# Lab Experiment: Collisions

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**Introduction:**

Physics is governed by laws not only of motion, but of conservation of certain values. One value which is always conserved is momentum, which is equal to the product of an object's mass and its velocity. When dealing with an isolated system, the law of conservation of momentum states that the total momentum of the system will remain constant; the individual momenta of colliding objects may vary, but the vector sum of the momenta remains the same. In this experiment, we used collisions of gliders on an air track to demonstrate this conservation law. By using photogates, we measured the velocities of the carts and applied the uncertainties in the values.

**Procedure:**

To set up this experiment, we placed two gliders on the air track, and positioned the photogates so that they were a few glider lengths apart. We connected the photogates to a computer and prepared to use the LoggerPro program to collect our data. For the first condition, we had both gliders be of approximately equal mass (one was initially more massive than the other, so we hooked additional masses to the lighter glider to equal it out). We set one of the gliders so it sat motionless directly in front of the gate closer to the middle of the track, and started the other glider at the end of the track, behind the first gate. Once the air blower was turned on, we clicked "Collect" on LoggerPro, and then slid the second glider toward the stationary glider. LoggerPro recorded the amount of time for which the flag on each glider was under each photogate. We repeated this procedure for two more trials, propelling the glider with two different speeds.

For the second condition, we approximately doubled the mass of one of the gliders by attaching additional masses to it. We used the less massive glider as the initially moving object. In the same manner as before, we slid this glider toward the stationary glider in three different trials, with three varying speeds, gathering the times for which the gliders' flags were underneath the photogates. In the final stage of the experiment, we switched the two gliders, propelling the more massive one toward the lighter one.

To find the momenta of the gliders, we needed the masses and velocities. To find the initial and final velocities, we measured the length of the gliders' flags, and divided this by the times recorded by LoggerPro. We simply used a scale to find the masses. By multiplying the mass by velocity for all of our conditions and trials, we calculated the momentum before and after each collision.

**Data:**

$m_{glider1} = (327.4 \pm 0.05)$ g $m_{glider2} = (328.0 \pm 0.05)$ g

Gate Time = how long the glider's flag is under the photogate. Gate 1 is the first gate reached by the first moving glider, and Gate 2 is closer to the center of the track.

**Gate times for first condition:**

| Gate Time 1 (s) | Gate Time 2 (s) |
|---|---|
| 0.295 | 0.307 |
| 0.160 | 0.166 |
| 0.133 | 0.139 |

**Gate times for second condition (Gate Time 3 = when the lighter glider rebounds past Gate 1):**

| **Gate Time 1 (s)** | **Gate Time 2 (s)** | **Gate Time 3 (s)** |
|---|---|---|
| 0.191 | 0.410 | 1.434 |
| 0.120 | 0.206 | 0.467 |
| 0.108 | 0.184 | 0.448 |

**Gate times for third condition (Gate Time 3 = when the more massive glider passes under Gate 2):**

| **Gate Time 1 (s)** | **Gate Time 2 (s)** | **Gate Time 3 (s)** |
|---|---|---|
| 0.068 | 0.057 | 0.265 |
| 0.071 | 0.058 | 0.324 |
| 0.083 | 0.068 | 0.455 |

Once we measured these times, we divided the "distance traveled" in that time (distance = length of flag = (10 ± 0.05) cm) by the time interval to get the velocities of the gliders. In each case, velocity 1 is the initial velocity of the first glider, and velocity 2 is the velocity of the second glider after the collision. In the second and third conditions, velocity 3 is the final velocity of the first glider, measured at Gate 1 in condition 2 and Gate 2 in condition 3.

Sample calculation: V1 = d/t = (10 ± 0.05 cm) / (.295 s) = (33.9 ± 0.17) cm/s

**Velocities for first condition:**

| V1 (cm/s) | V2 (cm/s) |
|---|---|
| 33.9 ± 0.17 | 32.57 ± 0.16 |
| 62.5 ± 0.33 | 60.24 ± 0.32 |
| 75.19 ± 0.38 | 71.94 ± 0.35 |

**Velocities for second condition:**

| V1 (cm/s) | V2 (cm/s) | V3 (cm/s) |
|---|---|---|
| 52.36 ± 0.26 | 24.39 ± 0.12 | -6.97 ± 0.04 |
| 83.33 ± 0.41 | 48.54 ± 0.24 | -21.41 ± 0.11 |
| 92.59 ± 0.46 | 54.35 ± 0.27 | -22.32 ± 0.12 |

**Velocities for third condition:**

| V1 (cm/s) | V2 (cm/s) | V3 (cm/s) |
|---|---|---|
| 147.06 ± 0.74 | 175.44 ± 0.91 | 37.74 ± 0.19 |
| 140.85 ± 0.75 | 172.41 ± 0.94 | 30.86 ± 0.15 |
| 120.48 ± 0.63 | 147.06 ± 0.80 | 21.98 ± 0.11 |

Finally, to find the momenta, we multiplied the masses of the gliders by the velocities. The final momentum in each case was found by adding P2 and P3, the final momenta of the second and first gliders, respectively.

Sample calculation: $p = mv = (328.0 \pm 0.05\ g)(33.9 \pm 0.17\ cm/s) = 11{,}119 \pm 0.57\ g*cm/s$

**Momenta for first condition:**

| P1 (g*cm/s) | P2 (g*cm/s) |
|---|---|
| 11,119 ± 57 | 10,663 ± 53 |
| 20,500 ± 57 | 19,720 ± 110 |
| 24,660 ± 13 | 23,550 ± 110 |

**Momenta for second condition:**

| P1 (g*cm/s) | P2 (g*cm/s) | P3 (g*cm/s) | $P_{final}$ (P2+P3) |
|---|---|---|---|
| 15,961 ± 77 | 17,174 ± 85 | -2,287 ± 12 | 14,887 ± 85 |
| 31,760 ± 170 | 27,330 ± 130 | -7,022 ± 37 | 20,308 ± 130 |
| 35,570 ± 180 | 30,370 ± 150 | -7,321 ± 39 | 23,049 ± 180 |

**Momenta for third condition:**

| P1 (g*cm/s) | P2 (g*cm/s) | P3 (g*cm/s) | $P_{final}$ (P2+P3) |
|---|---|---|---|
| 96,240 ± 480 | 24,700 ± 120 | 57,540 ± 290 | 82,240 ± 290 |
| 92,170 ± 500 | 20,140 ± 100 | 56,550 ± 320 | 76,690 ± 320 |
| 78,840 ± 400 | 14,384 ± 72 | 48,240 ± 270 | 62,624 ± 270 |

As seen in the momentum data tables, the calculated final momentum in each case was less than the calculated initial momentum (p1) of the first glider. P1 and $P_{final}$ are the two quantities to compare when analyzing conservation of momentum.

**Results/Discussion:**

For the first condition (roughly equal masses), the momentum after the collision was approximately equal to, but appeared a little less than, the momentum before the collision. Our results showed that the velocity of the second glider after the collision was slightly less than that of the first glider before the collision. Ideally, in an elastic collision of two equal-mass objects, one initially stationary, all momentum is transferred from the first object to the second, sending the second at the same velocity at which the first was moving, and leaving the first stationary. However, the collisions in our experiment were not perfectly elastic. Therefore, the second glider only gained most of the initial momentum and moved at a slightly slower speed than the first glider did initially, while external effects absorbed some of the energy from the collision. Since the collisions were not perfectly elastic, some mechanical energy was likely lost in the collision (transferred into other forms of energy such as heat). Plus, the track was not perfectly frictionless, so that definitely would serve to slow down the gliders.

In the second condition, in which we propelled a lighter glider toward one twice as massive, our results varied more from prediction. The first trial was somewhat close (an apparent loss of 1074 $g*m/s^2$), but in the second and third trials we had final momenta appearing to be 11,452 to 12,521 $g*m/s^2$ less than the initial momenta (an error of about 35%). This could possibly be attributed to the fact that one of the gliders was twice as massive as before, which might have produced more friction with the track, which continued to be a factor. Also, in this case we were measuring the final velocities of two gliders rather than just one, so the observed effects of lost energy might have been compounded. We had similar results in the third condition, when the more massive glider had the initial motion and both gliders continued in the direction of the original motion following the collision.

While the numbers do not exactly add up, our experiments seem to have conceptually supported conservation of momentum. The final momentum was never measured to be greater than the initial momentum, and was usually at least in the expected ballpark. If the final momentum had been greater, this would have called into question the conservation of momentum, but a lower final momentum makes perfect sense when considering what all is occurring. Thus, when we include factors which produced error, this experiment achieved what we set out to accomplish, demonstrating as best as we could that momentum in an isolated system is conserved.

**Conclusion:**

By performing this experiment, we learned that the law of conservation of momentum can indeed be demonstrated, but because the experiment materials are limiting factors, the final momentum will be shown to be slightly less than the initial momentum. This is true for most Newtonian mechanics; it is difficult to produce a situation which fits the exact calculated predictions because of the influence of outside forces such as friction and air resistance. In an experiment such as the one we conducted, when both objects have the same mass, all the velocity is transferred to the stationary object. When a lighter object is given the initial velocity, it will rebound upon colliding, sending both objects in different direction. Finally, if the more massive object has the initial velocity, both objects will continue in the direction of this velocity following the collision. In order to get results which fit more with calculated predictions, one would have to somehow reduce friction even further, and also probably reduce the collision time. It is near impossible to get experimental results to exactly equal predictions, but through experiments such as these, one can definitely observe the patterns of mechanics and conservation.