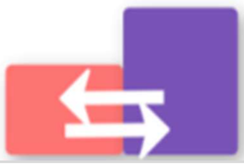
Newton's Third Law of Motion

Newton's Third Law of Motion explains a *fundamental symmetry* inherent in the forces in nature, it says:

"Whenever a body exerts a force on another body, it simultaneously experiences a force of equal magnitude but opposite direction from the other body"



If red box presses the purple box with force "F" purple box presses the red box with the same Force "F"

This law emphasizes the existence of *"force pairs"*, often referred to as action-reaction pairs, in interactions between two bodies (the white arrows in the diagram are action reaction pairs)

Illustrations of Newton's Third Law:

1. Book and Wall Interaction

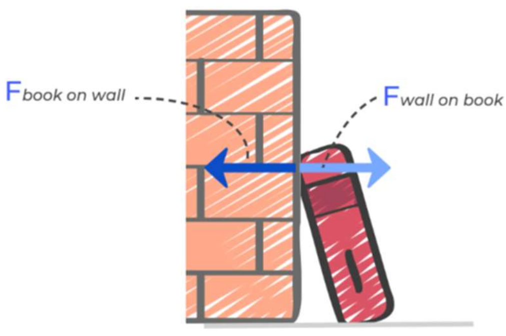
- When a book leans against a wall, it exerts a force on the wall. At the same time, the wall exerts an equal and opposite force on the book
- Denoting the forces as $F_{\{book\ wall\}}$ (force of book on wall) and $F_{\{wall\ book\}}$ (force of wall on book),

  Newton's third law asserts

  $F_{\{book\ wall\}} = -F_{\{wall\ book\}}$

  making the vector sum of the forces zero. i.e.

  $F_{\{book\ wall\}} + F_{\{wall\ book\}} = 0$

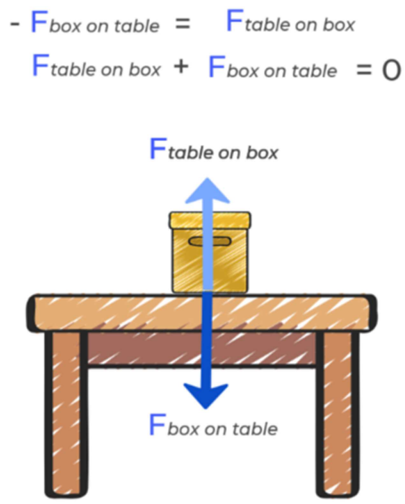


$F_{wall\ on\ book} = -F_{book\ on\ wall}$

$F_{wall\ on\ book} + F_{book\ on\ wall} = 0$

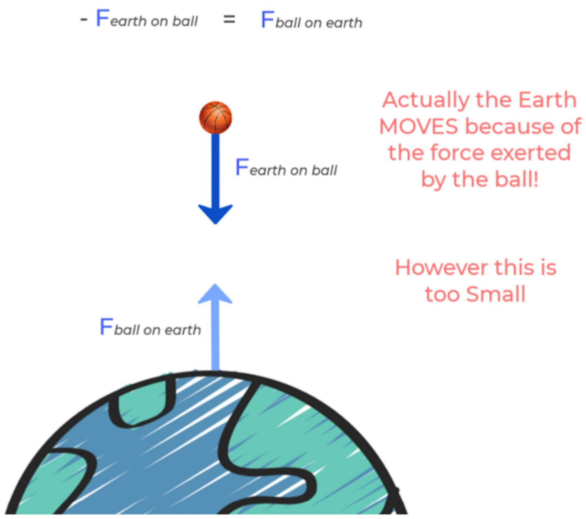
2. *Box and Table Interaction*

- A box resting on a table exerts a downward force on the table, while the table exerts an equal and opposite upward force on the box.



3. *Gravitational Interaction Between Earth and Ball* :

- A ball attracted towards the Earth by gravitational force exemplifies a *non-contact interaction*.
- The Earth and ball exert equal and opposite gravitational forces on each other, adhering to $F_{\{earth\ ball\}} = -F_{\{ball\ earth\}}$ or $F_{\{earth\ ball\}} + F_{\{ball\ earth\}} = 0$



Applying the law in Numerical Problems:

Consider two boxes, one of 4 kg and the other of 6 kg, placed on a table. A force of 10 N is applied on the 4 kg box. To ascertain the acceleration of each box and the inter-box force:

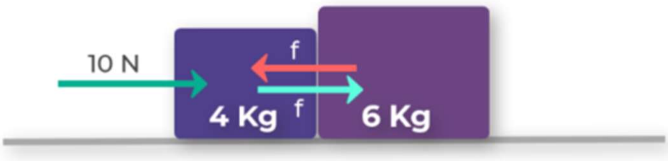
1. Free Body Diagram (FBD)
   - Draw FBDs for both boxes, identifying the forces acting on each.
   - Label the inter-box force as "f"

2. Applying Newton's Second Law $F_{\{net\}} = ma$

- For the 4 kg box: 10 - f = 4a
- For the 6 kg box: f = 6a

3. Solving the Equations ➗:

- Solve the above equations simultaneously to find $a = 1\frac{m}{s^2}$ and $f = 6\,N$.



$F_{46} = F_{64} = f$

$a = ?$

$F_{net} = ma$

<u>For 4 Kg</u>

$10 - f = 4a$ (1)

<u>For 6 Kg</u>

$f = 6a$ (2)

$10 = 10\,a$ (1) + (2)

$a = 1\,m/s^2$

$f = 6\,N$

$4 = 4\,a$	$6 = 6\,a$
$a = 1\,m/s^2$	$a = 1\,m/s^2$

Common Mistakes 🚫:

- The force pairs can act on same body: Not correct

  Newton’s force pairs always act on <u>different bodies, never on the same body</u>

This is Action Reaction Pair

Not and Action Reaction Pair

- Misunderstanding of Action-Reaction Pairs: Students often misunderstand the concept of action-reaction pairs. They may think that the two forces cancel each other out, resulting in no motion. However, this is not true because *the two forces act on different objects and have different directions*
- Forgetting that Newton's Third Law Applies to Gravity also: Just as the Earth pulls down on an object with a force, objects also pull on the Earth
- Believing that a Continued Force is Required to Sustain Motion: Another common misconception is the idea that sustaining motion requires a continued force. However, Newton's first law of motion declares that a force is not needed to keep an object in motion.
- When making free body diagram for a body, students mark force exerted by the body on other objects. In a free body diagram of an object, only mark forces acting on the object

When you draw a free body diagram, you only mark the forces acting on the object

Example of Action – Reaction Pairs for various situations

SN	*Situations*	*Action Force*	*Reaction Force*
1	Man pushing a car	Man pushing the car	Car pushing the man back
2	Bird flying	Bird flapping wings downwards	Air pushing the bird upwards
3	Rowing a boat	Person pushing water backwards	Water pushing the boat forwards
4	Rocket propulsion	Rocket expelling gases downwards	Gases pushing the rocket upwards
5	Hitting a nail with a hammer	Hammer exerting force on the nail	Nail exerting force on the hammer

6	Walking	Feet pushing the ground backwards	Ground pushing the feet forwards
7	A bouncing ball	Ball exerting force on the floor	Floor exerting force on the ball
8	Gun recoil	Gun exerting force on the bullet forward	Bullet exerting force on the gun backward
9	Magnet attraction	First magnet pulling the second magnet	Second magnet pulling the first magnet
10	Deflating balloon flying around	Air rushing out of the balloon backwards	Balloon moving forwards