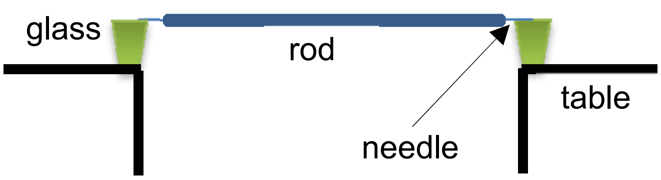

Figure 1 Breaking the rod setup

Alternatively, the rod may be suspended on two light threads, or it may even be rested on something like tomatoes or eggs. In these settings, if an optimum striking speed is achieved, the threads will not break, and the tomatoes and the eggs will stay intact (Featonby, 2014).

Before the demonstration, I first pose the following question: '*If I strike the middle of the rod strongly, what will be the expected result?*' I give students a minute or so of thinking time to process the question and produce a response. If any response arises during the 'waiting time', I ignore it. Then, I get several students to disclose their answers. At this stage, I only listen to the answers and do not make any comments. The most usual answer coming from the students is that the glasses will topple over. Then, I ask students to discuss their conclusions with their neighbours. This helps students to express their thoughts and discuss them in a supportive environment. Finally, I ask several student groups to explain their thoughts again. The answer usually remains the same, and the students insist that the glasses will fall down.

At the second stage, I perform the demonstration. For safety reasons, students watch it from about 4 metres away from the setup. With a 'Ninja-style' blow, I strike the rod in the middle with a wooden or iron bar. As described above, the rod (which is approximately 15 mm thick) breaks into several pieces while the glasses remain unmoved. After such an unexpected outcome, the students first stay silent for a moment trying to grasp what they just saw as they realise that their prediction was wrong.

Next, I ask students to try to explain why the glasses didn't fall down or break. I again want the students first to think for themselves and then argue about it with their friends. I collect the answers, do not comment, and accept all the inferences with as little facial expression or body language as possible. The amazing phenomenon usually puzzles the students hopelessly and they are not able to offer any explanation.

At the last stage, I explain the phenomenon as follows: All objects have inertia, the degree of which is directly proportional to the object's mass. The result of inertia is that when you just push the object it takes some time for it to start moving, even if you push it very hard. So, if you push too much, it might even break apart before it starts moving. And this is true even for a free-standing body. The students can immediately relate to this if you ask them if they could slash a watermelon in half with a katana (Japanese sword) in air, or in a space station in a state of weightlessness. Once they understand this, they are able to generalise this with the wooden rod, and they eventually realise that as long as the mass of the rod is large enough, and you hit it quickly enough, you don't in fact need any supports to break the rod. No wonder the glasses didn't fall over!

If, on the other hand, you hit the rod (or the watermelon) slowly enough, it has time to accelerate and just follow the hammer without breaking apart. And if it finds some obstacle on the way, it will naturally bump into it. That's why if you hit the rod slowly, the glasses of water will overturn. I demonstrate this too by conducting the experiment in 'slow motion': I substitute plastic cups for the glasses and hit the rod very slowly. The cups fall over, and the common expectation is restored.

Safety and care

Despite the intended and expected outcome, this activity does have risks due to other possible outcomes. The rod might not break if the wood is not of a suitable quality. It might be necessary to try several samples of wood before consistent success is achieved. One or both glasses might shatter. The needles could bend or break. If the wood does break, splinters might fly off. The person hitting the rod should wear safety glasses, and observers should not be closer than 4 metres.

Conclusion

This counter-intuitive demonstration (Balta, 2012) with simple materials is strikingly impressive in two aspects. First, it reveals the very essence of the concept of inertia (Balta and Eryılmaz, 2017). More specifically, it demonstrates 'the tendency of a body to stay at rest' – the resistance of the rod against the action is only limited by its breaking threshold (Mamola and Pollock, 1993). Second, it goes beyond the regular inertia demonstrations and implies that inertia is also proportional to the impulse that the object receives. With this demonstration in mind, the students can therefore understand inertia in some cases as the ability of a body to show 'hard reaction against a hard action'.

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