Using formulas to guide your thinking

**KEY**

**Comparing Momentum shifts within a closed systems**

Conservation Laws in Science: *In a closed system, the TOTAL amount of a particular measureable quantity stays the SAME while shifting within the system.*

The Law of Conservation of Momentum states THE TOTAL MOMENTUM IN A CLOSED SYSTEM REMAINS THE SAME.

Collisions & Explosions:

In an elastic collision, the objects will  ***BOUNCE*** off one another.

In an inelastic collision, the objects will ***STICK*** together and move in the ***SAME*** direction after impact.

For a bomb that is ***at rest****,* the momentum before & after the explosion is ***ZERO***.

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| Dimension | Variable | Standard  International  Unit | Definition |
| Mass | *m* | kg | Amount of matter in a object |
| Velocity | *v* | m/s | Speed in a certain direction |
| Momentum | *p* | Kg m/s | Strength of motion; inertia in motion, how hard to stop a moving object. |

Momentum Formula:  ***p = mv***

**Comparing separate systems using Momentum**

1. Two bullets have the same momentum. If their mass is the same, how do their velocities compare? **Momentum is mass times velocity. If mass and momentum are the same, then velocity must be the same, too, if p = mv.**
2. Objects X and Y are moving at the same velocity. If object’s X’s momentum is 3 times larger than Object Y’s, what information can you deduce about Object Y? **Momentum is mass times velocity. If velocity is the same, then the mass of X is 3 times larger in order than momentum can be three times larger.**
3. Two balls of the same mass and move in opposite directions at the same speed. If the first ball’s momentum is 18 kg m/s, what is the momentum of the other ball? **If the balls have the same mass and same speed, the value of their momentums is the same BUT (since momentum is a vector and is based on the direction of the velocity), the second ball’s momentum must be – 18 kg m/s.**
4. A red ball has twice the mass of a blue ball. The red ball is moving 3 times faster than the blue ball. Complete the sentence:

The red ball’s ***p*** is (**more**/less) than the blue ball’s p by a factor of **2x3 = 6**.

1. The total momentum in a system changes from 30 kg m/s to 60 kg m/s. Is this a closed or open system? Since momentum remains the same in a closed system, this must be an **open system** since total momentum changes.
2. Ball A & Ball B interact in a system. Ball A’s initial ***p*** is 16 kg m/s & Ball B’s initial ***p*** is -20 kg m/s. Later, the momentum has shifted due to an interaction and each ball’s momentum is 2 kg m/s. Is this an open or closed system? This is an OPEN system. The total momentum before is – 4 kg m/s. Since the total momentum after is + 4 kg m/s, the system must be open.
3. By what factor will momentum change if velocity doubles and mass decreases by half? The momentum will not change so the factor is one.

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| --- | --- | --- | --- |
| System A | System B | System C | System D |
| *p* = 72 kg m/s | *p* = -18 kg m/s | *p* = 36 kg m/s | *p* = 144 kg m/s |

1. For system C, what would be the velocity of the 4 kg object?

pc = 36 kg m/s p = mv

so 36 kg m/s = (4 kg) v (divide both sides by 4 kg

v =( 36 kg m/s) / (4 kg) = **9 m/s**

1. For system B, what is the object’s mass if its velocity is -72 m/s?

pB = -18 kg m/s p = mv

so -18 kg m/s = m (-72 m/s) v (divide both sides by- 72 m/s

m = (-18 kg m/s)/ (- 72 m/s) = **0.25 kg**

1. For system D, what is the object’s mass if its velocity is 12 m/s?

pD = 144 kg m/s p = mv

so 144 kg m/s = m (12 m/s) v (divide both sides by 12 m/s

m = (144kg m/s)/ ( 12 m/s) = **12 kg**

1. If the objects in system A and B each have a mass of 6 kg, find the velocities of each system.

pA = 72 kg m/s pB= -18 kg m/s

72 kg m/s = (6 kg) vA -18 kg m/s = (6 kg) vB

**vA = 12 m/s vB = -3 m/s**

1. If the mass of the object in system A is 9 kg, what is the mass of the object in system C if the velocity is the same for both systems?

pA = 72 kg m/s pC= 36 kg m/s

72 kg m/s = (9 kg) vA 36 kg m/s = (mC) (8 m/s)

**vA = 8 m/s mB = (36kg m/s) /(8 m/s) = 4.5 kg**

1. Two carts, each with a mass of 8 kg, have different momentums. If cart A’s momentum is double Cart B’s momentum, how do their velocities compare?

Since mA = mB, then the velocity of cart A must be double the velocity of cart B.

1. A red ball has a momentum of + 5 kg m/s. A blue ball has a momentum of - 8 kg m/s. How do their velocities compare? There is not enough information to determine their exact velocities. However, the red ball is moving in the positive direction and the blue ball is moving in the negative direction.

Impulse

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| Dimension | Variable | Standard  International  Unit | Definition |
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| Velocity | *v* | m/s | Speed in a certain direction |
| Momentum | *p* | Kg m/s | Strength of motion; inertia in motion, how hard to stop a moving object. |
| Impulse | *J* | Kg m/s | The change in momentum |
| Force | *F* | N | A push or a pull |
| Time | *t* | s | Duration of an event |

Formulas: Momentum: ***p = mv*** Impulse ***J = Δp***  or ***J = Ft***

1. The momentum of a 2 kg object changes from 20 kg m/s to 12 kg m/s in 3 seconds.
   1. What is the impulse on the object?

p = 20 kg m/s p’= 12 kg m/s

***J = Δp***  = *p’ – p* = 12 – 20 = - 8 kg m/s

* 1. What Force caused the change in momentum? ***J = Ft***

- 8 kg m/s = F ( 3 sec)

F = - 8/3 N = -2.67 N

1. A 12 kg cart moves at 3 m/s before a force of 3 N is applied to it. If the cart’s momentum after the force is applied is 72 kg m/s, how long was the force applied?

p = m v before = (12 kg ) ( 3 m/s) = 36 kg m/s

p’= 72 kg m/s

***J = Δp***  = *p’ – p* = 72 – 36 = 36 kg m/s

F = 3 N

***J = Ft so t = J/F = (36 kg m/s)/(3 N) =*** 12 seconds

1. A system’s total momentum changes from 4 kg m/s to 12 kg m/s. Is the system open or closed? The system is open because momentum remains constant in a closed system
2. A 7 kg cart’s momentum is – 56 kg m/s.
   1. What is the cart’s velocity? V = p/m = (-56 kg m/s)/(7kg) = -8 m/s
   2. Next, the velocity changes to +2 m/s. What is the impulse?

pbefore = -56 kg m/s p ‘ = mv = (7kg) (2 m/s) = 14 kg m/s

***J = Δp***  = *p’ – p* = 14 – (-56) = 70 kg m/s

* 1. If the impulse change occurs over 3 seconds, how much force was applied?

***J = Ft so F = J/t = (70 kg m/s)/(3 s) =*** 23.3 N