احجز مكانك واستعد للامتحان بثقة كاملة

ملزمة الفيزياء الفصل الثاني
Inspire 9 متقدم لعام 2026

تنويه:

تم إنشاء هذه الملزمة لمساعدتك، ولكن المرجع الرئيسي هو الكتاب، وسيكون هناك ملف إضافي للأمثلة.

Module (4): Forces in One Dimension

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01 First Lesson: Force and Motion

The Quest to Understand Motion

For millennia, humanity has observed the world in motion—a falling apple, a rolling stone, the planets in the sky. But what truly governs these movements? What is the fundamental rule that ditates why an object starts moving, stops, or changes direction? **This is not just a question for physicists**; it is a **quest** to understand the very fabric of our reality.

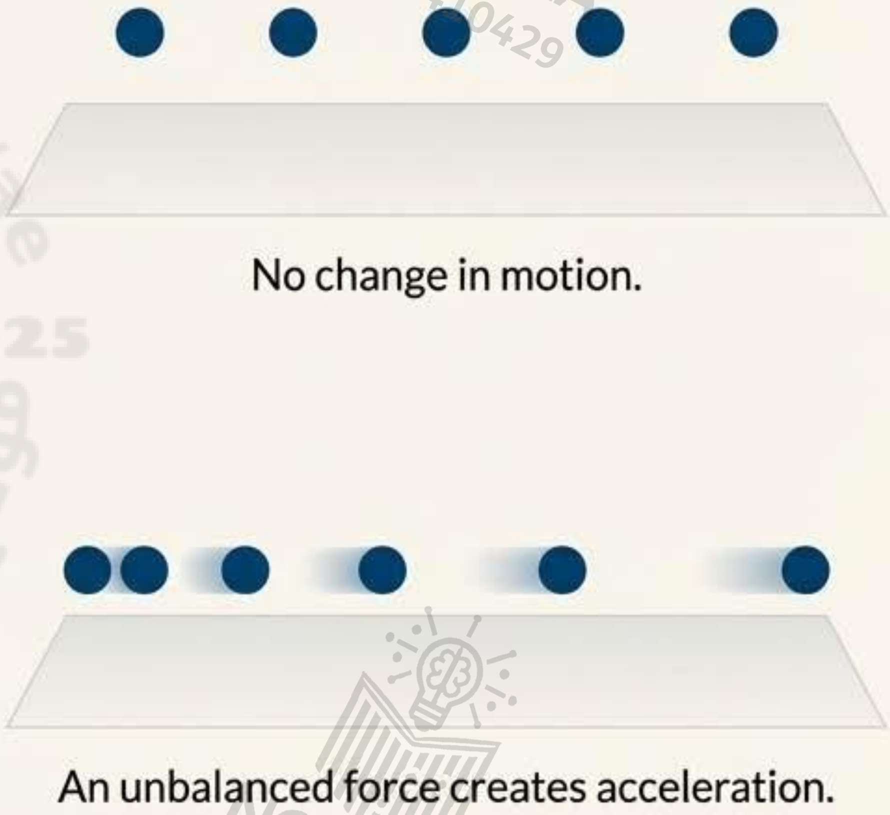
What causes a change in motion?

The First Clue: A Push or a Pull

The first piece of the puzzle is the concept of **force**. A force is simply a push or a pull exerted on an object. Because forces have both magnitude (how strong they are) and direction, they are vectors. The unit of force is the **newton (N)**.

Key Insight

However, just any force won't change an object's motion. A book resting on a table is subject to forces, yet it remains still. The key is an **unbalanced force**. An unbalanced force is what causes an object to accelerate—to change its speed or direction.



To Understand a Force, You Must Isolate the System

To analyze how forces affect an object, we must first define our **system**—the object or objects of interest. Everything else is the **external world**. The forces we care about are those exerted *by* the external world *on* the system.

Contact Forces

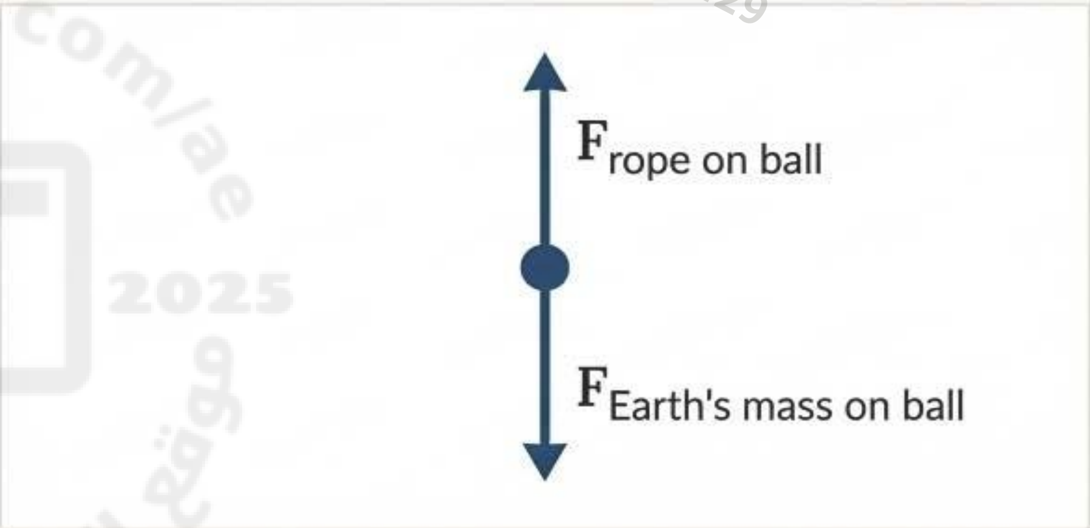
Act on an object by direct contact. The agent of the force touches the system. (e.g., your hand **pushing** a book, a rope pulling a ball).

Field Forces

Act on an object without contact. (e.g., gravity, the force Earth exerts on the book even without touching it).

Visualizing the Evidence: The Free-Body Diagram

A **free-body diagram** is a simple yet powerful tool that translates a complex physical situation into a clear map of **forces**. It helps us visualize all the **external forces** acting on a system.

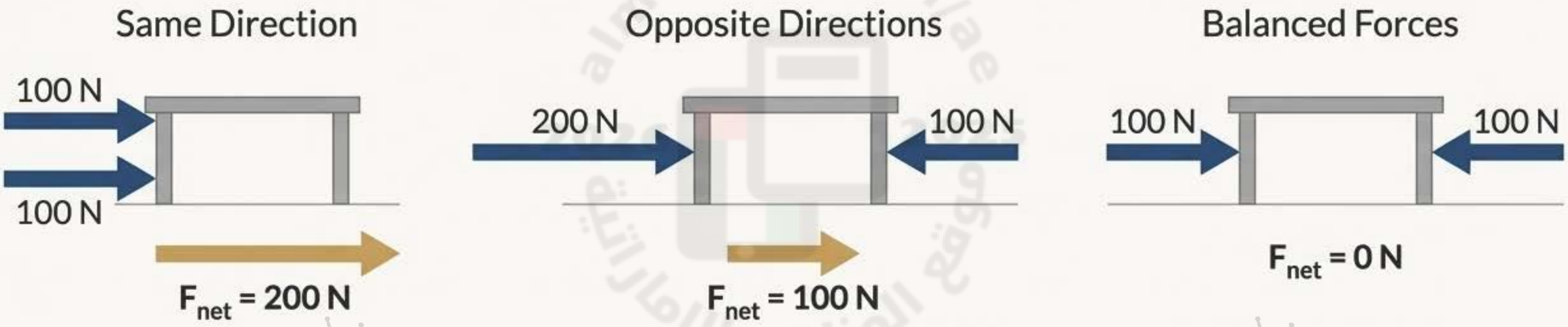


The Method

1. Represent the system as a single dot (the particle model).
2. Draw **vector arrows** representing all **forces** acting *on* the system, originating from the dot.
3. The length of each arrow should be proportional to the force's magnitude.
4. Label each force vector to identify its agent (e.g., F_{hand} on ball).

The Sum of the Clues: It's the Net Force That Matters

An object is often acted on by multiple forces simultaneously. The decisive factor for its acceleration is the **net force (F_{net})**, which is the vector sum of all the forces acting on the object.



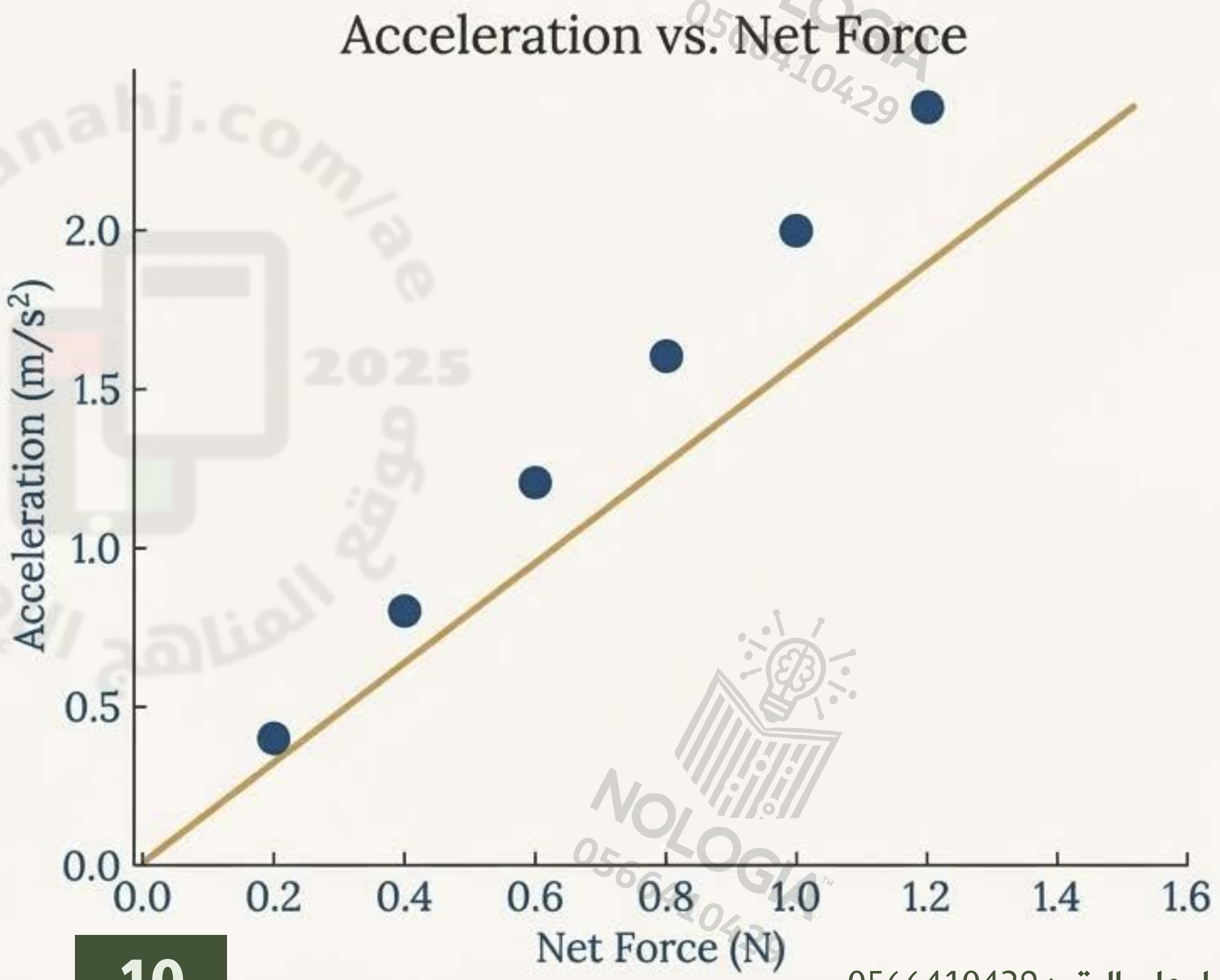
Key Takeaway: If the net force on an object is zero, there is no change in motion. The object will not accelerate.

The First Breakthrough: A Direct Link Between Force and Acceleration

Experiments provide the crucial evidence. When we apply a constant unbalanced force to an object (like a cart), it produces a constant acceleration. What happens if we increase the force?

The Experiment: By pulling a cart with different, constant forces and measuring the resulting acceleration, a clear pattern emerges.

The Finding: The acceleration of an object is directly proportional to the net force applied to it. Double the net force, and you double the acceleration.

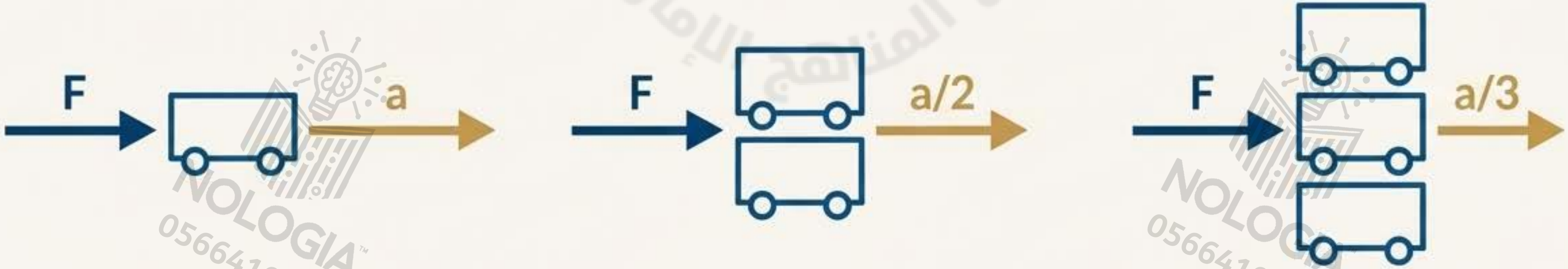


A Complicating Factor: The Role of Mass

The relationship between force and acceleration is clear, but there's another factor. What happens if we apply the *same* force to objects with *different* amounts of matter?

The Experiment: Apply an identical net force to one cart, then two carts, then three.

The Finding: As mass increases, acceleration decreases. An object's mass is a measure of its **inertia**—its resistance to a change in motion. A greater force is needed to produce the same acceleration for a more massive object.



The Revelation: Newton's Second Law Unlocks the Code of Motion

We have assembled all the pieces. Acceleration is directly proportional to net force and inversely proportional to mass. This relationship, discovered through observation and experiment, is one of the most fundamental laws of the universe.

Newton's Second Law: The acceleration of an object is equal to the sum of the forces acting on the object, divided by the mass of the object.

$$a = \frac{F_{net}}{m}$$

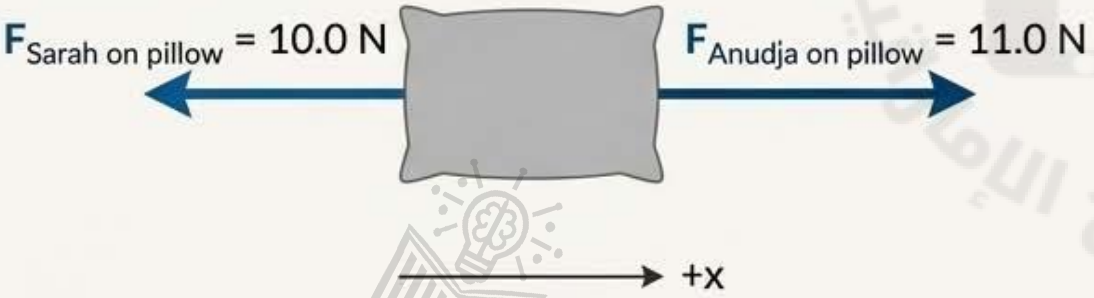
$$F_{net} = ma$$

Putting the Law into Practice

The power of Newton's Second Law is its ability to make precise predictions. Let's analyze a simple scenario.

Case Study

Two people pull on a 0.30 kg pillow in opposite directions. Anudja pulls with 11.0 N, and Sarah pulls with 10.0 N. What is the pillow's acceleration?



Analysis

1. Define System & Coordinates:
The system is the pillow. Let Anudja's direction be positive.

2. Calculate Net Force:
$F_{net} = F_{Anudja} + F_{Sarah}$
$F_{net} = (+11.0\ N) + (-10.0\ N) = +1.0\ N$

3. Apply Newton's Second Law:
$a = F_{net} / m$
$a = 1.0\ N / 0.30\ kg$
$a = 3.3\ m/s^2$

Conclusion: The pillow accelerates at 3.3 m/s² in the direction of Anudja's pull.

An Elegant Consequence: The Law of Inertia

Newton's Second Law ($F_{net} = ma$) also tells us what happens when the net force is zero. If $F_{net} = 0$, then $a = 0$. Zero acceleration means velocity does not change. This is Newton's First Law.

> **Newton's First Law**: An object that is at rest will remain at rest, and an object that is moving will continue to move in a straight line with constant speed, if and only if the net force acting on that object is zero.

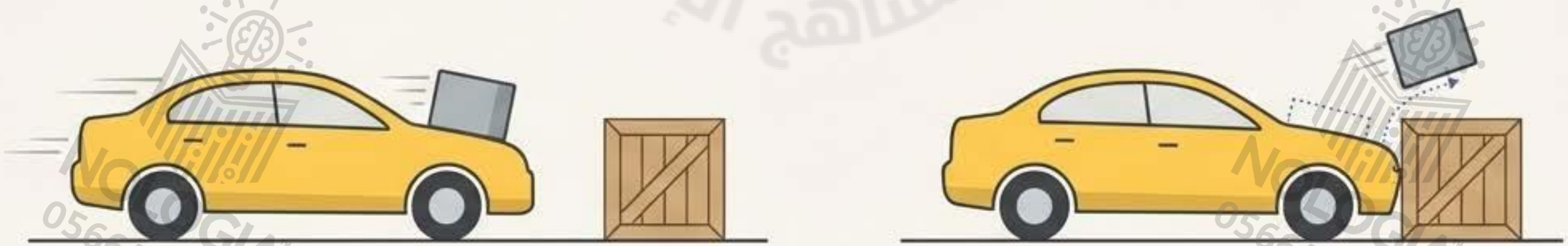
$F_{net} \neq 0$	$F_{net} = 0$
↓	↓
$a \neq 0$	$a = 0$
↓	↓
Change in Motion	**No Change in Motion (Inertia)**

This tendency of an object to resist changes in its velocity is called **inertia**.

Inertia in Action

Inertia is not a force; it is the property of mass to resist acceleration. Consider a car with a block resting on its hood, both moving at the same constant speed.

The Scenario: The car suddenly stops when it hits the wooden box. The car experiences a large net force, causing it to rapidly decelerate.
The Result: Because no significant horizontal force acts on the block, its inertia causes it to continue moving forward at its original speed, flying off the hood. It resists the change in motion that the car experienced.



From Mystery to Mastery

We began with a simple question: What causes a change in motion? The journey led us from the initial concept of force, through the essential tools of analysis, to the experimental evidence that illuminated the roles of mass and acceleration.

What causes a change in motion?

$$F_{net} = ma$$

The Answer: A change in motion is caused by a **net force**.
The Revelation: The relationship between that force, an object's mass, and its resulting acceleration is not a mystery, but is described by one of the most powerful and elegant principles in science.

Module (4): Forces in One Dimension

02 Second Lesson: Weight and Drag Force

The Unseen Forces of Flight

Understanding Weight, Drag, and the Physics of a Skydiver's Journey

The Big Question: What Happens Next?

"How does the drag force change after a skydiver deploys their parachute?" To answer this, we need to understand the forces that govern their entire fall. Let's break down the journey, step by step.

It All Starts with Weight

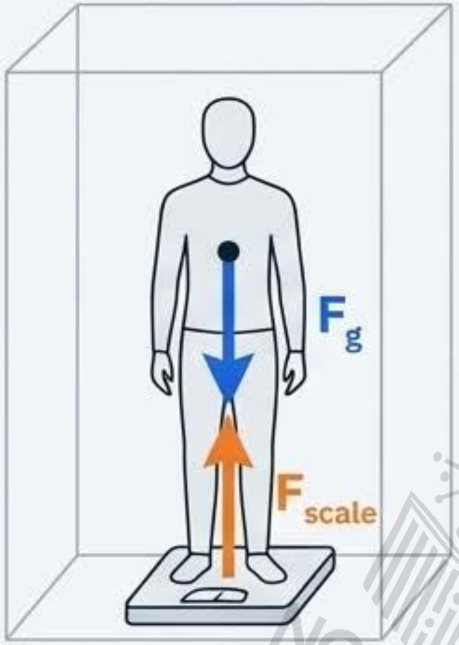
The instant a skydiver jumps, one force acts on them: Weight.

- **Weight (Fg)** is the gravitational force experienced by an object due to Earth's mass.
- It is a constant force, always pulling the skydiver toward the center of the Earth.
- The formula is $Fg = mg$, where m is mass and g is the gravitational field strength (near Earth's surface, g is 9.8 N/kg).

Is Weight What You Feel? Not Exactly.

Your weight (F_g) is constant, but your *sensation* of weight can change. This is **Apparent Weight**.

At Rest

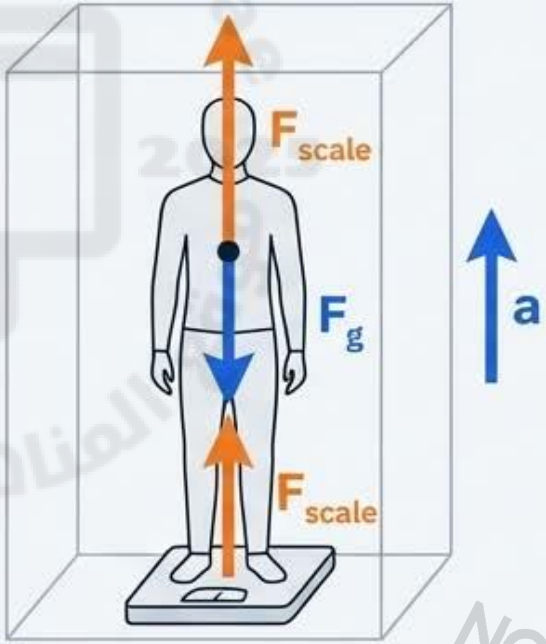


The scale reads your true weight. The upward force from the scale equals your weight.

($F_{scale} = F_g$).

For a 75.0 kg person, this is 735 N.

Accelerating Up

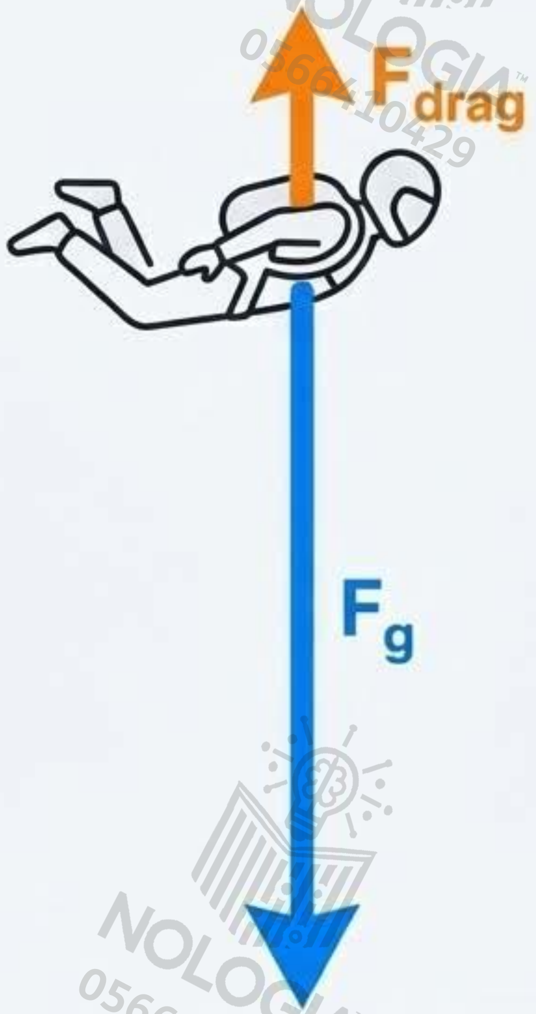


The floor pushes harder to accelerate you. You feel heavier, and the scale reads a higher value.

($F_{scale} > F_g$).

If accelerating at $2.00\ m/s^2$, the scale reads 885 N.

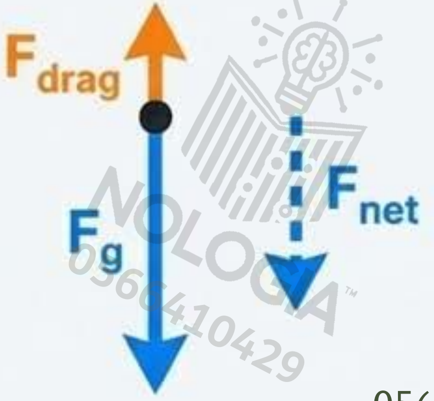
Key Idea: A skydiver experiences this same sensation of changing forces throughout their fall.



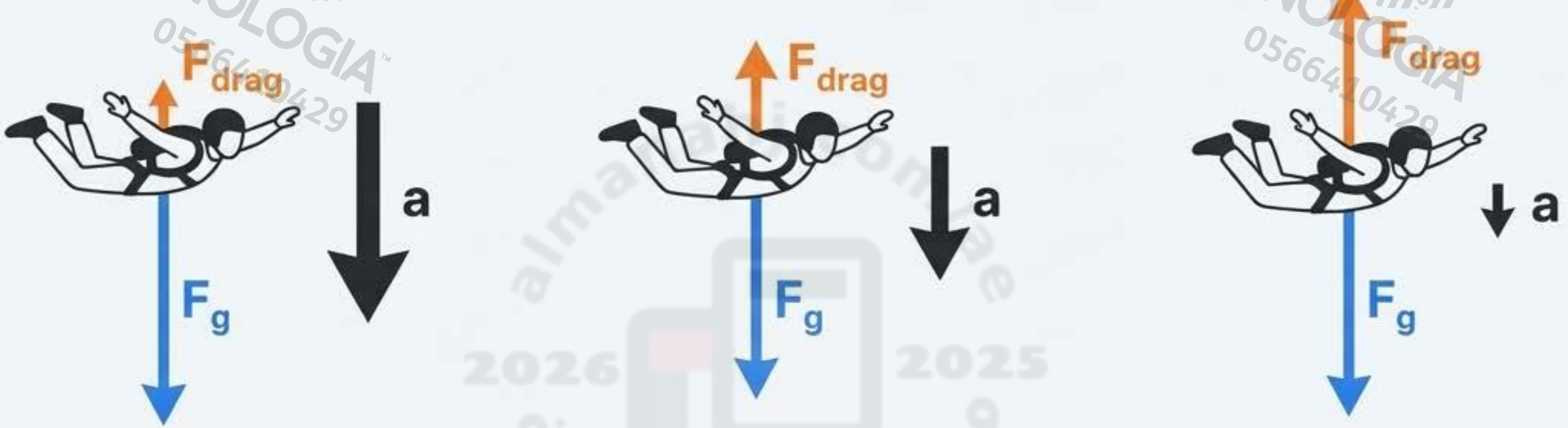
Meet Drag Force: The Air Pushing Back

As the skydiver's speed increases, they collide with more air particles. This creates an upward fluid friction called **Drag Force (Fdrag).**

- Drag is a force exerted by a fluid that opposes an object's motion.
- Drag is *not* constant. It increases with:
  - **Velocity:** The faster you go, the greater the drag.
  - **Surface Area:** A larger area pushes more air, creating more drag.
  - **Properties of the fluid** (like air density).



The Race to Equilibrium



Initially, the downward force of weight (F_g) is much greater than the upward drag force (F_{drag}).

- This creates a large downward Net Force ($F_{net} = F_g - F_{drag}$), causing the skydiver to accelerate (Newton's Second Law, $F_{net} = ma$).
- As velocity increases, F_{drag} increases.
- This reduces the net force and therefore reduces the acceleration.

Key Insight: The skydiver's acceleration is not constant. It is highest at the start and decreases as they approach top speed.

The Balance Point: Terminal Velocity

Eventually, the skydiver becomes so fast that the upward drag force perfectly balances the downward force of weight.

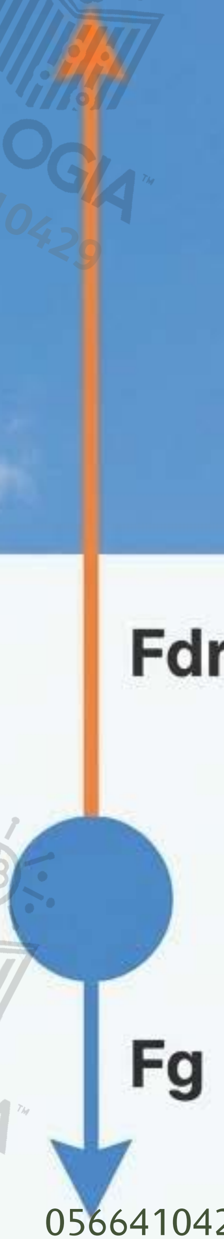
- At this point: $F_{drag} = F_g$
- The **Net Force** on the skydiver becomes zero ($F_{net} = 0$).
- With zero net force, there is **zero acceleration.** The skydiver stops speeding up and falls at a constant maximum speed. This is **Terminal Velocity.**

Data Point: For a typical skydiver, this is around 50 m/s (about 180 km/h).

Pull the Cord: Drastically Changing the Forces

The parachute is an engineering tool designed to do one thing: **massively increase surface area.**

- This causes an immediate and enormous increase in the **Drag Force (Fdrag)**.
- In this instant, the upward drag force becomes much greater than the downward force of weight.
- **Fdrag >> Fg**



The Answer: Drag Force Changes Dramatically

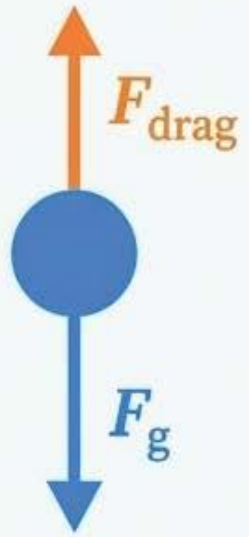
The deployment of the parachute causes a sudden, massive **increase** in drag force.

Key Insight: This creates a large **upward Net Force.** According to F_net = ma, an upward net force causes an upward acceleration. This means the skydiver rapidly **decelerates**, or slows down.

Finding a New, Slower Balance

As the skydiver slows down, the drag force (which depends on velocity) decreases again.

- Eventually, the smaller drag force perfectly balances the skydiver's weight once more.
- $F_{drag} = F_g$
- The net force is zero again, and the skydiver reaches a new, much slower terminal velocity.



Data Point: This new terminal velocity is safe for landing, typically around 5 m/s (18 km/h).

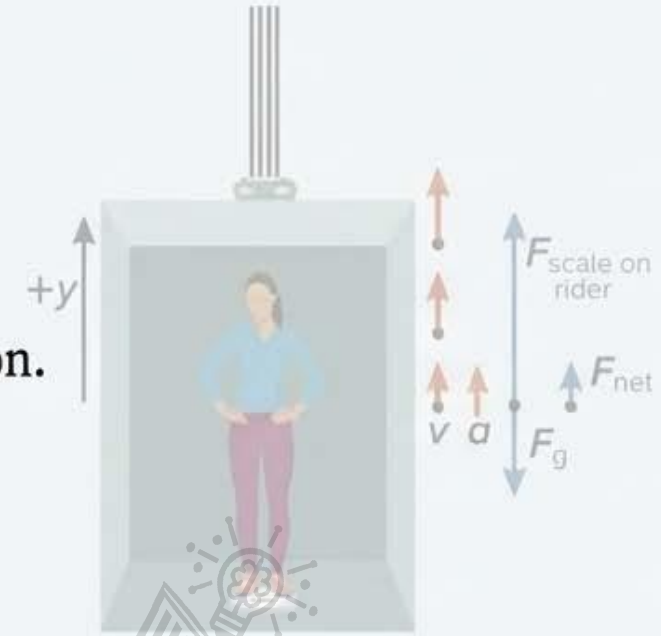
The Skydiver's Journey: A Summary of Forces

1. The Leap — F_g dominates. F_{net} is large, acceleration is maximum.
2. The Fall — Speed increases, F_{drag} increases, acceleration decreases.
3. Terminal Velocity 1 — $F_g = F_{drag}$. $F_{net} = 0$, acceleration is zero. Constant high speed.
4. Parachute Deploys — $F_{drag} >> F_g$. F_{net} is large and upward. Rapid deceleration.
5. The Descent — Speed decreases, F_{drag} decreases until...
6. Terminal Velocity 2 — $F_g = F_{drag}$. $F_{net} = 0$, acceleration is zero. Constant slow speed.

A Strategy for Any Force Problem

The same logic applies to any problem involving forces and motion. Follow these steps:

1. Read the problem carefully, and sketch a pictorial model.
2. Circle the system and choose a coordinate system.
3. Create a physical model by drawing a motion diagram.
4. Create a free-body diagram showing the direction of the acceleration.
5. Use Newton's laws to link acceleration and net force.
6. Rearrange the equation to solve for the unknown quantity.
7. Substitute known quantities and solve.
8. Check your results to see if they are reasonable.



Weight and Drag are Everywhere

The principles we've discussed apply to countless real-world scenarios:

- **Engineering:** Designing aerodynamic cars, planes, and buildings.
- **Logistics:** Using parachutes to safely deliver heavy supplies, as seen in the 'Physics Challenge' with the 415-kg container.
- **Biology:** The shape of a bird's wing or a dandelion seed is optimized for interacting with air.

Your Core Concepts Checklist

Weight (Fg): The constant gravitational force exerted by a large body, like a planet, on an object. Fg = mg.

Drag Force (Fdrag): A variable fluid friction force that opposes motion. It increases with velocity and surface area.

Terminal Velocity: The constant speed that a freely falling object eventually reaches when the resistance of the medium through which it is falling equals the force of gravity.

Apparent Weight: The force an object experiences as a result of all the forces acting on it, which can change with acceleration.

You've Landed the Concepts.

Questions?

Module (4): Forces in One Dimension

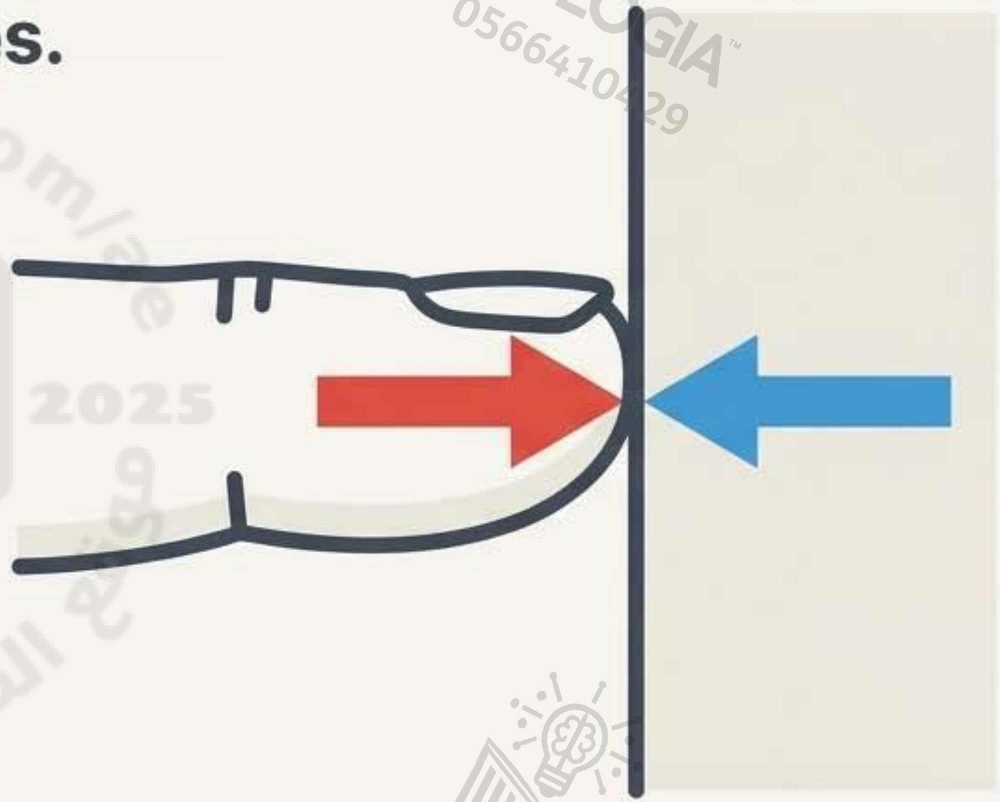
03 Third Lesson: Newton’s Third Law

The Symmetrical Universe

A fundamental question about forces.

If you push on a wall, what force does the wall exert on you?

This question leads to a paradox: If every force is met with an equal and opposite reaction, why does anything move at all? Why isn't the universe at a permanent standstill?



A stylized representation of an interaction pair: The force the finger exerts on the wall, and the equal and opposite force the wall exerts on the finger.

The First Clue: Newton's Third Law

Core Principle

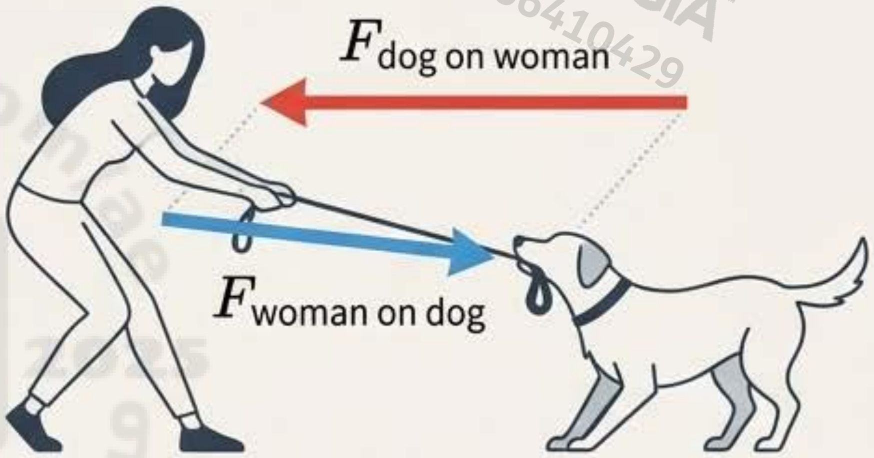
All forces come in pairs. For every action, there is an equal and opposite reaction.

Formal Definition

The force of object A on object B is equal in magnitude and opposite in direction to the force of object B on A.

Equation

$$\vec{F}_{A \text{ on } B} = -\vec{F}_{B \text{ on } A}$$

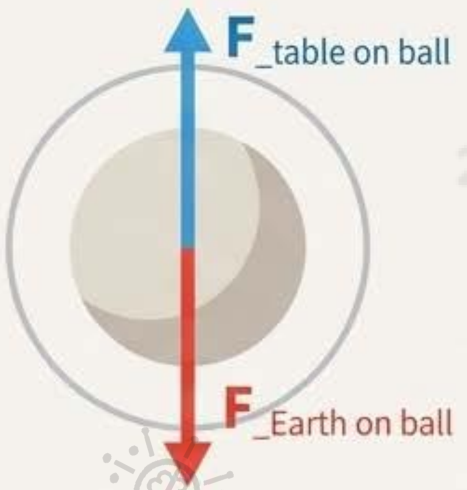


Evidence: Consider a woman and her dog. The force the dog exerts on the woman is perfectly matched by the force the woman exerts on the dog. These two forces are an interaction pair: a set of two forces that are in opposite directions, have equal magnitudes, and act on different objects.

A Critical Distinction: Not All Opposite Forces Are an Interaction Pair

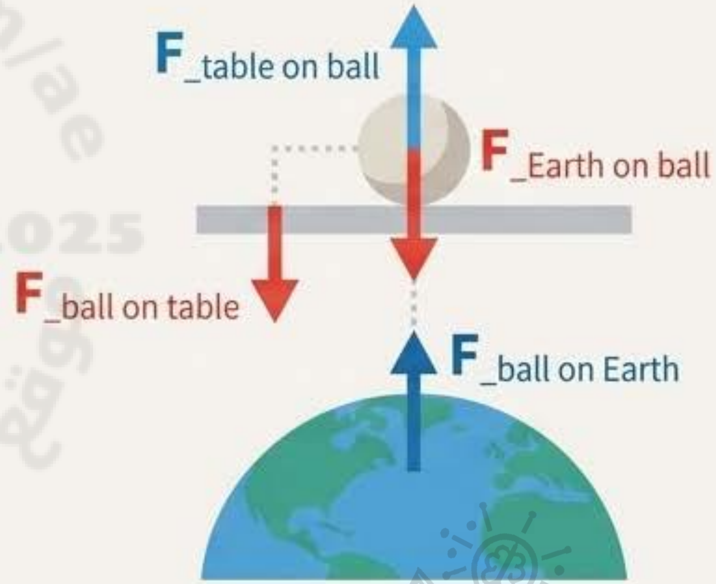
The Scenario: A ball rests on a table.

Common Misconception: Forces on a Single System (The Ball)



These forces are equal and opposite, but they are **NOT an interaction pair**. Why? Because they both act on the *same object* (the ball).

The Reality: True Interaction Pairs



The true pairs act on different objects. The table and ball interact, and the Earth and ball interact.

The Paradox Solved: Equal Forces, Unequal Fates

The Case: A 0.18 kg softball is in freefall, interacting with the Earth (mass = 6.0×10^{24} kg).

The Forces are Equal

Force of Earth on ball (Weight)

$F = mg$

$(0.18\ \text{kg})(-9.8\ \text{N/kg}) =$

-1.8 N

Force of ball on Earth (3rd Law)

$F_{\text{ball on Earth}} = -F_{\text{Earth on ball}}$

+1.8 N

The softball pulls up on the entire planet with a force of 1.8 N.

The Accelerations are Not

Softball's Acceleration

$$a = \frac{F}{m} = \frac{-1.8\ \text{N}}{0.18\ \text{kg}}$$

$-9.8\ \text{m/s}^2$

Earth's Acceleration

$$a = \frac{F}{m} = \frac{1.8\ \text{N}}{(6.0 \times 10^{24}\ \text{kg})}$$

$2.9 \times 10^{-25}\ \text{m/s}^2$

The world isn't at a standstill because while the ***forces*** in an interaction pair are always equal, the ***effects*** (acceleration) depend entirely on the mass of the objects involved.

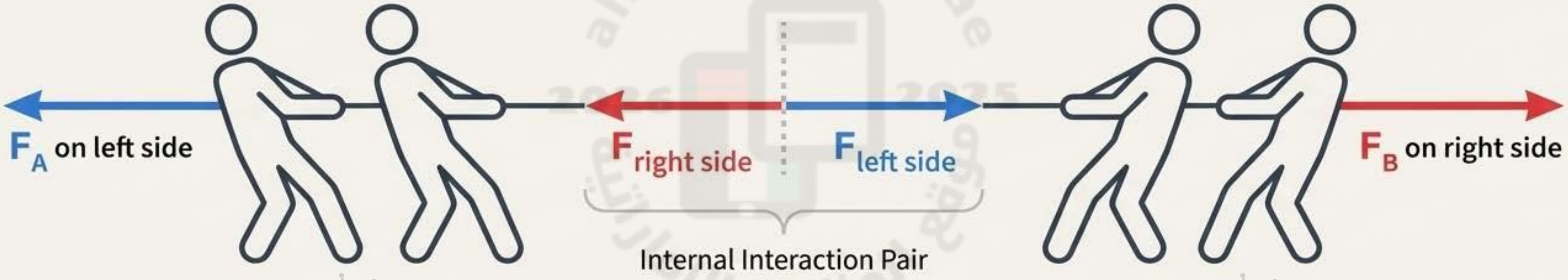
Case File #1: Tension, The Internal Conversation of a Rope

Definition

Tension is a specific name for the force that a string or rope exerts. In a simplified (massless) rope, tension is constant throughout.

How it Works

In a tug-of-war, Team A pulls on the rope. By Newton's Third Law the rope pulls back on Team A. This force is transmitted through the rope to Team B. At the other end, the rope pulls on Team B, and Team B pulls back on the rope.

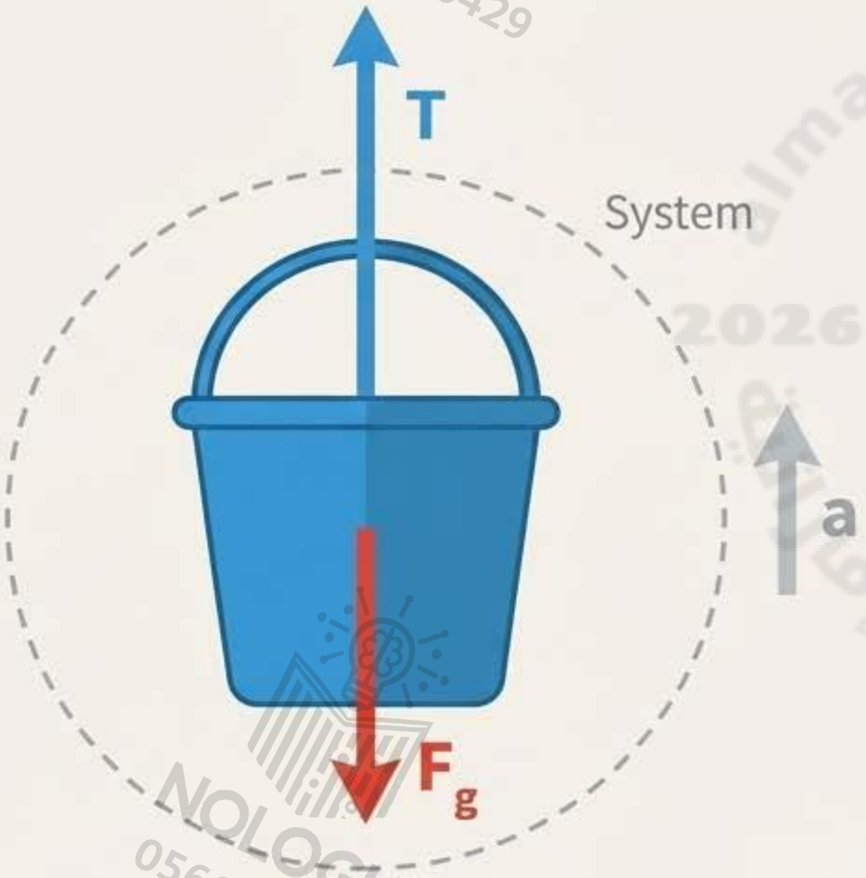


The Interaction Pairs

The force of Team A on the rope and the rope on Team A are one pair. The force of Team B on the rope and the rope on Team B are another. Internally, the force of the left half on the right half and the right half on the left half form a pair. The magnitude of these internal forces is the tension. If Team A pulls with 500 N and there is no acceleration, Team B must also pull with 500 N.

Tension in Motion: Lifting a Bucket

Problem Statement: A 50.0 kg bucket is lifted by a rope. It starts at rest and reaches a speed of 3.0 m/s after being lifted 3.0 m. What is the tension (T) in the rope?



1. Identify Forces

The upward tension (T) and the downward force of gravity (F_g).

2. Calculate Acceleration

Since the bucket is speeding up, there is a net upward force.

Using the kinematic equation $v_f^2 = v_i^2 + 2ad$:

$a = (v_f^2 / 2d) = (3.0\ m/s)^2 / (2 * 3.0\ m) = 1.5\ m/s^2$.

3. Apply Newton's Second Law

$F_{net} = ma$.

$F_{net} = T - F_g$.

$T = F_{net} + F_g = ma + mg$

4. Solve for Tension

$T = 50.0\ kg\ (1.5\ m/s^2 + 9.8\ m/s^2) =$ **560 N**.

The tension (560 N) is greater than the bucket's weight (mg = 490 N). This additional force is required to accelerate the bucket upward.

Case File #2: The Normal Force, A Surface's Responsive Push

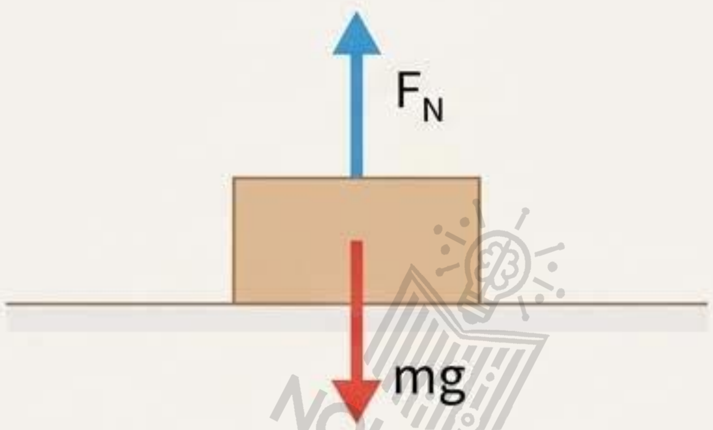
Definition

The normal force (F_N) is the perpendicular contact force that a surface exerts on an object. It is the force that prevents objects from passing through each other.

Key Insight

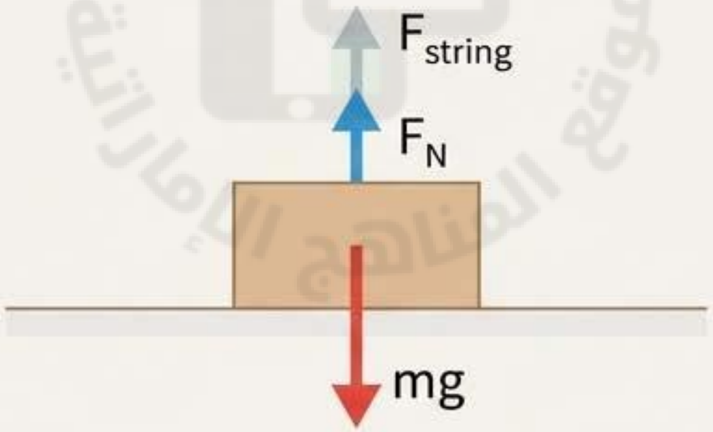
The normal force is not always equal to an object's weight. It adjusts based on other vertical forces.

Object at Rest



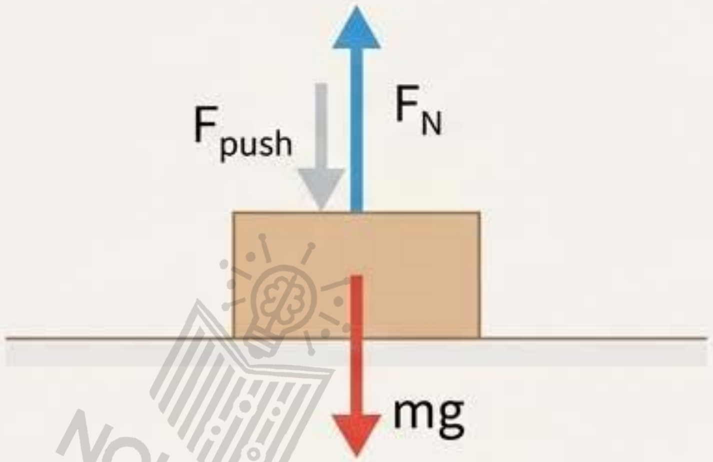
$F_N = mg$

Pulling Up Gently



$F_N = mg - F_{string}$

Pushing Down



$F_N = mg + F_{push}$

The Physicist's Toolkit: A 7-Step Method for Analyzing Interactions

A systematic approach to deconstruct any problem involving force interactions.

1. **Isolate the Systems**
   Define the objects of interest and separate them from their environment.
2. **Draw the Diagram**
   Create a pictorial model with coordinate systems for each system.
3. **Identify Interactions**
   Draw free-body diagrams for each system, showing all forces acting on it.
4. **Connect the Pairs**
   Use dashed lines to explicitly link the action-reaction pairs between systems.
5. **Apply the Second Law** ($\vec{F}=m\vec{a}$)
   For each system, use F_net = ma to relate forces and acceleration.
6. **Apply the Third Law**
   Set the magnitudes of interaction pair forces equal to each other.
7. **Solve and Verify**
   Solve the system of equations and check that the answer's units, signs, and magnitude are physically reasonable.

The Principle of Interaction

The Investigation Concludes: Forces never exist in isolation. They are the result of a mutual interaction between two objects. You cannot touch without being touched.

Revisiting the Paradox:
- If you push on a wall, the wall pushes back on you with an equal force. This is the law.
- Why isn't the world at a standstill? Because these equal forces act on **different objects**. Your push acts on the wall; the wall's push acts on you.
- The outcome is determined by each object's mass and the net sum of *all* forces acting upon it.

The Fundamental Truth: Newton's Third Law isn't about balanced forces canceling each other out. It's the law that governs the symmetry of every interaction in the universe.

ختاماً، نسأل اللّه أن يوفقكم، وأن
تكون هذه الملزمة قد حققت
الفائدة المرجوة ❤

لا تتردد في التواصل معنا
قم بمسح رمز الـQR