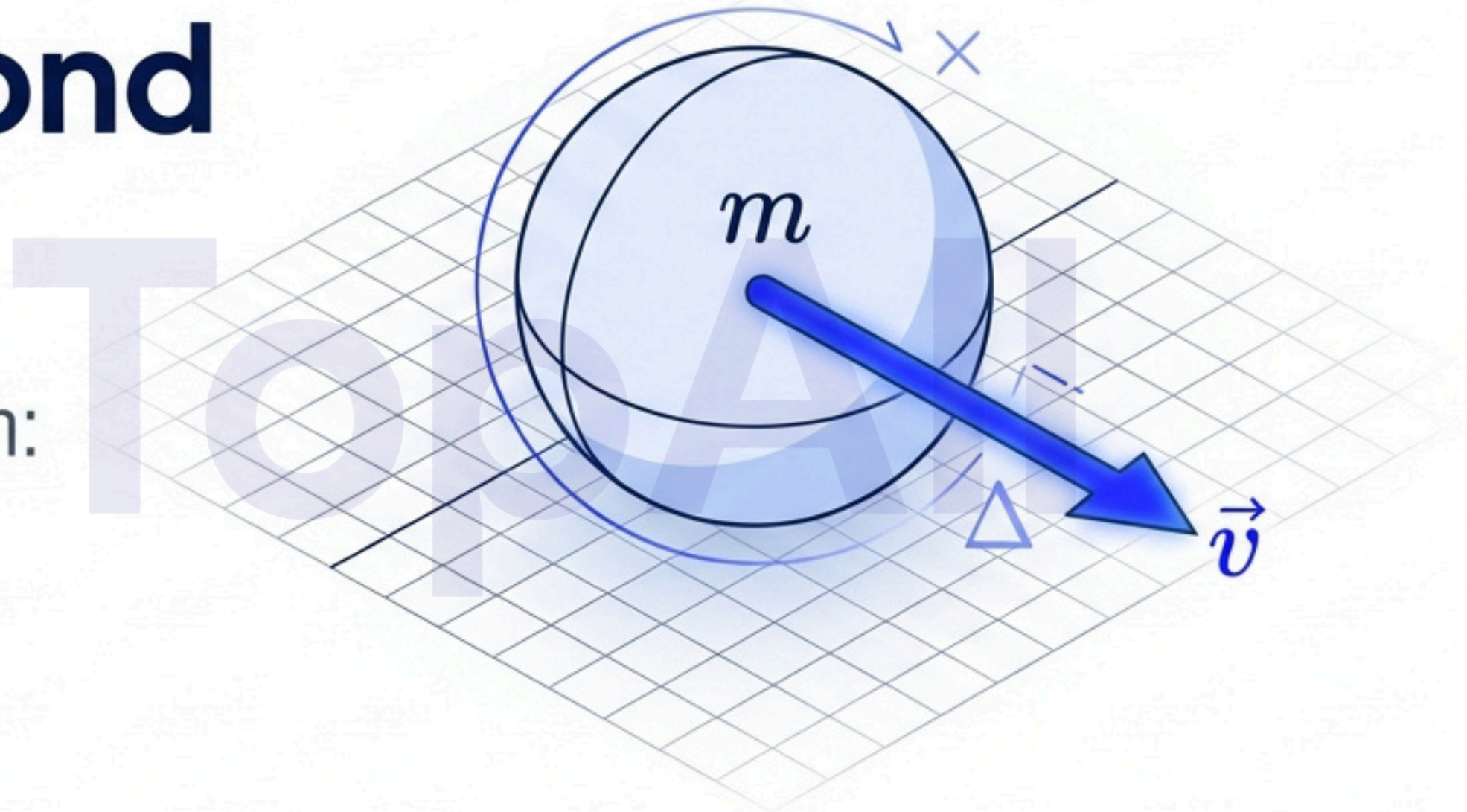


CLASS 11 PHYSICS • CHAPTER 4.5

Newton's Second Law of Motion

From Momentum to Acceleration:
Understanding the forces that
govern the universe.

Target Exams: NEET / JEE



Understanding Momentum

Momentum is the "quantity of motion" contained in a body. It combines how heavy an object is with how fast it is moving.

EQ. (4.1)

$$p = m \times v$$

Momentum (**p**) is a vector quantity (acting in the exact same direction as velocity).

Mass Matters



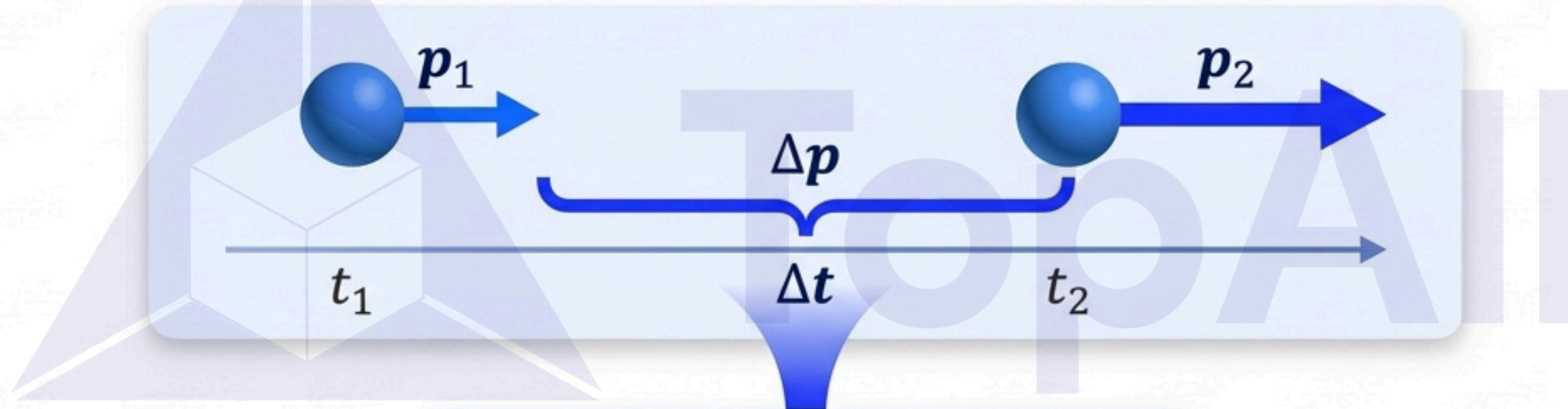
Velocity Matters



Force Changes Momentum

A force is required to change an object's momentum. **Crucially**, the **magnitude** of the force depends entirely on how **fast** that change happens.

- ✓ Same momentum change in a shorter time = Greater force.
- ✓ Force acts in the exact direction of the change in momentum.



NEWTON'S SECOND LAW | EQ. (4.2)

$$F = \frac{dp}{dt}$$

The rate of change of momentum is directly proportional to the applied net force.



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$$E=mc^2$$



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Deriving $F = ma$

Step 1: Start with the core law

$$\mathbf{F} = \frac{d\mathbf{p}}{dt}$$

Step 2: Substitute momentum ($\mathbf{p} = m\mathbf{v}$)

$$\mathbf{F} = \frac{d(\mathbf{mv})}{dt}$$

Step 3: For a body of fixed mass m , pull m out

$$\mathbf{F} = \mathbf{m}\left(\frac{d\mathbf{v}}{dt}\right)$$

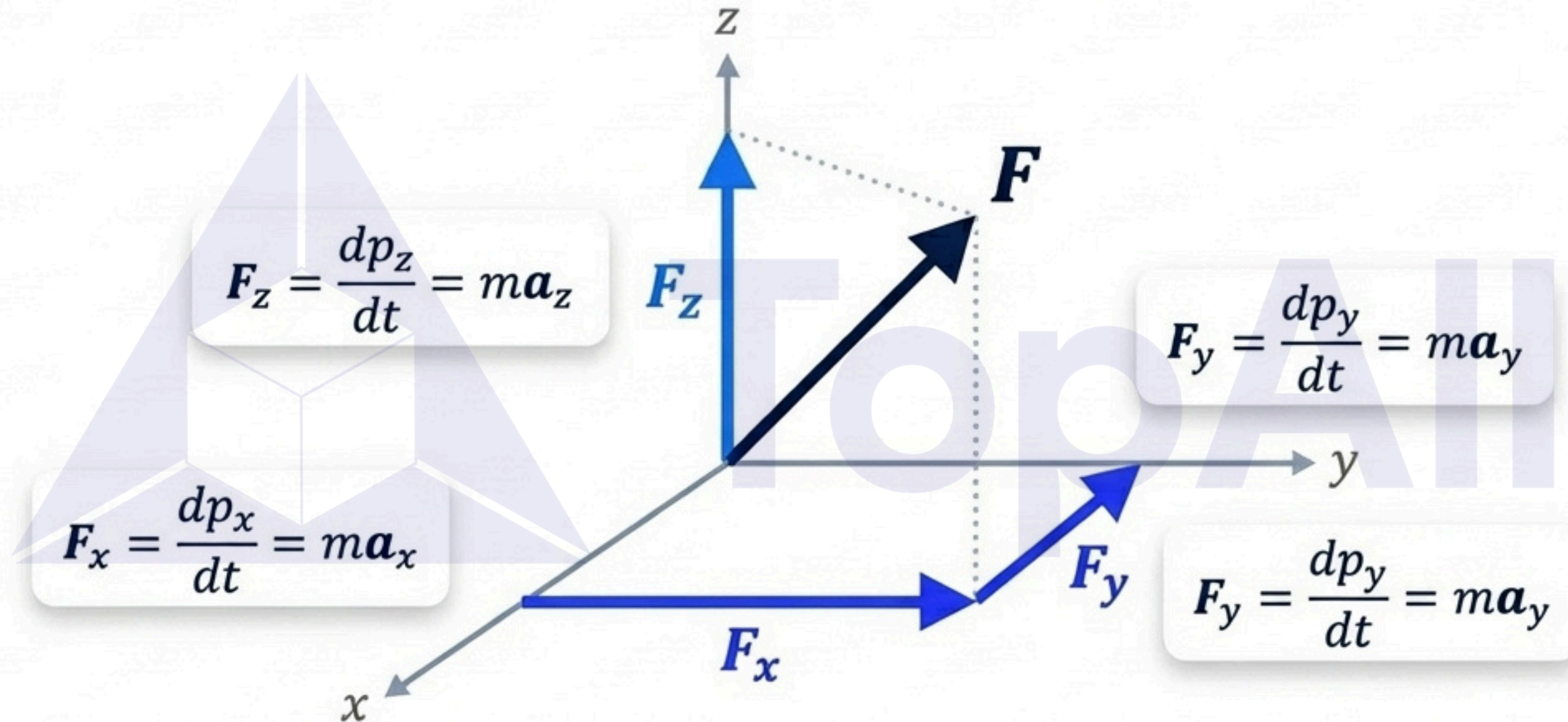
Step 4: Since acceleration $\mathbf{a} = d\mathbf{v}/dt$

$$\mathbf{F} = \mathbf{ma} \quad (\text{Eq. 4.5})$$

EXAM TIP: In SI units, the proportionality constant $k = 1$, making 1 Newton exactly equal to $1 \text{ kg}\cdot\text{m}/\text{s}^2$.

The Vector Nature of Force

The second law is actually three independent equations. A force only changes the **velocity** component that is parallel to it.



EXAM TIP | Projectile Motion: Gravity acts vertically (y -axis). Therefore, horizontal velocity (x -axis) remains completely unchanged!

Impulse: Short, Massive Forces

Sometimes a massive force acts for a tiny duration (like a bat hitting a ball). We measure this total effect as **Impulse**.

EQ. (4.7)

$$\begin{aligned}\text{Impulse} &= \text{Force} \times \text{Time Duration} \\ &= \text{Change in Momentum}\end{aligned}$$

Catching a Cricket Ball

Novice (Hands Fixed)



Ball stops instantly $\rightarrow$ Time is short $\rightarrow$
 $\rightarrow$ Force on hands is massive (It hurts!).

Pro (Hands Drawn Back)



Increases the time (Δt) to stop the ball
 $\rightarrow$ Force is vastly reduced.

Key Takeaways

- ✓ **Momentum ($p=mv$):** The core variable of motion. Force is simply the rate at which this momentum changes ($F=dp/dt$).
- ✓ **$F=ma$ requires constant mass:** The famous equation is a special case of the Second Law, assuming mass doesn't change.
- ✓ **Independent Axes:** Forces act completely independently in the x, y, and z directions.
- ✓ **Impulse:** A large force over a tiny time interval. Increasing contact time decreases the applied force.

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