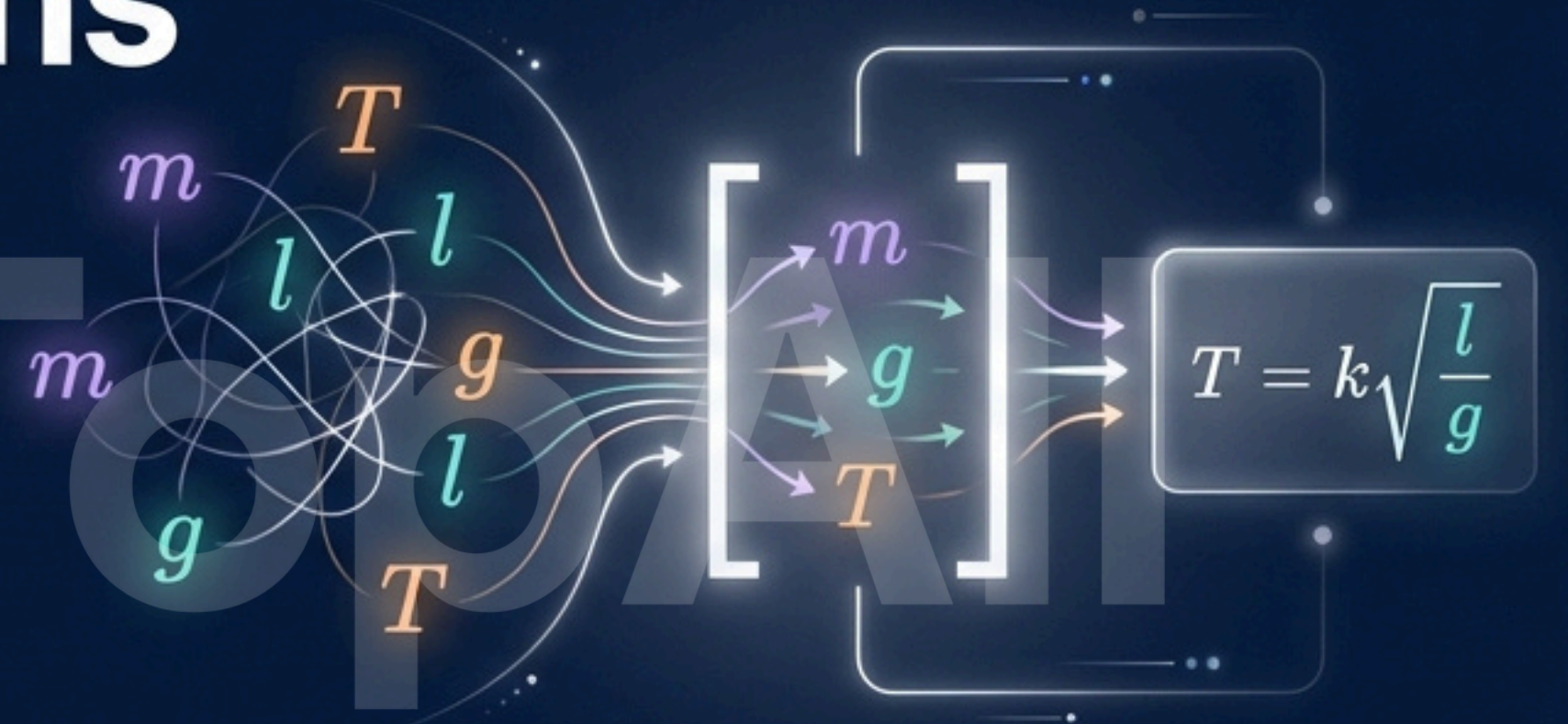


Deducing Relations Among Physical Quantities

Using Dimensional Analysis to Reverse-Engineer Formulas



Reverse-Engineering Physics Formulas



The Problem

We know a physical quantity depends on certain factors, but we don't know the exact formula connecting them.



The Dimensional Engine

If we assume a product-type dependence, we can use the **dimensions** of the **physical world** to reverse-engineer the exponents.



$$\Sigma = x^2 + b^1$$

The Output

The exact algebraic form of the relationship, up to an unknown dimensionless constant.

! The Rule of 3

This method works for a maximum of 3 independent variables, matching our three primary dimensions of mechanics: **Mass [M]**, **Length [L]**, and **Time [T]**.

The 3-Step Deduction Algorithm

1

The Setup (Define the Inputs)

Write the target quantity as a product of the variables raised to unknown exponents (x, y, z).

$$\text{Quantity} = k \cdot (\text{Var1})^x \cdot (\text{Var2})^y \cdot (\text{Var3})^z$$

k is a dimensionless constant.

2

The Substitution (Translate to Dimensions)

Replace every physical quantity on both sides of the equation with its fundamental dimensional formula.

$$[M^a L^b T^c] = [M, L, T \text{ terms}]$$

3

Homogeneity (Equate & Solve)

Apply the Principle of Homogeneity. Equate the powers of M, L, and T from both sides to create three simple linear equations. Solve for x, y, and z.



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$$E=mc^2$$



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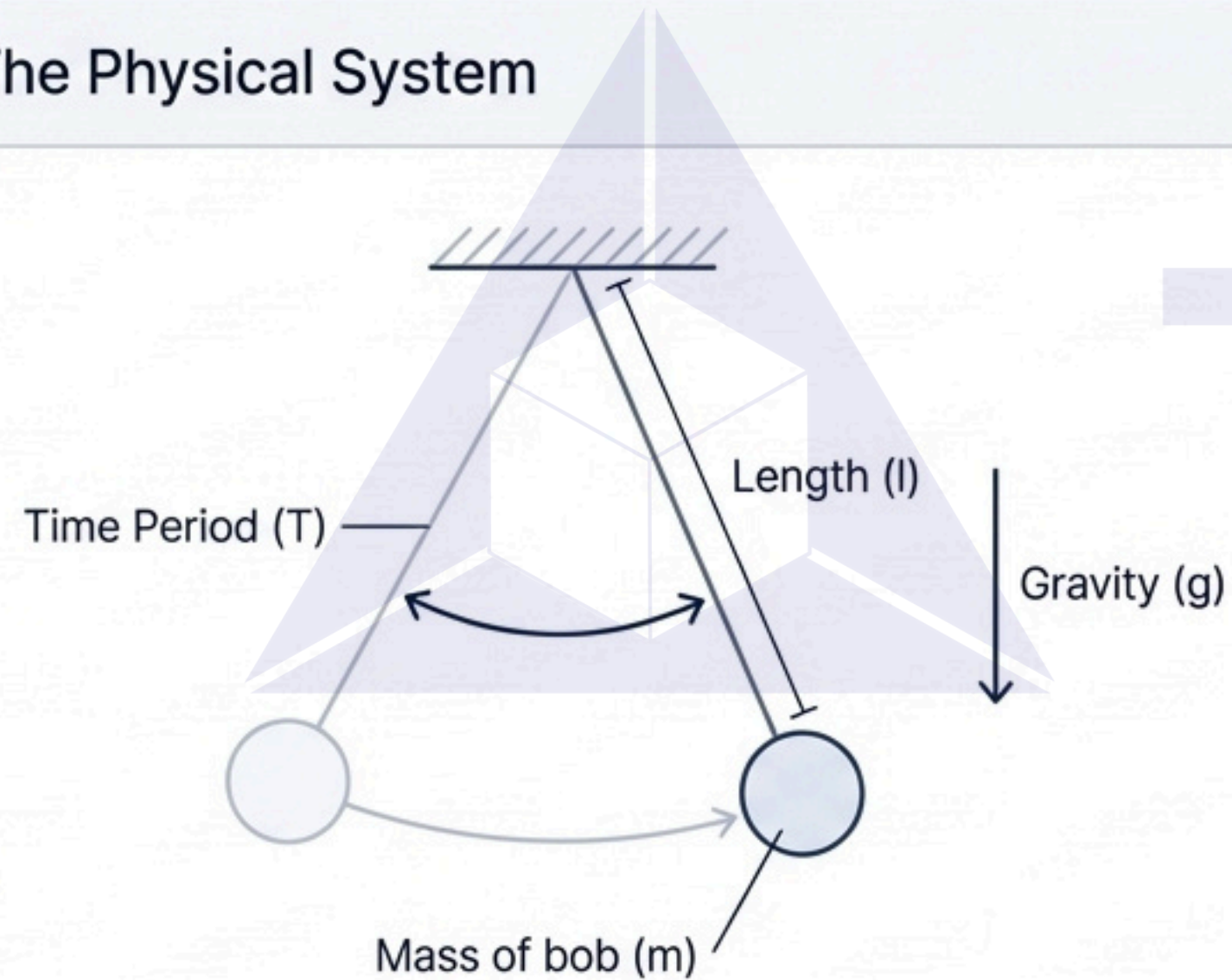
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Running the Algorithm: The Simple Pendulum

The Physical System



The Data Workspace

Step 1: Setup Equation

$$T = k \cdot l^x \cdot g^y \cdot m^z$$

Step 2: Dimensional Dictionary

Mass $\rightarrow m = [M]$

Length $\rightarrow l = [L]$

Gravity $\rightarrow g = [L][T^{-2}]$

Time $\rightarrow T = [T]$

Execution: Equating the Powers

Calculation Workspace

Substitute & Combine

$$[M^0 L^0 T^1] = [L]^x \cdot ([L][T^{-2}])^y \cdot [M]^z$$



$$[M^0 L^0 T^1] = [M^z \cdot L^{x+y} \cdot T^{-2y}]$$

Calculation Workspace

Linear Equations (Step 3)

For **M**: $z = 0$ (Mass doesn't matter!)

For **L**: $x + y = 0$

For **T**: $-2y = 1 \Rightarrow y = -1/2 \Rightarrow x = 1/2$

Output Status

$$T = k \cdot l^{1/2} \cdot g^{-1/2} \Rightarrow T = k\sqrt{l/g}$$



Algebraic form
successfully deduced.

Diagnostic Matrix: Capabilities vs. Limitations

✓ What We CAN Do (Success)

- **Find the exact algebraic form:**
We successfully proved T depends on the square root of l and inversely on g .
- **Prove non-dependence:**
We proved that the mass m of the bob has zero effect on the time period ($z=0$).

✗ What We CANNOT Do (Limitations)

- **Find pure constants:**
The method outputs a dimensionless k . Experimental physics is required to find that $k = 2\pi$. The exact equation $T = 2\pi\sqrt{l/g}$ cannot be found by dimensions alone.
- **Handle Complex Math:**
Fails if the equation involves addition/subtraction, trigonometric, or logarithmic functions (which are dimensionless).

Takeaway: Dimensions give you the shape of the formula, but experiments give you the scale.



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