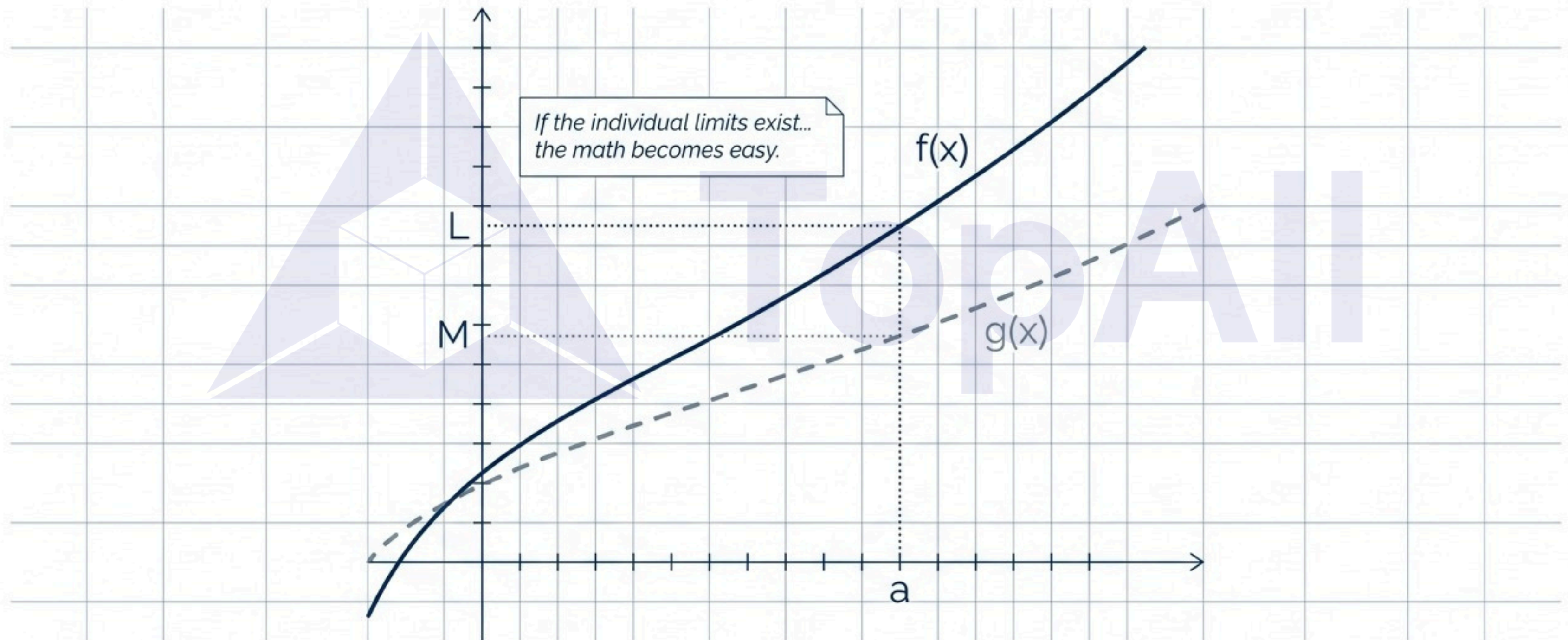


Limit Rules That Simplify Calculations

12.3.1 Algebra of Limits: Breaking Down Complex Functions



When calculating limits of complex functions, you don't have to evaluate them as a single, overwhelming block.

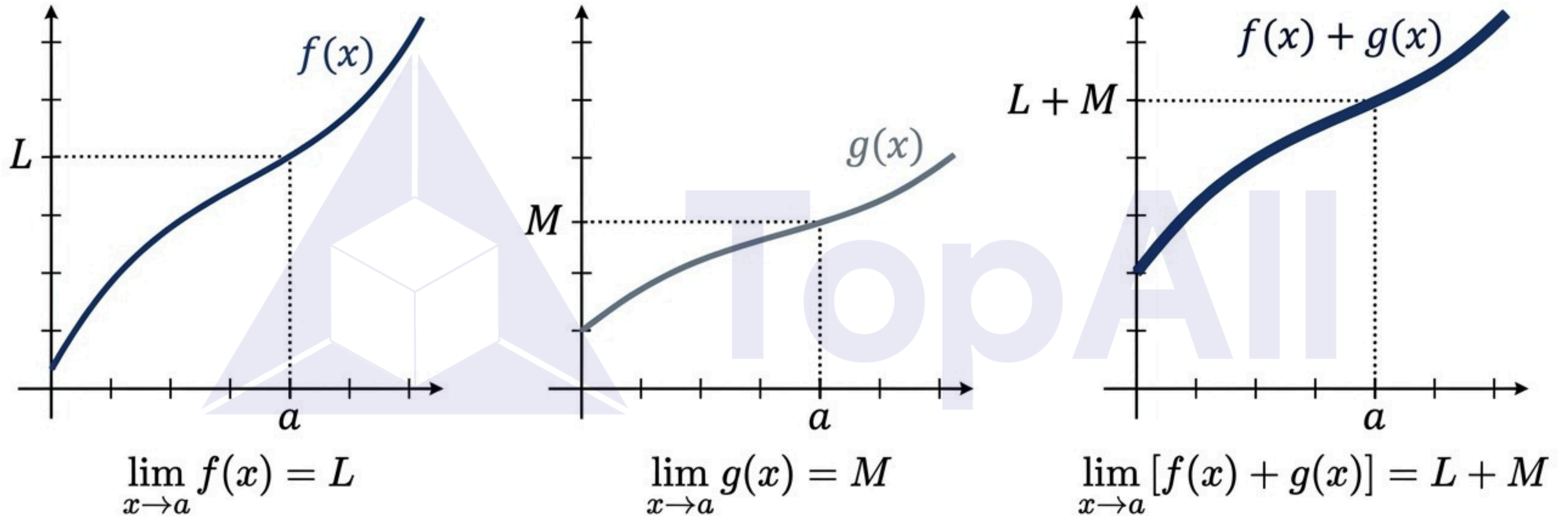
The Algebra of Limits proves that the limiting process seamlessly respects basic arithmetic:

- Addition
- Subtraction
- Multiplication
- Division

Key Takeaway: The Principle of Separation

If you know the individual limits of two **well-defined functions** at a point, you can algebraically **combine those limits to find the limit of the combined function.**

Visualizing the Algebra of Limits



The limit of a sum is literally the sum of the physical heights (L and M) that the original curves approach.



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$$E=mc^2$$



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Given two functions where both $\lim_{x \rightarrow a} f(x)$ and $\lim_{x \rightarrow a} g(x)$ **exist**:

Sum

$$\lim_{x \rightarrow a} [f(x) + g(x)] = \lim_{x \rightarrow a} f(x) + \lim_{x \rightarrow a} g(x)$$

Difference

$$\lim_{x \rightarrow a} [f(x) - g(x)] = \lim_{x \rightarrow a} f(x) - \lim_{x \rightarrow a} g(x)$$

Product

$$\lim_{x \rightarrow a} [f(x) * g(x)] = \lim_{x \rightarrow a} f(x) * \lim_{x \rightarrow a} g(x)$$

For a constant λ , $\lim_{x \rightarrow a} [\lambda * f(x)] = \lambda * \lim_{x \rightarrow a} f(x)$

Quotient

$$\lim_{x \rightarrow a} \left[\frac{f(x)}{g(x)} \right] = \frac{\lim_{x \rightarrow a} f(x)}{\lim_{x \rightarrow a} g(x)}$$

JEE TRAP ALERT: The Denominator Trap

The Quotient Rule is the only algebraic limit rule with a strict mathematical condition.

You can only apply: $\lim_{x \rightarrow a} \left[\frac{f(x)}{g(x)} \right] = \frac{\lim_{x \rightarrow a} f(x)}{\lim_{x \rightarrow a} g(x)}$

IF AND ONLY IF:

$$\lim_{x \rightarrow a} g(x) \neq 0$$

If the denominator limit is exactly zero, the **quotient rule fails**. You have hit an **indeterminate form** (like 0/0) or an undefined limit, requiring factorization, rationalization, or advanced calculus to resolve.

Mini Application: Polynomial Limits

How do we mathematically justify evaluating a polynomial like $\lim_{x \rightarrow 1} (x^2 + x)$?
We build it using the limit algebra.

Step 1: Apply Sum Rule

$$\lim_{x \rightarrow 1} (x^2 + x) = \lim_{x \rightarrow 1} (x^2) + \lim_{x \rightarrow 1} (x)$$

Step 2: Apply Product Rule (to x^2)

$$= \left[\lim_{x \rightarrow 1} (x) * \lim_{x \rightarrow 1} (x) \right] + \lim_{x \rightarrow 1} (x)$$

Step 3: Evaluate Base Limits (since $\lim_{x \rightarrow a} x = a$)

$$= [1 * 1] + 1$$

Step 4: Solve

$$= 1 + 1 = 2$$

*Because polynomials are just **sums** and **products** of x , their limits can always be evaluated by direct substitution.*

Before you apply the algebra of limits, you must pass one critical gateway check.

REVISION: EXISTENCE PRECEDES ALGEBRA

You can **ONLY** split a combined limit into separate parts if **the limits of those component functions actually exist**.

If $\lim_{x \rightarrow a} f(x)$ does not exist, or $\lim_{x \rightarrow a} g(x)$ does not exist, the rules of limit algebra are invalid—**even if the limit of their combined sum or product does happen to exist**.

Check for existence first. Split second.



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