MODULE 9
UNDERSTANDING FORCES BEFORE NEWTON'S LAWS

INTRODUCTION

If you have ever tried to push a stalled motorcycle, drag a heavy desk across the floor, or suddenly brake a fast-moving bicycle, then you have already met Newton's Laws of Motion even if you did not know their names.

Every day, we interact with objects that move and objects that stubbornly refuse to move. Some start moving easily, others resist. Some stop quickly, others seem unwilling to stop at all. Yet we often describe these experiences using casual words such as *"heavy"*, *"fast"*, or *"hard to push"*. These words are useful in daily conversation, but they are not good enough for physics. Physics enjoys asking uncomfortable questions.

After completing **the previous topic,** a curious student should naturally begin to ask deeper questions such as:

- *Why does a body at rest require effort to start moving?*
- *Why does the same push affect different objects differently?*
- *Why do we feel thrown forward when a bus suddenly stops?*

These questions are no longer about ***how*** objects move, but about ***why*** they move the way they do. The answers are found in a set of simple but powerful ideas known as **Newton's Laws of Motion**.

Newton's Laws do not describe rare or special situations. They describe ordinary motion; walking, pushing, braking, jumping, and falling. Yet from these everyday actions, they explain an astonishing range of physical phenomena, from the motion of vehicles on the road to the motion of rockets in space.

Because of this, Newton's Laws form the **foundation of mechanics**. Everything that follows in A-Level Physics builds upon them. A weak understanding here makes later topics unnecessarily difficult.

There is, however, a common danger. Many students memorize Newton's Laws as statements, but struggle to use them correctly. This happens when the laws are learned as words rather than as tools for thinking.

To avoid this, this chapter will not rush directly into formulas or laws. Instead, it will focus first on the central idea that gives meaning to all three laws. That idea is **force**.

If Newton's Laws were a complete meal, then force would be the ingredient that gives the meal its taste. Once force is understood clearly, Newton's Laws become natural and logical rather than mysterious.

With this in mind, we now turn our attention to force.

FORCE

In the previous topic, we described motion using quantities such as displacement, velocity, and acceleration. We answered questions like *how fast*, *how far*, and *how motion changes with time*. However, one important question was left unanswered: ***Why does motion change in the first place?***

For example:

- *Why does a body at rest start moving when pushed?*
- *Why does a moving object sometimes slow down even when no one is touching it?*
- *Why does the same push affect a light object more than a heavy one?*

To answer such questions, physics introduces the idea of **force**.

Why Do We Need the Idea of Force?

A ball lying on the ground remains at rest for a long time. When kicked, it suddenly starts moving. After some distance, it slows down and eventually stops.

Describing this motion using velocity and acceleration is possible, but those quantities alone do not explain the **cause** of the motion or its change. Objects do not begin to move, stop, or change direction by themselves.

Experience tells us that motion changes only when something acts on the object. This "something" is what physics calls a **force**.

So at this stage, it is important not to treat force as an abstract formula. Instead, it should be understood as the **physical reason** behind changes in motion.

At this point, a simple but very important question arises: ***What a force is, and what it is not?***

A force can be described as a **push or a pull** resulting from the interaction between two bodies.

However, this description must be used carefully.

A force:

- is not a property that an object possesses,
- cannot exist without another body involved,
- is always associated with an interaction.

For example:

- When you push a wall, the force exists because your hand and the wall interact.

- When the Earth attracts a stone, the force exists because of the interaction between the stone and the Earth.

An isolated object, completely alone, cannot experience a force. This idea will become important later when discussing interacting systems and Newton's third law.

Avoid This Misconception

A very common misconception is that force is required to keep an object moving. Everyday experience seems to support this idea: when a person stops pushing a box, the box slows down and stops.

However, this observation does not tell the full story, how?

From the previous topic, we learned that:

- Acceleration is the rate of change of velocity.
- Motion with constant velocity corresponds to zero acceleration.

Now we connect this to force as follows:

When the velocity of an object changes; either in magnitude or direction, the object is accelerating. Such a change does not occur without a cause. That cause is the presence of a **net force** acting on the object.

If the net force acting on a body is zero, then its acceleration is zero. In that case, the body either remains at rest or continues to move with constant velocity. This does not mean that no forces act on the body. It means that the forces acting on it **balance each other**.

Therefore:

- Force is linked to **change of motion**, not motion itself.
- An object can move with constant velocity even while forces are acting on it.

This idea is central to Newton's laws and must be clearly understood before moving forward.

Multiple Forces Acting on a Body

In real situations, a body is rarely acted upon by only one force. Usually, several forces act at the same time. For example:

- A book resting on a table is pulled downward by the Earth and pushed upward by the table.
- A moving vehicle experiences a driving force forward and resistive forces backward.

What determines the motion of the body is not any single force, but the **combined effect of all forces acting on it**. This combined effect is called the **net force** or **resultant force**.

- If the net force is zero, the motion does not change which implies that acceleration is zero.
- If the net force is not zero, the motion changes and acceleration occurs in the direction of the net force.

This idea will appear repeatedly throughout this chapter and must be kept in mind at all times.

With the ideas now simmering nicely, let us serve them properly through a few worked examples and enjoy the flavour of physics in action.

BINDER Example 1

A stone rests on the ground and remains at rest for a long time. Explain, using force ideas, why the stone does not start moving on its own.

Solution

The stone is acted upon by two main forces: its weight acting downward and the support force from the ground acting upward. These two forces act in opposite directions and balance each other. Since the resultant force on the stone is zero, there is no acceleration. With zero acceleration, the stone remains at rest.

Making Sense of the Answer: *If one force were stronger than the other, the stone would start moving upward or downward. Since it stays at rest, the forces must be balanced.*

Think Like a Physicist: *Rest or constant velocity means the resultant force on the body is zero.*

REAL Example 2

Kipute pushes a heavy wooden crate along a straight path. At first, the crate speeds up. After some time, she continues pushing with the same effort, but the crate moves at constant velocity. Explain this observation using force ideas.

Solution

At the beginning, Kipute's pushing force is greater than the forces opposing the motion, so the net force is forward. This produces acceleration, causing the crate to speed up.

Later, when the crate moves at constant velocity, its acceleration is zero. Zero acceleration means the resultant force is zero. Therefore, the resistive forces must have increased until they balance Kipute's pushing force.

Making Sense of the Answer: *It feels harder to start moving a heavy object than to keep it moving steadily, which agrees with the idea that acceleration requires a non-zero resultant force, but constant velocity does not.*

Think Like a Physicist: *Constant speed means forces are balanced, not that no force is applied.*

HOT Example 3

Three forces act on a body moving along a straight line. Two of the forces have magnitudes of 18N and 6N and act in the same direction. The third force has magnitude 10N and acts in the opposite direction.

(a) Determine the net force acting on the body.
(b) State the effect of this net force on the motion of the body.

Solution

(a) Forces acting in one direction: 18N + 6N = 24N

Opposing force: 10N

Net force = 24N − 10N = 14N, acting in the direction of the 18N and 6N forces.

(b) Since the net force is not zero, the body accelerates in the direction of the net force. Its velocity increases in that direction.

Making Sense of the Answer: *The larger combined force must dominate, but part of it is cancelled by the opposing force, leaving a smaller resultant force of 14N.*

Think Like a Physicist: *You can decide whether motion changes by finding the net force, even before knowing the mass.*

The worked examples have done their part. Now, with curiosity switched on, let us enjoy the next subtopic as it unfolds.