Experimentally Examining Newton's Third Law of Motion

by Kevin P. Siu, Engineering Science, University of Toronto
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Lab Section: ESC101 - P0108
TA: Michael Rogers

Abstract

The lab described as follows examines one of the fundamental laws of motion, that is, Newton's Third Law of Motion. By measuring the forces acting on two masses during a collision, it was determined that equal forces were indeed applied to both objects in opposite directions, verifying Newton's Law.

Introduction

Newton's Third Law of Motion states, *for every action there is an equal and opposite reaction*. This oft-quoted law is better explained in terms of forces – essentially, the law says that for every force applied, there is an reaction force in equal magnitude but in the opposite direction of the applied force[1]. The goal of this experiment is to verify Newton's Law. In particular, the forces applied by two colliding objects onto each other will be measured and analysed to confirm the law.

Experimental Method

To measure forces, an electronic force sensor was attached to the front of two toy trucks, such that they make contact with each other, acting as 'bumpers' during the collision of the two trucks. Masses were loaded and unloaded onto the trucks as necessary to vary the mass of the two sides of collision. A diagram of the experimental apparatus is shown in Fig. 1.

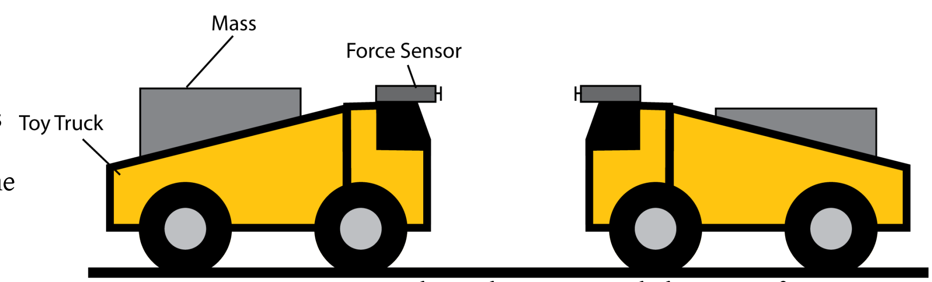

Fig. 1: Apparatus - two toy trucks with masses and electronic force sensors

In two trials, the trucks were given an initial push by hand, and the trucks rolled towards each other until they collided and bounced back. The two trials differed in the masses of the trucks – in the first trial, the two trucks were of roughly equal mass, while in the second trial, the trucks were of unequal masses. In a third trial, one of the trucks was pushed against a heavier truck with a near-constant acceleration to test if the forces would still be equal in an accelerated reference frame. The data was collected by a computer, and analysed graphically using DataStudio software.

Results

The main data that this experiment was concerned with was the force applied on each object over the time of contact. The collected data was graphically analysed using DataStudio. A graph of the force applied to each force sensor over time is displayed in Fig. 2. It was noted that the shape of the graphs for both sensors in any given run were almost identical, with a slight difference in the magnitude of forces. To see whether this difference was systematic and significant, a graph of the difference in forces over a single trial was created. The data is displayed in histogram form in Fig. 3. The differences of the forces experienced by the two sensors were very close to zero, in fact, had a mean of 0.050 N with a standard deviation of 0.967. The distribution is approximately Gaussian, centred at a slightly negative value. Similar results were obtained for both constant velocity collision and accelerated 'pushing' of the trucks.

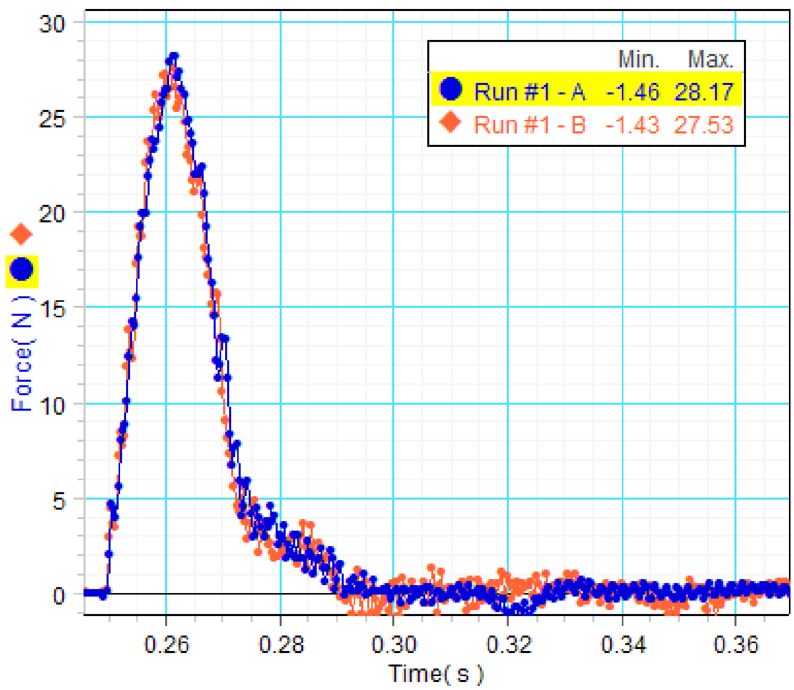

Fig. 2: Force vs. Time Graph, Run #1 (Equal Masses)

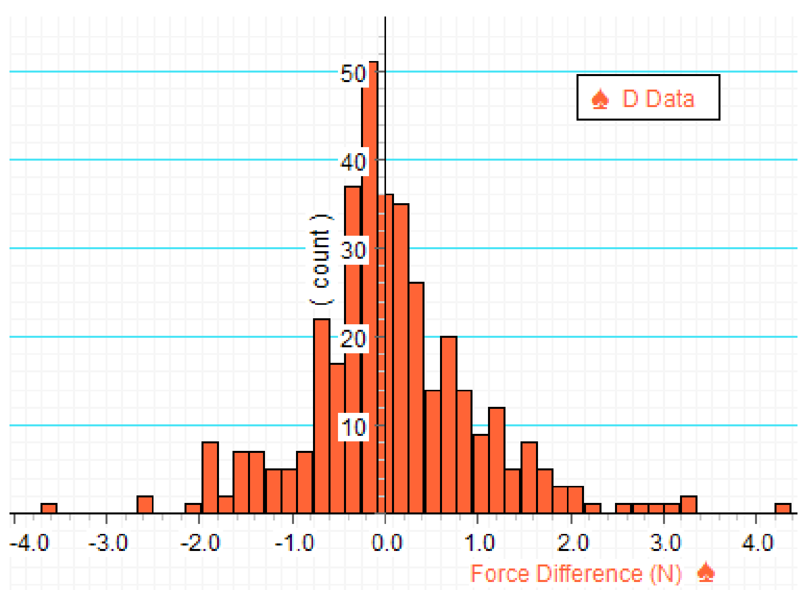

Fig. 3: Force difference in sensors A and B, run #1

Theoretically, the force difference value should be zero, but due to several experimental errors, the data collected did not match the theory perfectly. First, the two electronic force sensors that were used did not agree on a value of zero. Even after calibration with the tare button on the sensors, both sensors measured a small positive force while they were at rest. The difference in the 'zeroes' of the sensors had a value of approximately -0.080 N. This negative value indeed accounted for the non-zero value found in the force differences. A more empirical, though less systematic error comes from the actual collision of the toy trucks used in this experiment. It was observed, particularly in the second trial with unequal masses, that the trucks bounced vertically from the table at the moment of impact. This upwards motion caused the force sensors to fall out of alignment, as one sensor was effectively pushing on the bottom half of the other sensor. In addition, the collision was not perfectly 1-dimensional as would have been ideal for this experiment – instead, there was a slight horizontal component which may have caused some discrepancies in the measurement.

Conclusion

It was found in the preceding experiment that in three trials over several runs, the forces applied to both trucks at any given time were equal, whether the masses of the trucks were equal or not. This result applies to an inertial frame with the trucks moving at constant speed, and also in non-inertial accelerated frames. This essentially supports Newton's Third Law of Motion, stating that all forces applied will have an equal reaction force.

References

1. Serway, Raymond A. and John W. Jewett, Jr. *Physics for Scientists and Engineers*. Toronto: Nelson Thomson Learning, 2004.