Newton's Third Law: A Verification with Buoyancy Forces

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As presented at SEPS AAPT April 2013 Drexel University

Newton's third law is the "law of interaction." For every force that acts on one object, there is an equal force (equal in size, opposite in direction) that acts on a second object. Thus, this law is often called the "Law of Action and Reaction."

This law will be tested using buoyancy forces.
A large can of soup has an overall density a bit greater than water. When the can is lowered into a big beaker of water, the can will sink. But as it sinks, the can has an upward (buoyant) force acting on it from the water it displaces. The pressure on the bottom of the can from the water pushing the CAN upwards is greater than the pressure on the top of the CAN from the water, pushing the can downwards. The bottom of the can is at a greater depth in the fluid (the water) and pressure in a fluid increases with depth. Thus, there is an upward buoyant force acting on the CAN by the WATER. The CAN still sinks because the buoyant force is not greater than the weight of the can—but it is close.

From the point of view of the water in the beaker, what is happening? If the water exerts an upwards force on the CAN, then does the CAN exert an equal and opposite DOWNWARD force on the water and beaker (Newton's third law)? If so, then the water (and the beaker) should "weigh more" as the CAN is lowered into the water. In fact, if the CAN loses X newtons of weight due to the buoyancy of the water, then the BEAKER of WATER should GAIN X newtons of force. We will test this idea using two force sensors, a CAN, a large BEAKER and some water.

APPARATUS NEEDED

A Vernier Dual-Range Force Sensor (0–50 N) is used to "weigh" a can when suspended in air and when lowered into water. For the moment, ignore the buoyancy effect of the air, since it is so small. The CAN is attached to the Dual-Range Force Sensor by some string. A Vernier Force Plate (0-850 N) is used to measure the weight of a large beaker filled partially with water.

PROCEDURE

1. Record the weight of the CAN (in newtons) both before and after lowering it into the large beaker of water. Measure the apparent CHANGE in the can's weight due to the buoyancy of the water.

2. Also record the weight of the BEAKER of WATER before and after lowering the can into the water. Measure the apparent CHANGE in weight of the beaker of water due to the buoyant effect of the water on the can.

3. Start data collection. Data will be collected for 10 seconds at 50 samples per second. If the CAN loses a weight, X newtons, and if the BEAKER of water gains the same weight, X newtons, then it looks like Newton's third law holds.

   Or, if we ADD the two force sensor readings, both before and after lowering the can into the water, the TOTAL force should remain constant.

RESULTS

Here is the evidence, recorded on 4/23/2013 by the two Vernier force sensors. The CAN has a weight of 9.9 N when in air and 0.9 N when it is submerged completely under water (but not touching the sides or bottom of the beaker). Thus, the CAN "lost" 9.0 N of weight when lowered completely under water. Our margin of error is about 0.1 N.

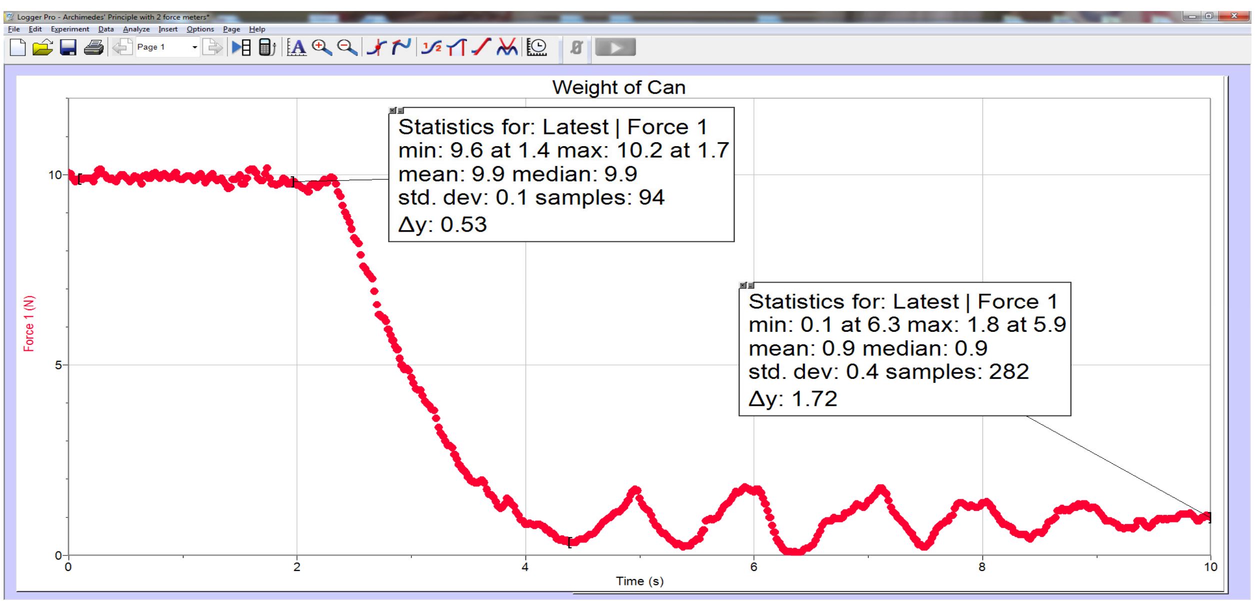
The BEAKER and WATER has a weight of 31.9 N at first, and then, when the can is submerged under the water, the BEAKER and WATER has a weight of 40.8 N. Thus the BEAKER of WATER "gained" 8.9 N of apparent additional weight.

A graph of the SUM of the force readings from both sensors is a constant (horizontal) line.

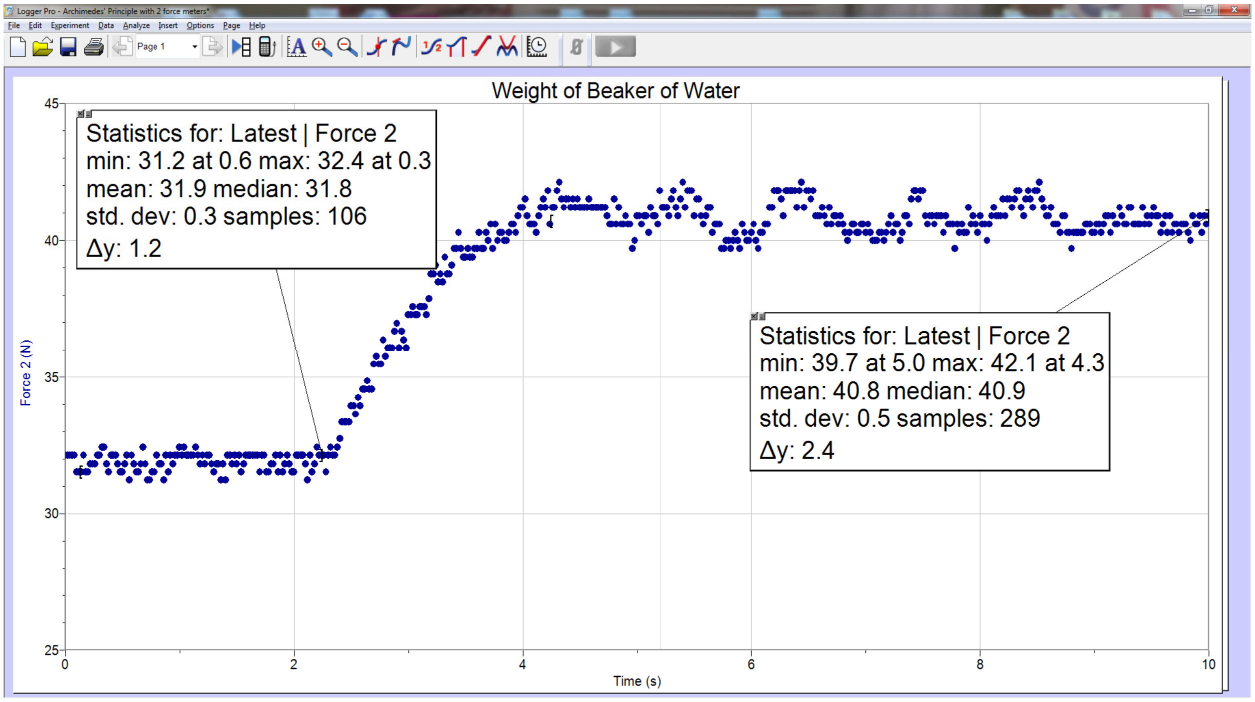
Conclusion: the CAN lost 9.0 N of weight and the BEAKER gained 8.9 N of weight… +/- 0.1 N … pretty close to equal changes in weight.

Newton's third law seems to be valid in our demo.

Here is the graph for the CAN as it is lowered into the water around $t = 2$ seconds.



Here is the graph for the BEAKER of WATER as the can is lowered into the water at a time $t = 2$ seconds.



Here is a graph of the SUM of the two force sensors.