**Momentum and Energy in Collisions**

**ABSTRACT:** This experiment studied the change of momentum and energy in collisions by measuring the velocities of gliders with different weights before and after they collide on an air track. The change in velocity for each glider is then used to investigate the change in momentum and the kinetic energy. It was validated that the linear momentum is always conserved, whereas the kinetic energy is conserved only in elastic collision.

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**INTRODUCTION**: In classical mechanics, the momentum is the product of the mass and velocity of an object. Momentum, or linear momentum in this experiment, is a vector quantity. It has a direction and a magnitude.

The total momentum in an isolated system is always conserved when there is no external force. In other words, in a system with more than one particle the total momentum will always be conserved regardless of collision type.

Pf = Pi

M1v1’ + M2v2’ = M1v1 + M2v2 (elastic collision)

M1v1 + M2v2 = (M1+M2) vfinal

The kinetic energy is defined as the energy of motion. Any object in motion has some amount of kinetic energy due to its velocity and mass.

KE = ½ \* m \* v^2

This energy, unless acted upon by an external force, is conserved or stored in another type of energy. In elastic collisions the kinetic energy is conserved but not in inelastic collisions. In this experiment the two gliders on a level air track, which has almost no surface friction, collide elastically and inelastically and these quantities are investigated respectively.

**PROCEDURE**: The air source is turned on and the air track is adjusted so that the track made no angle with respect to horizontal surface. By doing this, it is verified that the glider motion is only in one dimension. Next, the equipment is connected and photogates are located at position 1/3 and 2/3 from one end of the track. The ULI transformer is turned on.

Each glider, including the flag, is weighted and recorded. Also the length of the flag is measured. Some practice collisions are performed. The range 0.05 m/s and 0.5 m/s should be carefully followed in order to avoid any experimental errors. At speeds much slower than this, the slight unlevelness of the track makes a contribution, while at much faster speeds the colliders may jump during collision.

For the first elastic collision two red gliders are used. The bumpers without Velcro are used in order to achieve an elastic collision. That way, the gliders are not stuck after collision. From the end of the air track, one glider is launched. The velocity and time intervals during which the photogates are blocked are recorded through LoggerPro. After each glider passes through one photogate, the trial is over.

Second collision is performed much like the collision one, but this time with different gliders. One blue and other( target ) is red. This time, the launched glider does not stop after collision, so we waited until the blue glider also passes through second photogate.

Collision three is performed with Velcro strips and red/blue gliders. This collision should be carried out as in first collision type. Each collision type should be demonstrated five times to collect data. The data is then transferred to Excel. Using the length of the flag and times, the velocities are determined. All this information is then used to calculate the total momentum and kinetic energy before and after collision. The following tables are prepared.

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| --- | --- | --- | --- | --- | --- | --- |
| COLLISION#1 - ELASTIC | | | | | | |
| trial | **before** | | **after** | | change | |
| # | P (kg\*m/s) | KE (J) | P (kg\*m/s) | KE (J) | pf-pi (kg\*m/s) | Kef - Kei (j) |
| 1 | 0,042663674 | 0,002694182 | 0,039309766 | 0,002287238 | -0,003353907 | -0,000406944 |
| 2 | 0,050826529 | 0,003823766 | 0,048162816 | 0,003433477 | -0,002663713 | -0,000390289 |
| 3 | 0,074896361 | 0,008302938 | 0,071135874 | 0,007490102 | -0,003760487 | -0,000812836 |
| 4 | 0,106592313 | 0,016817527 | 0,101501337 | 0,01524944 | -0,005090976 | -0,001568087 |
| 5 | 0,059549821 | 0,005248936 | 0,056483302 | 0,004722267 | -0,003066519 | -0,000526669 |

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| --- | --- | --- | --- | --- | --- | --- |
| COLLISION#2 - ELASTIC WITH RED & BLUE GLIDERS | | | | | | |
| trial | **before** | | **after** | | change | |
| # | P (kg\*m/s) | KE (J) | P (kg\*m/s) | KE (J) | pf-pi (kg\*m/s) | Kef - Kei (j) |
| 1 | 0,220770257 | 0,050506214 | 0,202926373 | 0,046685248 | -0,017843884 | -0,003820966 |
| 2 | 0,201533015 | 0,042087787 | 0,182200629 | 0,038570684 | -0,019332385 | -0,003517103 |
| 3 | 0,311342671 | 0,100447927 | 0,294585867 | 0,093410542 | -0,016756804 | -0,007037385 |
| 4 | 0,309359596 | 0,099172411 | 0,292674225 | 0,093230541 | -0,016685371 | -0,005941869 |
| 5 | 0,411605564 | 0,175560238 | 0,393039513 | 0,165414504 | -0,018566052 | -0,010145734 |

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| COLLISION#3 - INELASTIC WITH RED & BLUE GLIDERS | | | | | | |
| trial | **before** | | **after** | | change | |
| # | P (kg\*m/s) | KE (J) | P (kg\*m/s) | KE (J) | pf-pi (kg\*m/s) | Kef - Kei (j) |
| 1 | 0,09504786 | 0,009361563 | 0,088883105 | 0,004815379 | -0,006164755 | -0,004546185 |
| 2 | 0,148530448 | 0,022860971 | 0,145630343 | 0,01292694 | -0,002900105 | -0,00993403 |
| 3 | 0,174084074 | 0,031403769 | 0,169902067 | 0,017595002 | -0,004182007 | -0,013808766 |
| 4 | 0,287393234 | 0,085588766 | 0,278960826 | 0,047432765 | -0,008432408 | -0,038156001 |
| 5 | 0,19905515 | 0,041059204 | 0,194746237 | 0,02311693 | -0,004308913 | -0,017942274 |

**RESULTS AND ANALYSIS:**

For the previous tables, the following calculations are made:

x(length of the flag) = v \* t (time during which the photogate is blocked)

The equation should be solved for v.

Since only the launched glider has velocity at first, the total momentum and total kinetic energy before collision is equal to:

Ptot: m (launched glider) \* v

KE (before) = ½ \* m (launched glider ) \* v^2

After collision 1# and 2#, since they are elastic, the total momentum is calculated by taking each glider into account separately:

Ptot: m(launched glider) \* v1’ + m(target) \* v2’

KE: ½ m(launched glider) \* v1’^2 + ½ m (target) \* v2’^2

After collision #3, however the gliders stick together so the total momentum after collision is:

Ptot: (m(launched) + m (target)) \* (v)

The difference between initial and final momenta and energies are then calculated by substracting the respective values and tabulated accordingly.

After these tables, the percent change in momentum and the percent change in kinetic energy across each of fifteen trail runs are calculated. The date is compared with the class pool together. Theoretically, the percent changes in momenta in all collisions must have been 0. And the percent changes in kinetic energies in the first two collisions must also have been 0. In first collision, when compared with class using class-wide statistical analysis, our total momenta and KE change are close enough to zero. In the second collision, the total momenta change is a bit off the class average, although total KE is close enough zero. In the third collision, the total momenta change is almost zero, whereas there is a significant change in total KE, which is parallel to the class-wide statistics.

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| --- | --- | --- | --- |
| EXPERIMENT 1 |  |  |  |
| Elastic Collision | 100% x (Pf-Pi)/Pi | Elastic Collision | 100% x (Kf-Ki)/Ki |
| Run # | % Difference Momentum | Run # | % Difference Kinetic |
| 1 | -7,86 | 1 | -15,1 |
| 2 | -5,24 | 2 | -10,21 |
| 3 | -5,02 | 3 | -9,79 |
| 4 | -4,78 | 4 | -9,32 |
| 5 | -5,15 | 5 | -10,03 |
|  |  |  |  |
| EXPERIMENT 2 |  |  |  |
| Elastic Collision | 100% x (Pf-Pi)/Pi | Elastic Collision | 100% x (Kf-Ki)/Ki |
| Run # | % Difference Momentum | Run # | % Difference Kinetic |
| 1 | -8,08 | 1 | -7,57 |
| 2 | -9,59 | 2 | -8,36 |
| 3 | -5,35 | 3 | -7,01 |
| 4 | -5,39 | 4 | -5,99 |
| 5 | -4,51 | 5 | -5,78 |
|  |  |  |  |
| EXPERIMENT 3 |  |  |  |
| Inelastic Collision | 100% x (Pf-Pi)/Pi | Inelastic Collision | 100% x (Kf-Ki)/Ki |
| Run # | % Difference Momentum | Run # | % Difference Kinetic |
| 1 | -6,49 | 1 | -48,56 |
| 2 | -1,95 | 2 | -43,45 |
| 3 | -2,4 | 3 | -43,97 |
| 4 | -2,93 | 4 | -44,58 |
| 5 | -2,16 | 5 | -43,7 |

**CONCLUSION**: The following conclusions can be drawn from the obtained data: The total momentum is conserved for all collisions performed. The total kinetic energy is conserved for all collisions except the inelastic one. There is considerable missing kinetic energy after the third collision. One of the reasons is the air friction, so the velocities of the gliders are constantly decreasing throughout the experiment. But this reason is minor. The third collision was an inelastic collision, that means the gliders stuck after they collided and during the collision most of the energy turned into other types of mechanical energy such as sound waves and heat energy(vibration of atoms). If we considered the whole room as our system, there would be no energy loss because the KE is just converted to other types of energy. The total energy is always conserved throughout the universe. The other major reason why the measurements are not perfectly accurate is because in some trials the velocity of the launched glider was greater than 0.5 m/s, which in return caused the gliders to jump during collision and hence created inaccurate data. Also, the unavoidable levelness of the track might have played a role too.