MODULE 12
NEWTON'S THIRD LAW MADE CLEAR

INTRODUCTION

Newton's second law tells us what a resultant force does to a body: it produces acceleration and changes velocity. But it does not answer a deeper question: *Where do forces come from?*

In real life, a force never appears from nowhere. Whenever a force acts, it comes from an interaction between two bodies. Newton's third law tells us what is always true about forces that arise from interactions. It states that:

When two bodies interact, each body exerts a force on the other. These two forces are equal in magnitude, opposite in direction, and act on different bodies.

This is often written in short form as:

To every action there is an equal and opposite reaction.

Be careful with that short form. The key idea is not the words "action" and "reaction." The key idea is: *The pair of forces act on different bodies.*

Avoid the Most Common Misconception

Many students think Newton's third law means forces always cancel. That is not correct.

Newton's third law pairs do not cancel because they act on different bodies. Forces cancel only when they act on the same body and are opposite.

So always separate these two ideas:

1) Forces **on one body** can cancel (balanced forces).
2) Action–reaction forces do not cancel because they act on two different bodies.

How to Recognise a Third Law Pair

A Newton's third law force pair always has the following essential properties:

1. They are the same type of force (for example, both gravitational, both normal, or both frictional).
2. They have equal magnitudes.
3. They act in opposite directions.
4. They act on different bodies (never on the same object).
5. They arise from the same interaction between the two bodies.

The most reliable way to identify a third law pair is to describe the forces using clear, complete language:

- Force on A by B
- Force on B by A

These two forces form a Newton's third law pair. For example:

- Force on the book by the table (upward)
- Force on the table by the book (downward)

Newton's Third Law and Motion

Newton's third law does not directly tell you whether a body accelerates. Acceleration depends on the resultant force on that body (second law). Third law tells you how interaction forces come in pairs.

A body can still accelerate even though it is part of a third law pair, because the partner force acts on the other body, not on it. This is one reason Newton's third law becomes very powerful when studying systems such as:

1. Walking and running.
2. Vehicles moving on a road.
3. Pushing objects.
4. Recoil.
5. Two bodies connected by a string.
6. Collisions.

Later, when we study momentum and collisions, Newton's third law becomes the bridge between forces and changes in momentum during interactions. *Since the forces during an interaction are equal in magnitude and opposite in direction, the momentum changes of the two interacting bodies occur in opposite directions.* We will examine this relationship in detail when we study collisions.

For now, take a short breath and set momentum and collisions aside, let us warm up with some carefully chosen worked examples.

BINDER Example 17

A student presses a palm strongly against a wall. The hand feels pain, even though the wall does not move. Explain why the hand feels a force from the wall.

Solution

Reason:

The wall exerts a force on the hand equal in magnitude and opposite in direction to the force the hand exerts on the wall.

Explanation:

The hand and the wall interact. When the hand pushes the wall, the wall pushes back on the hand. By Newton's third law, these forces are equal and opposite and act on different bodies. The force from the wall acts on the hand, producing pressure on the skin, which is why pain is felt.

Making Sense of the Answer: *If the wall did not push back, the hand would go through the wall, which is not realistic for a rigid wall.*

Think Like a Physicist: *If you can name "force on A by B," the partner force is automatically "force on B by A."*

REAL Example 18

Kipanga is running on a dry road. Each time his foot pushes backward on the ground, his body moves forward. Explain how Newton's third law helps to explain forward motion in running.

Solution

Kipanga moves forward because the ground pushes him forward.

Explanation:

When Kipanga's foot pushes backward on the ground, the ground exerts an equal and opposite force forward on his foot. That forward force is transmitted to his body, producing a forward resultant force and therefore forward acceleration. Without the forward push from the ground, his velocity could not increase forward.

Making Sense of the Answer: *On a slippery surface, the ground cannot provide a strong forward force, so it becomes hard to run forward effectively.*

Think Like a Physicist: *You do not "move forward by pushing yourself forward"; you move forward by pushing something backward and receiving an equal forward force.*

HOT Example 19

Two students, Kipute and Kipanga, stand facing each other on a smooth surface. Kipute exerts a horizontal force of 60N on Kipanga.

(a) State the magnitude and direction of the force exerted by Kipanga on Kipute.
(b) If Kipute has mass 50kg and Kipanga has mass 75kg, find their accelerations immediately after the push.

Solution

(a) By Newton's third law, the force exerted by Kipanga on Kipute is equal in magnitude and opposite in direction to the force exerted by Kipute on Kipanga. So *the force on Kipute by Kipanga is 60N opposite to the direction of the force on Kipanga by Kipute.*
(b) For Kipute: resultant force = 60N (in her backward direction)
Using $F = ma$

$$60\text{N} = 50\text{kg} \times a;\ a = 1.2\text{m/s}^2$$

For Kipanga: resultant force = 60N (in his forward direction)
Using $F = ma$

$$60\text{N} = 75\text{kg} \times a;\ a = 0.8\text{m/s}^2$$

Thus Kipute's acceleration is 1.2m/s^2 and Kipanga's acceleration is 0.8m/s^2, in opposite directions.

Making Sense of the Answer: *The forces are equal, but the accelerations are different because the masses are different. The smaller mass gets the larger acceleration.*

Think Like a Physicist: *Equal and opposite forces do not mean equal accelerations; acceleration depends on mass*.

With the regular worked examples now complete, we can step back and enjoy the bigger picture; a set of miscellaneous worked examples where all the ideas meet at the same table.