Action-Reaction and the Law of Momentum Conservation

Lesson Notes

Strategic Questions

- What is meant by the law of action-reaction?
- How does the momentum conservation principle emerge from the law of action-reaction?
- What does it mean to say that momentum is conserved?

Newton's Third Law

For every **action**, there is an **equal** and **opposite** **reaction**.

Forces are the result of simultaneous, mutual, interactions between two objects.

Interaction Force Pair Example

- Person pushes down on floor.
- Floor pushes up on person.

A **force** is a push or pull acting on an object whenever it pushes or pulls on another object.

Forces vs. Accelerations

Newton's Third Law:

The interaction forces between objects are equal in magnitude.

$F_{on\ car} = -F_{on\ truck}$ $F_{on\ bug} = -F_{on\ bus}$

Newton's Second Law:

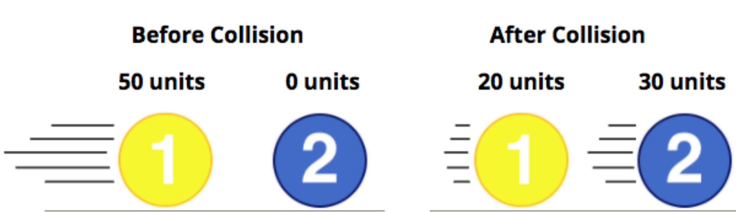
The acceleration of an object is inversely proportional to its mass.

$a_{of\ car} >> a_{of\ truck}$ $a_{of\ bug} >>>> a_{of\ bus}$

The 3rd law describes the cause of acceleration. The 2nd law describes the effect of the force.

The Law of Momentum Conservation:

For any collision occurring in an isolated system, the total amount of momentum possessed by objects within the system is conserved.



$p_{total\text{-}before} = p_{total\text{-}after}$

$\Delta p_1 = -\Delta p_2$

(p = momentum)

- The combined momentum of the system does not change.
- The momentum lost by Ball 1 is equal to the momentum gained by Ball 2.

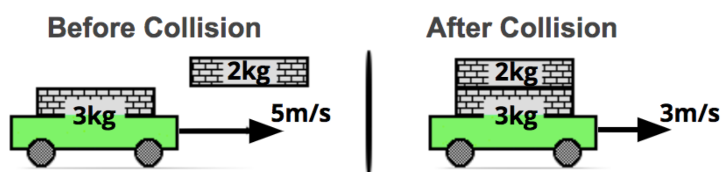
Logical Basis of Momentum Conservation

In a collision between **Object 1** and **Object 2**, the following is true.

Statement	Symbolic Form	Basis
The forces between objects are equal and opposite ...	$F_1 = - F_2$	Newton's 3rd Law
… enduring for the same amount of time ...	$\Delta t_1 = \Delta t_2$	Logic
… causing the same impulse on each object ...	$F_1 \bullet \Delta t_1 = - F_2 \bullet \Delta t_2$	Math Logic
… resulting in the same momentum change	$m_1 \bullet \Delta v_1 = - m_2 \bullet \Delta v_2$	Physics Logic

The Cart and the Brick Example

A 3-kg cart is in motion at 5 m/s. A 2-kg brick, initially at rest, is dropped onto the moving cart. After the collision, the brick and cart move together with a speed of 3 m/s.



	p Before Coll'n	p After Coll'n	Δp
Cart	3•5 = 15 kg•m/s	3•3 = 9 kg•m/s	-6 kg•m/s
Dropped Brick	2•0 = 0 kg•m/s	3•2 = 6 kg•m/s	+6 kg•m/s
System Total	15 kg•m/s	15 kg•m/s	0 kg•m/s

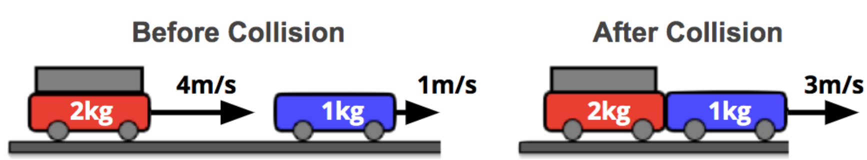
Momentum Conservation

$p_{total\text{-}before} = p_{total\text{-}after}$

$\Delta p_{object\ 1} = - \Delta p_{object\ 2}$

Red Cart Collides with Blue Cart Example

A 2-kg red cart moving at 4 m/s collides with a 1-kg blue cart moving at 1 m/s. The carts collide, stick together, and continue in motion at the same speed of 3 m/s.



	p Before Coll'n	p After Coll'n	Δp
Red Cart	2•4 = 8 kg•m/s	2•3 = 6 kg•m/s	-2 kg•m/s
Blue Cart	1•1 = 1 kg•m/s	1•3 = 3 kg•m/s	+2 kg•m/s
System Total	9 kg•m/s	9 kg•m/s	0 kg•m/s

Momentum Conservation

$p_{total\text{-}before} = p_{total\text{-}after}$

$\Delta p_{object\ 1} = - \Delta p_{object\ 2}$