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| **Subject:** | **Physics** | **Time: 1h 15 min** |
| **Level:** | A-Level | |
| **Worksheet Title:** | **P06 – Collisions between two bodies – Virtual Laboratory** | |

**Apparatus List**

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| 01 × laptop |

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| 1. In this practical you will investigate the dynamics of collisions with TIPERs worksheets using the easy Java simulation ejs\_users\_sgeducation\_lookang\_Momentum1D2010web02.jar. |
| The following sections consist of various collision scenarios.  Read through the context carefully before making an educated guess as to the outcome. Explain your reasoning.  Finally, run the simulation to verify your prediction.  Are your predicted outcome and the simulated outcome identical? If they are not, explain the discrepancy.  How to use the Virtual Laboratory   * Select the type of collision by clicking the radiobutton .  * Key in the masses of the cart 1 and press the enter key. Repeat for cart 2 * Key in the initial velocity of cart 1 and press the enter key. Repeat for cart 2. * Click the play button to start the simulation.  * Reset the simulation by clicking on reset button.  * You may wish to explore other features such as graphs in your own free time. * E.g.: *e* is the coefficient of restitution and it is the ratio of speeds after and before an impact, taken along the line of the impact (i.e. a measure of how much kinetic energy is lost). |

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| **(a)** | Carts A and B are shown just before they collide.  ***No other information is given. Don’t Ask.* ☺**  Four students discussing this situation make the following contentions: |
|  | Eugene: “*After the collision, the carts will stick together and move off to the left. Cart B has more speed, and its speed is going to determine which cart dominates in the collision.*”  Sean: “*I think they’ll stick together and move off to the right because Cart A is heavier. It’s like when a heavy truck hits a car: The truck is going to win no matter which one’s going fastest, just because it’s heavier.*”  Thomas: “*I think the speed and the mass compensate, and the carts are going to be at rest after the collision.*”  Meili: “*The carts must have the same momentum after the collision as before the collision, and the only way this is going to happen is if they keep the same speeds. All the collision does is change their directions, so that Cart A will be moving to the left at 3 m/s and Cart B will be moving to the right at 4 m/s.*” |
|  | Which, if any, of these four students do you agree with?  Eugene\_\_\_\_\_ Sean \_\_\_\_\_ Thomas \_\_\_\_\_ Meili \_\_\_\_\_ None of them\_\_\_\_\_\_  Explain. |
|  | Answer: None of these contentions is correct. We do not have enough information to determine the velocity of either cart after the collision. Momentum will be conserved for the collision, but this could happen in a number of ways, such as the carts sticking together and remaining at rest, or the carts bouncing off one another. What actually happens depends on the construction of the carts and on the material of the surfaces that come into contact (rubber, clay, Velcro, etc.).  …………………………………………………………………………………………………………. |
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| **(b)** | Two identical carts traveling in opposite directions are shown just before they collide. The carts carry different loads and are initially travelling at different speeds. The carts stick together after the collision. |
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|  | Three physics students discussing this situation make the following contentions:  Sherwin: “*These carts will both be at rest after the collision since the initial momentum of the system is zero, and the final momentum has to be zero also.*”  Sunny: “*If that were true it would mean that they would have zero kinetic energy after the collision and that would violate conservation of energy. Since the right-hand cart has more kinetic energy, the combined carts will be moving slowly to the left after the collision.*”  Steven: “*I think that after the collision the pair of carts will be traveling left at 20 cm/s. That way conservation of momentum and conservation of energy are both satisfied.*” |
|  | Which, if any, of these three students do you think is correct?  Sherwin \_\_\_\_\_ Sunny \_\_\_\_\_ Steven \_\_\_\_\_ None of them\_\_\_\_\_\_  Please explain your reasoning. |
|  | Answer: Sherwin is correct. The momenta of the two carts are equal and opposite before the collision, so the total initial momentum is zero and the total final momentum has to be zero also.  …………………………………………………………………………………………………………. |
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| **(c)** | In Case A, a *metal* bullet penetrates a wooden block.  In Case B, a *rubber* bullet with the same initial speed and mass bounces off an identical wooden block. |
|  | ***No other information is given. Don’t Ask.* ☺** |
|  | 1. Will the speed of the wooden block after the collision be greater in Case A, greater in Case B, or the same in both cases? |
|  | Explain. |
|  | Answer: Greater for B. The initial momentum in both cases is the same and points to the right. The final momentum of the bullet points to the right in Case A and to the left in Case B. Since the final momentum of the system consisting of the bullet and the block is the same as the initial momentum, and this final momentum is the vector sum of the momentum of the bullet and the momentum of the block, the momentum of the block must be greater in Case B.  …………………………………………………………………………………………………………. |
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|  | 1. Will the speed of the bullet in Case B after the collision be greater than, less than, or the same as the speed of the bullet just before the collision?   Explain. |
|  | Answer: Less than. The energy of the system containing both block and bullet cannot be greater after the collision than before. The initial energy is the kinetic energy of the bullet, and the final energy is the sum of the kinetic energies of the bullet and the block. Since the block has a non-zero final kinetic energy, the final kinetic energy of the bullet must be less than the initial kinetic energy of the bullet.  …………………………………………………………………………………………………………. |
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**Half Way Check Point**

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|  | For each of the earlier situations **(a)** to **(c)**, answer the following questions. |
| 1. Assume friction is negligible. | 1. List all the external forces exerted on the system. 2. Does the system have an initial momentum? Describe any changes in its total momentum. 3. Does the system experience a net impulse during the specified time period? Explain. |
| **(a)** | * weight of system * normal reaction force on system |
|  | 1. Initially, the system has zero momentum. The total momentum does not change with time. Or rather, the change in momentum is zero. 2. There is no net impulse delivered to the system. The gravitational and normal forces balance.   …………………………………………………………………………………………………………. |
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| **(b)**  1. Assume friction is negligible. | * weight of system * normal reaction force of system |
|  | 1. Initially, the system has zero momentum. The total momentum does not change with time. Or rather, the change in momentum is zero. 2. There is no net impulse delivered to the system. The gravitational and normal forces balance.   …………………………………………………………………………………………………………. |
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|  | * weight of wooden block * normal reaction force on wooden block * weight of bullet |
| **(c)**  1. Assume friction is negligible. |  |
| 1. Initially, the system has momentum. The total momentum does not change with time. Or rather, the change in momentum is zero. 2. There is no net impulse delivered to the system. The gravitational force on the bullet causes a small vertical downward change in momentum of the bullet, which is negligible. | …………………………………………………………………………………………………………. |
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**Extending Your Understanding**

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| **(e)** | Two identical steel balls, *P* and *Q*, are shown at the instant that they collide.  The paths and velocities of the two balls before and after the collision are indicated by the dashed lines and arrows.  The speeds of the balls are same before and after collision.  For the questions below, use the directions indicated by the arrows in the direction rosette, or use ***J*** for no direction, ***K*** for into the page, ***L*** for out of the page, or ***M*** if none of these are correct. |  |
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|  | 1. Which letter best represents the direction of the change in momentum for ball *Q*?   Explain. | |
|  | Answer: ***A***. The change in velocity of ball Q is its final velocity minus its initial velocity, and is found by subtracting vectors as shown.    …………………………………………………………………………………………………………. | |
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|  | 1. Which letter best represents the direction of the change in momentum for ball *P*?   Explain. | |
|  | Answer: ***E***. The change in velocity of ball P is its final velocity minus its initial velocity, and is found by subtracting vectors as shown.  …………………………………………………………………………………………………………. | |
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|  | 1. Choose the letter that best represents the direction of the initial momentum for the system of both balls *P* and *Q* before collision.   Explain. |
|  | Answer: ***C***. The initial momentum of the system is the vector sum of the initial momenta of the individual balls. When added together, these momenta point to the right as shown.  …………………………………………………………………………………………………………. |
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|  | 1. Choose the letter that best represents the direction of the final momentum for the system of both balls *P* and *Q* after collision.   Explain. |
|  | Answer: ***C***. The final momentum of the system is the vector sum of the final momenta of the individual balls. When added together, these momenta point to the right as shown. Note that since momentum is conserved for this system, the final momentum is equal to the initial momentum.  …………………………………………………………………………………………………………. |
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|  | 1. Choose the letter that best represents the direction of the impulse during this interaction for the system of both balls *P* and *Q*.   Explain. |
|  | Answer: ***J***. There is no direction since there is no impulse on the system during the interaction. There are no external forces, and so no impulse and no change in momentum for the system.  …………………………………………………………………………………………………………. |
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