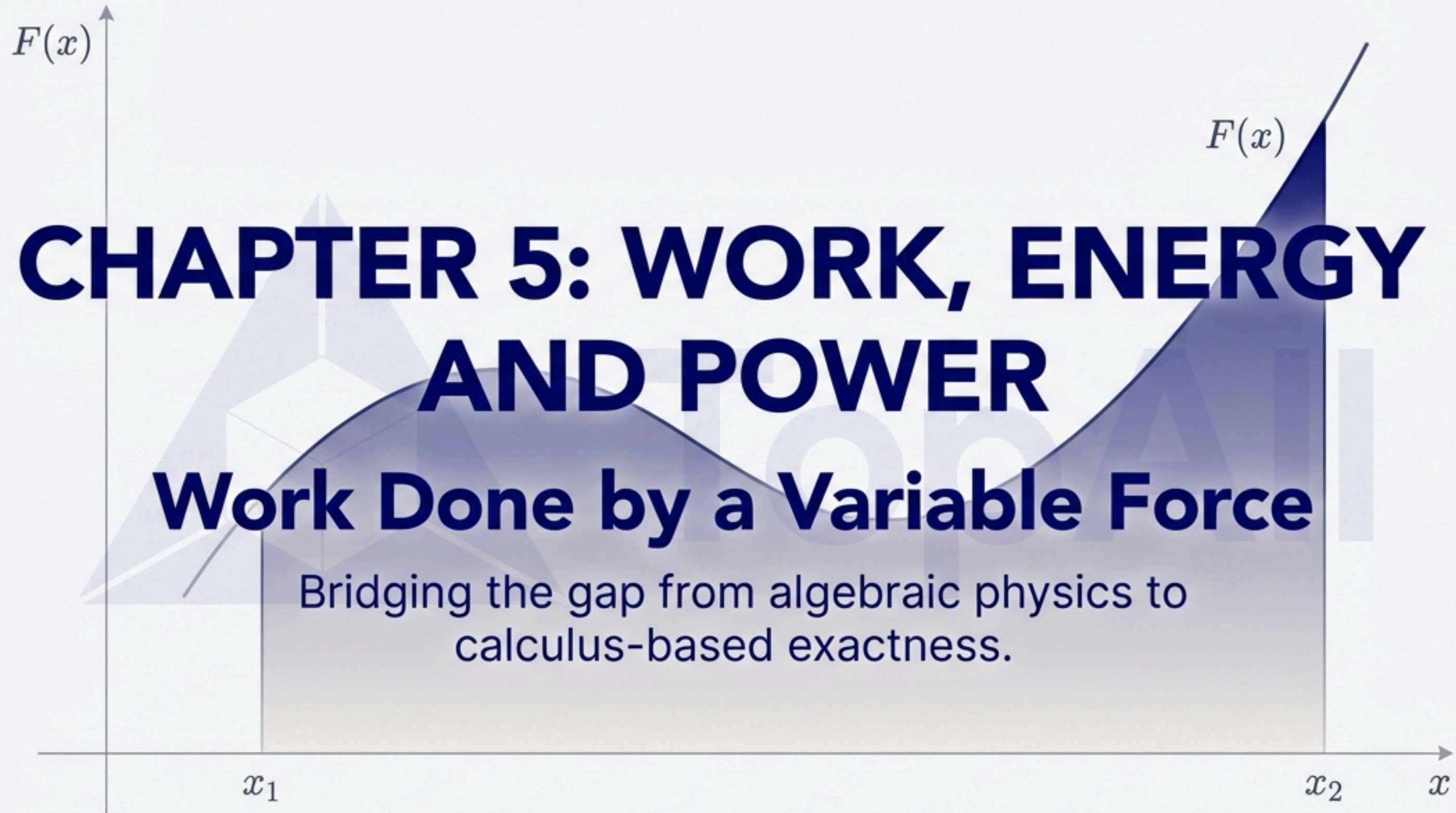


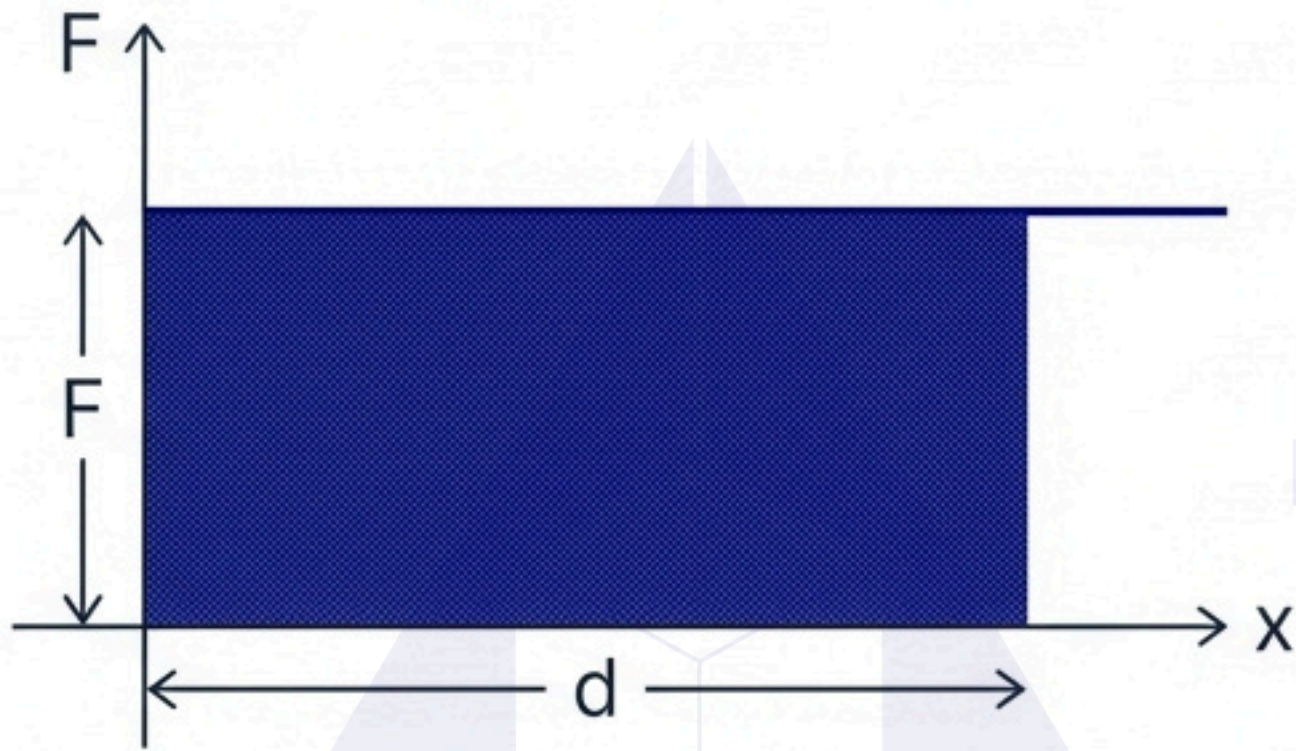


CHAPTER 5: WORK, ENERGY AND POWER

Work Done by a Variable Force

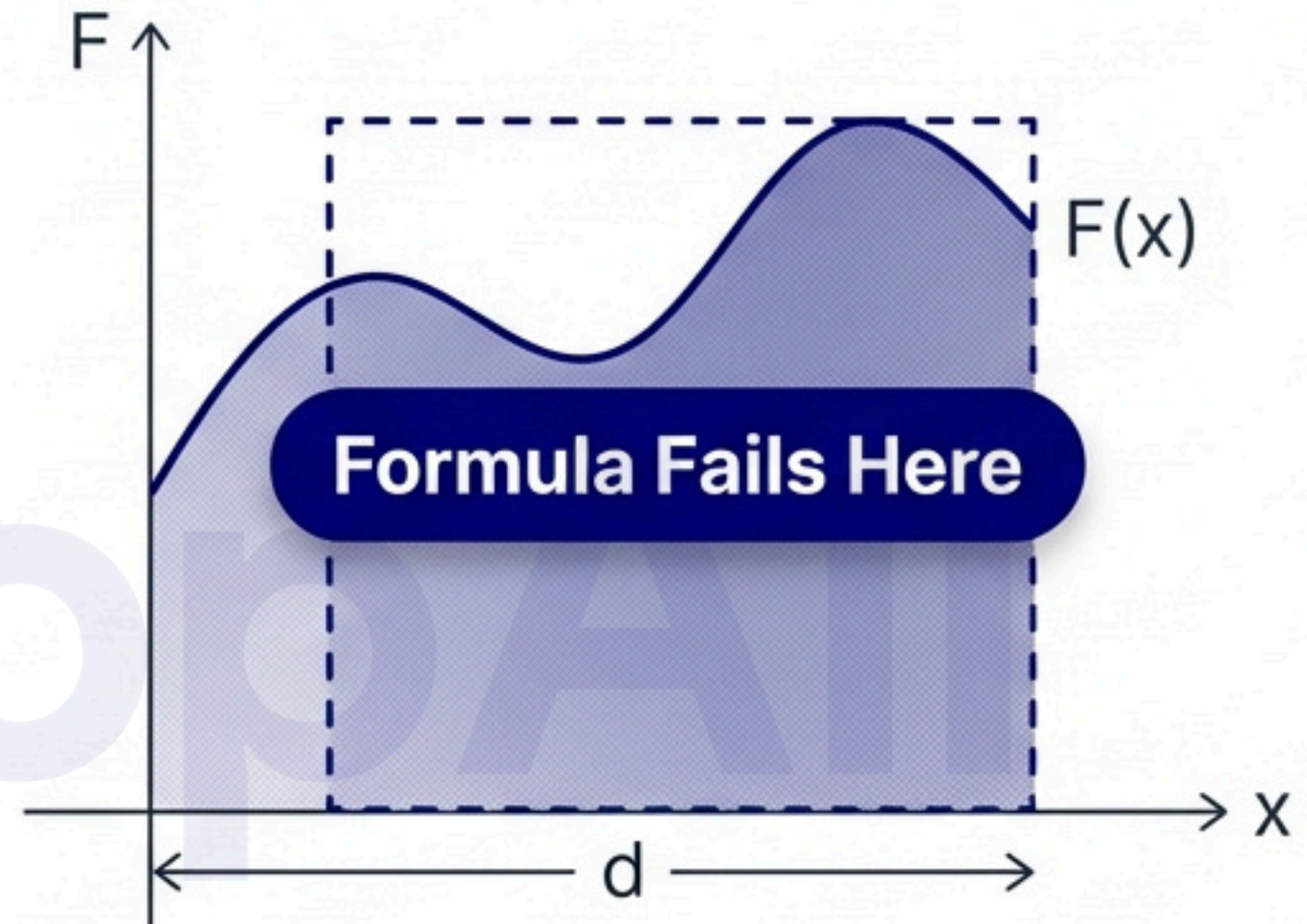
Bridging the gap from algebraic physics to
calculus-based exactness.

Constant Force



$$W = F \cdot d$$

Variable Force



Real-world forces—like compressing springs, variable gravity, or resistive drag—are rarely constant. Basic geometry cannot calculate this irregular area.

The Small Rectangles Approximation

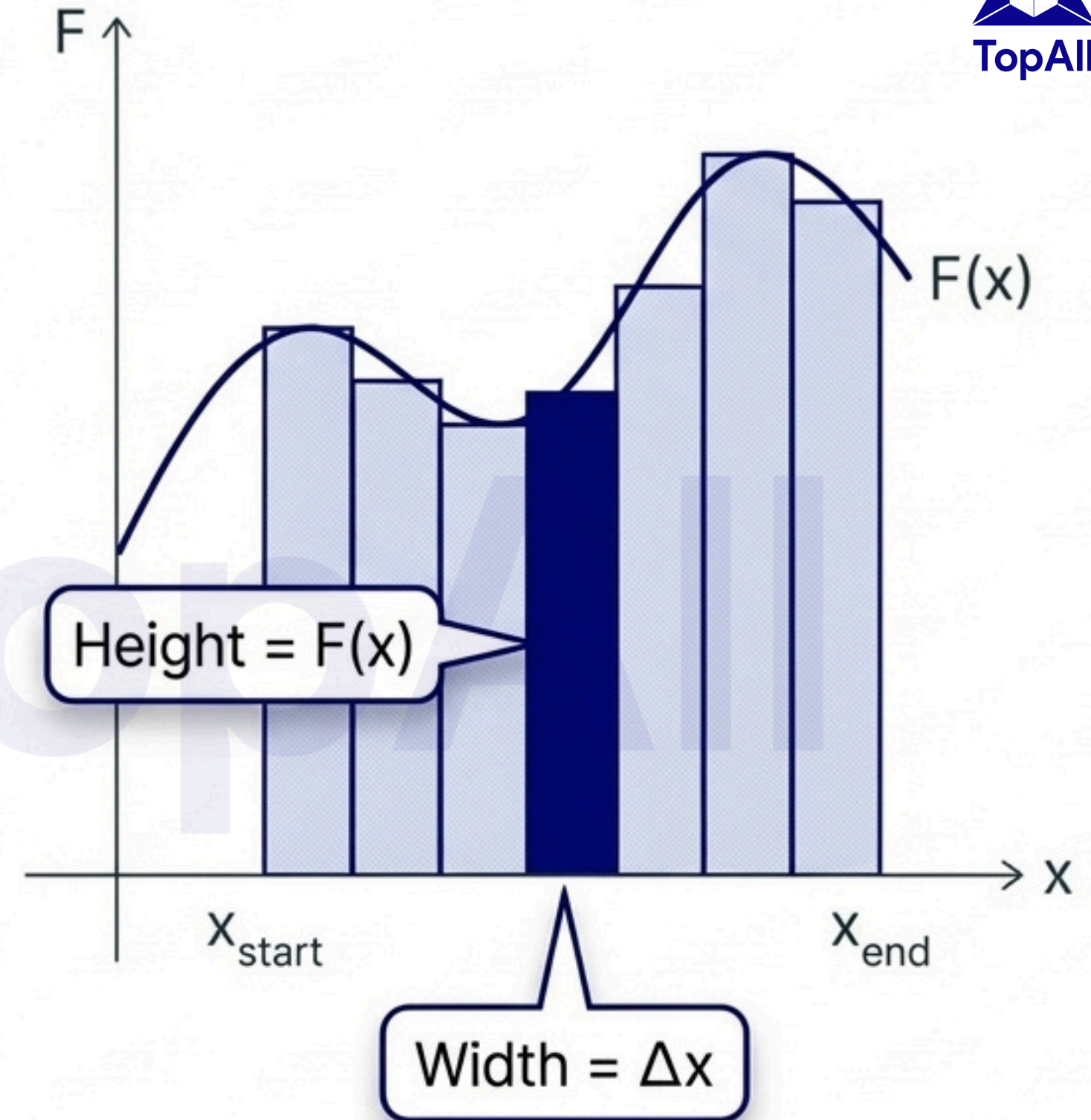
For an infinitesimally small displacement Δx , the variable force $F(x)$ is approximately constant.

Area of one piece:

$$\Delta W = F(x)\Delta x$$

Total approximated work:

$$W \cong \sum F(x)\Delta x$$





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$$E=mc^2$$



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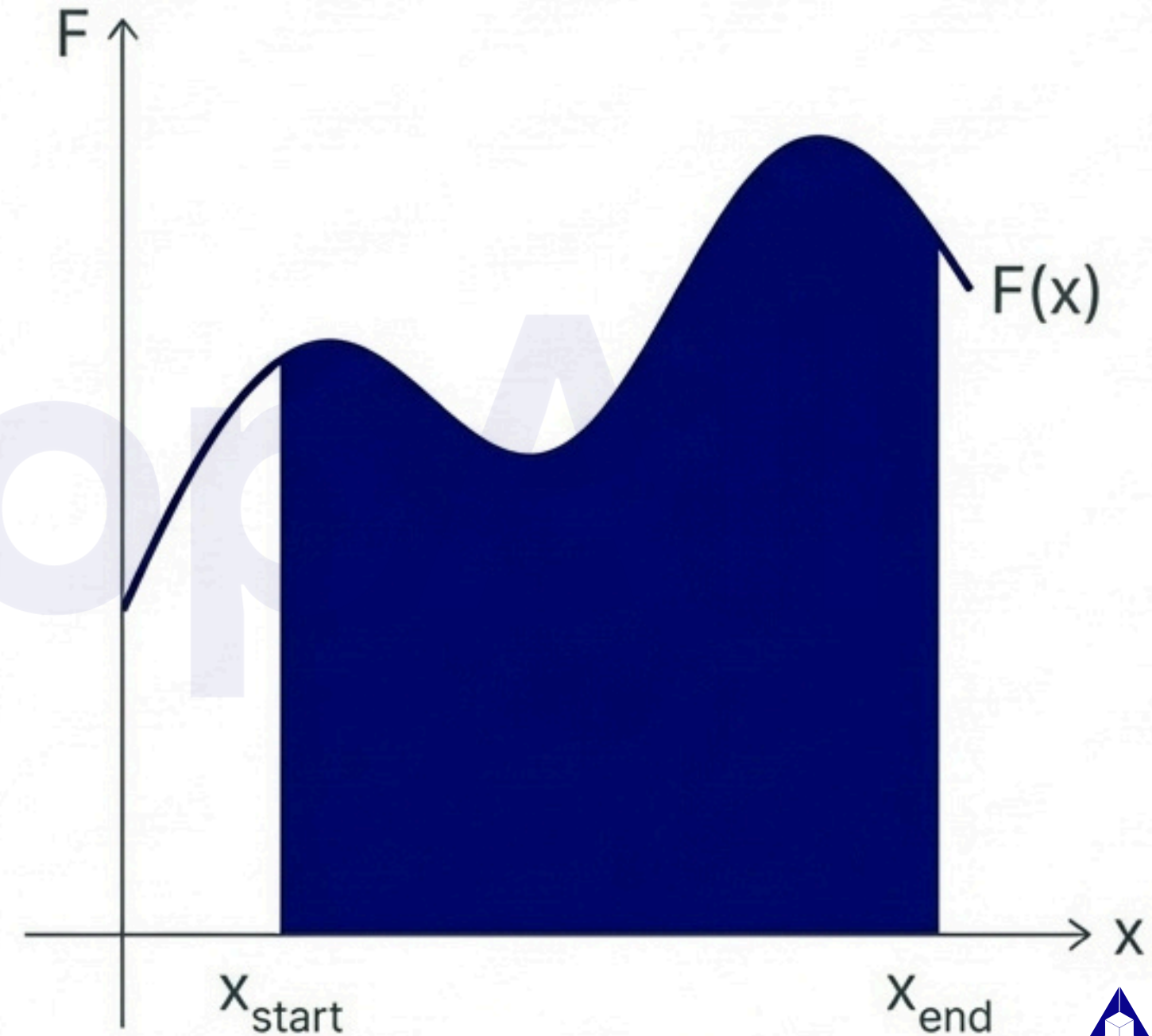


The Area Under the Curve

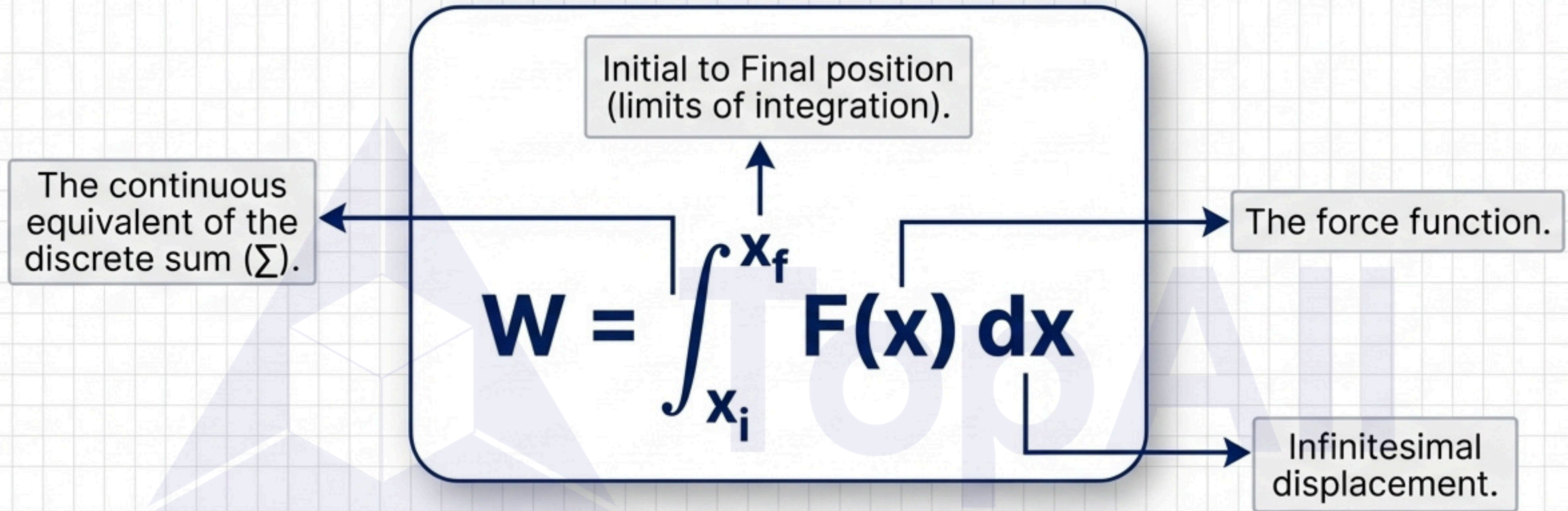
$$\Delta x \rightarrow 0$$

As the displacement width shrinks to zero, the number of rectangles approaches infinity. The sum of these rectangles becomes the exact continuous area under the F-x curve.

$$W = \lim_{\Delta x \rightarrow 0} \sum F(x) \Delta x$$



The Calculus Definition of Work



The diagram illustrates the calculus definition of work, $W = \int_{x_i}^{x_f} F(x) dx$, with several annotations:

- Initial to Final position (limits of integration).**: Points to the upper limit x_f of the integral.
- The continuous equivalent of the discrete sum (Σ).**: Points to the integral symbol $\int$.
- The force function.**: Points to $F(x)$.
- Infinitesimal displacement.**: Points to dx .

NEET/JEE Tip

The integral yields algebraic area. Area above the x-axis is positive work, while area below the x-axis represents negative work (e.g., resistive friction).



Key Takeaways

- **Constant Force = Basic Geometry**

Calculate work using the area of a simple rectangle ($W = F \cdot d$).

- **Variable Force = Integration**

When force changes with position, apply the integral formula: $W = \int F(x) dx$.

- **The Graphical Rule**

Total Work done is always exactly equal to the area under the Force-Displacement ($F-x$) graph.

- **Watch the Signs**

Area above the x -axis is positive work; area below the x -axis is negative work.



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