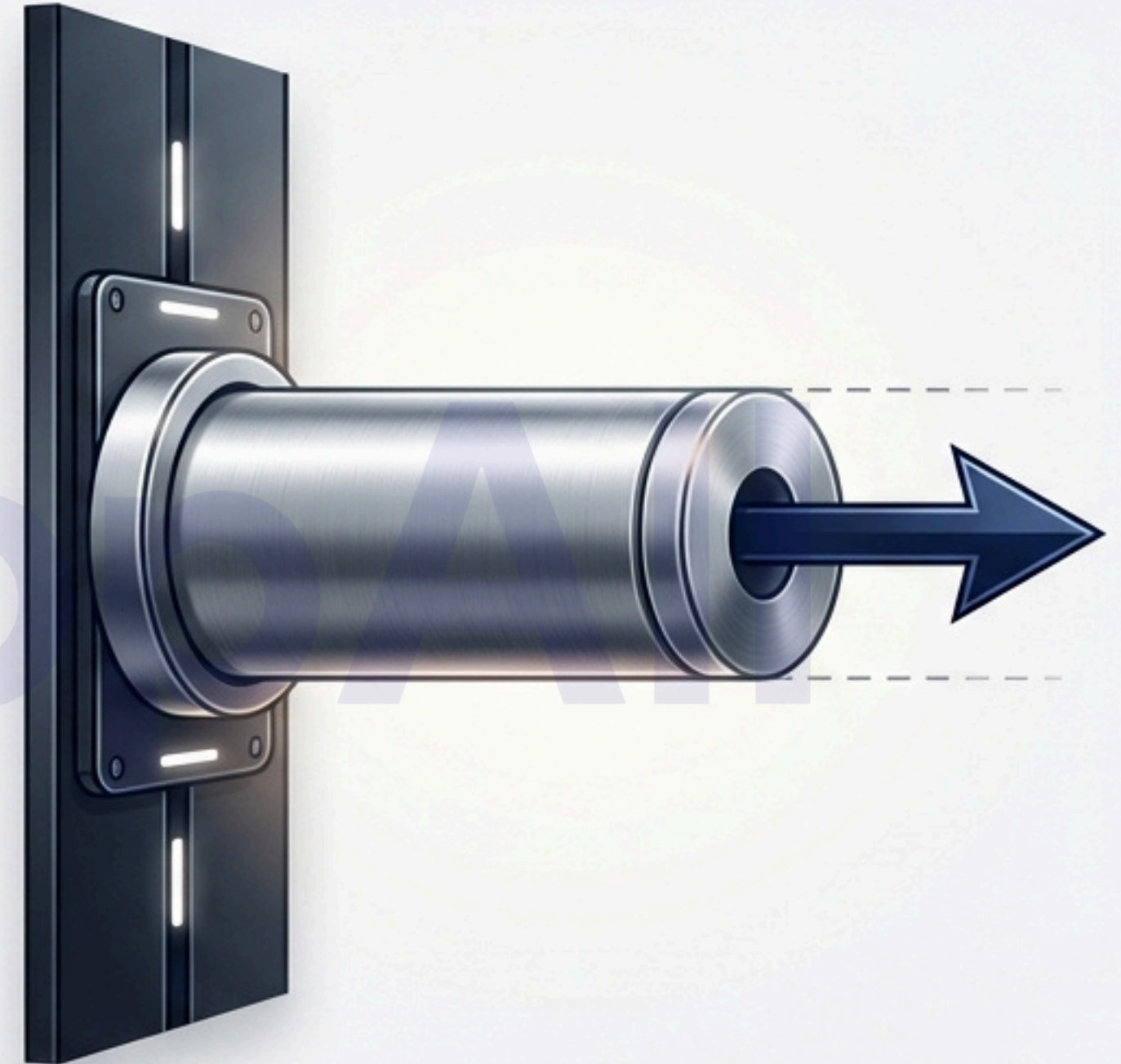


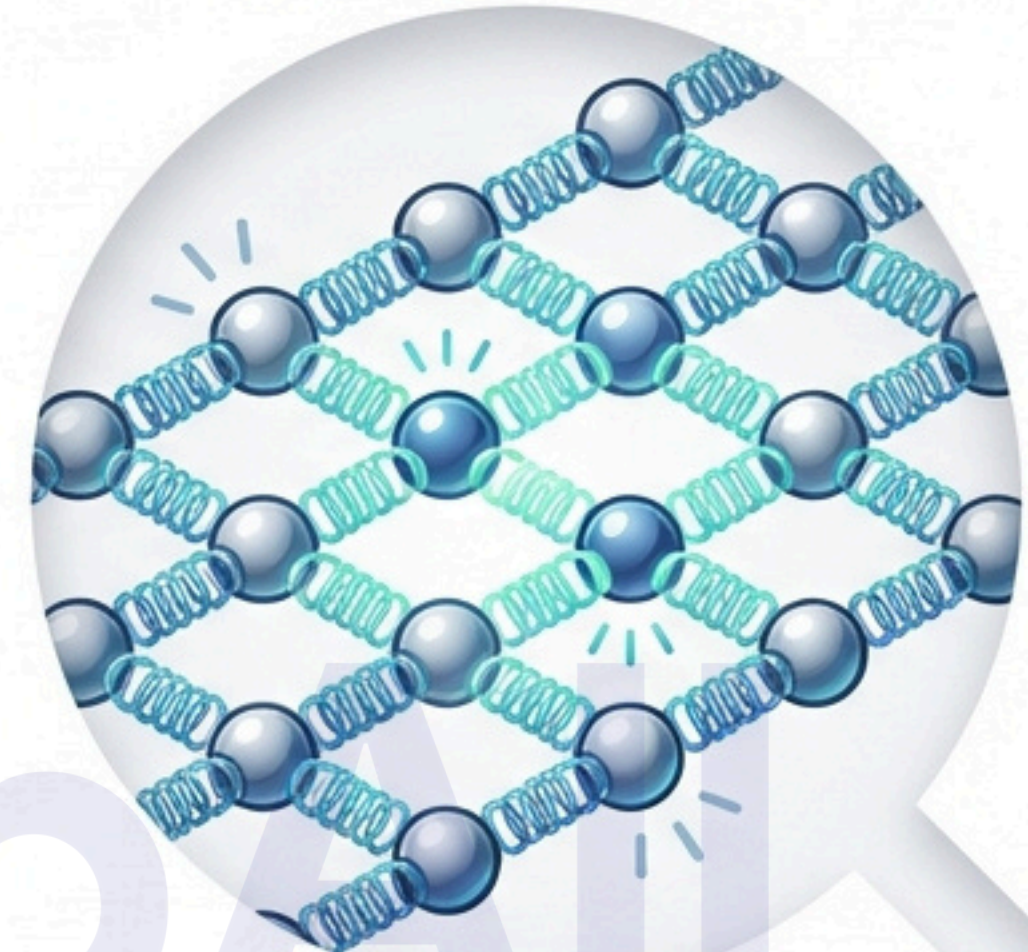
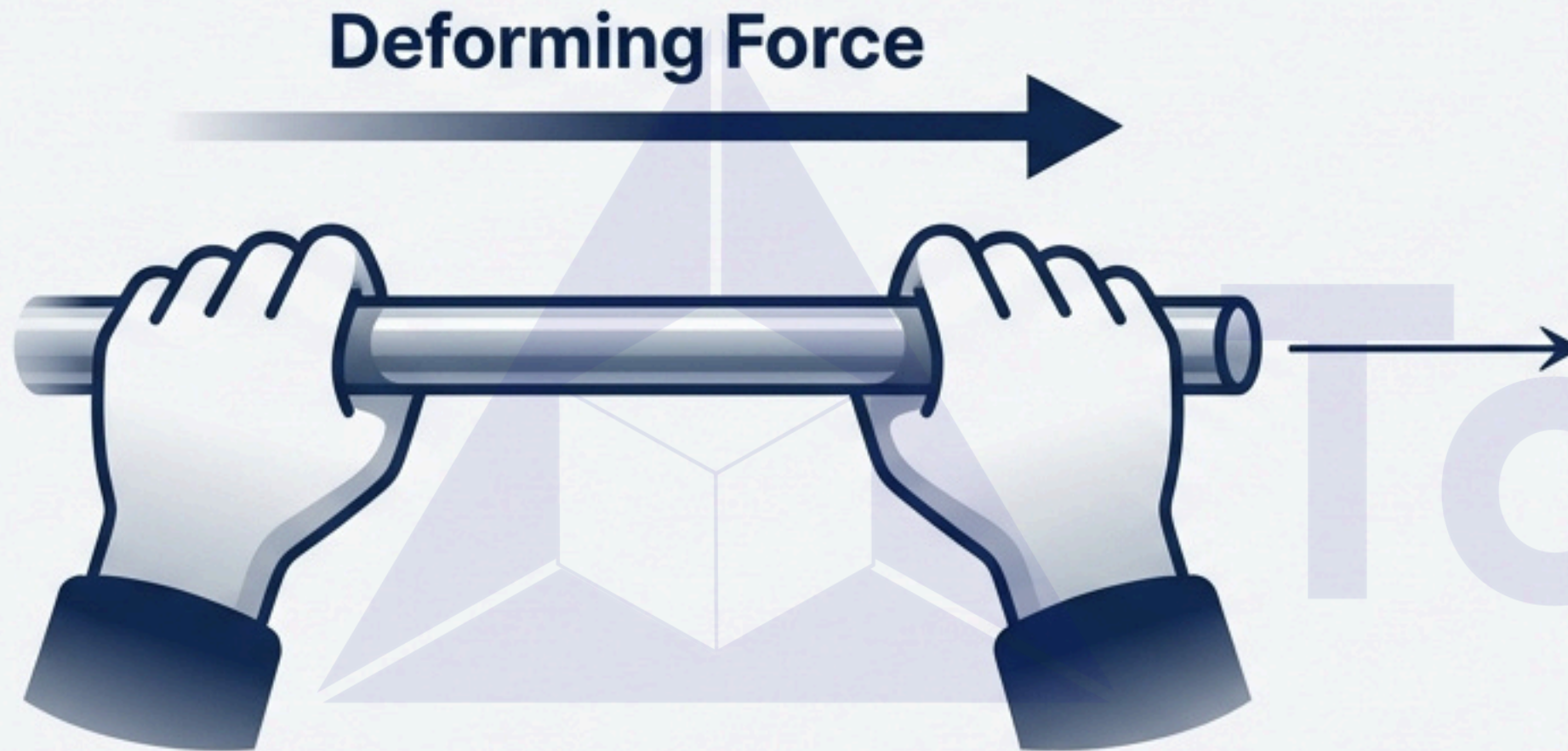
CLASS 11 PHYSICS • CHAPTER 8

Elastic Potential Energy in a Stretched Wire

Deriving the work done against inter-atomic forces and how it is stored as energy.



Where Does the Work Go?

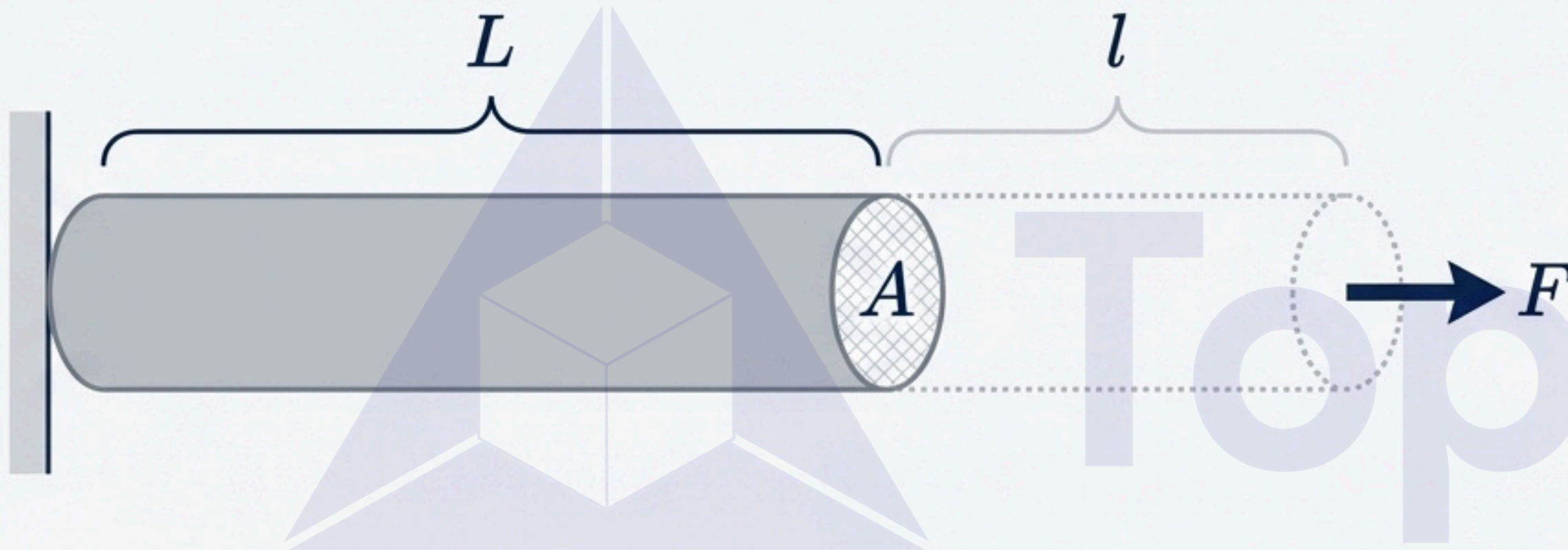


Against Inter-Atomic Forces. When you stretch a wire, you are physically pulling atoms apart against their natural attractive forces. This requires work.



The **Principle of Energy Storage**: The work done against these inter-atomic forces does not disappear—it is safely stored within the wire as **Elastic Potential Energy (U)**.

Setting Up the Geometry



L = Original Length



A = Area of Cross-Section



F = Deforming Force



l = Elongation

Hooke's Law Foundation (from Young's Modulus)

$$F = Y \times A \times \frac{l}{L}$$



Setup first! Always establish the variable restoring force equation (F) before you start the integration.

Deriving the Work Done (Part 1)

The Infinitesimal Step

Imagine stretching the wire by a tiny, infinitesimally small amount dl .

$$\text{Small work done: } dW = F \times dl$$

Substitute Hooke's Law for F

The Substitution

$$dW = \left(\frac{Y \cdot A \cdot l}{L} \right) dl$$

Note: Y , A , and L are constants for this specific wire. Only the stretch l is changing.



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$$E=mc^2$$



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Deriving the Work Done (Part 2)

Integration Limits

0

l

Total Work via Integration

To find total work (W), integrate the small work dW from elongation 0 to l .

$$W = \int_0^l \left(\frac{Y A}{L} \right) l dl$$

Pull out constants & integrate l

The Result

$$W = \left(\frac{Y A}{L} \right) \left[\frac{l^2}{2} \right]_0^l$$

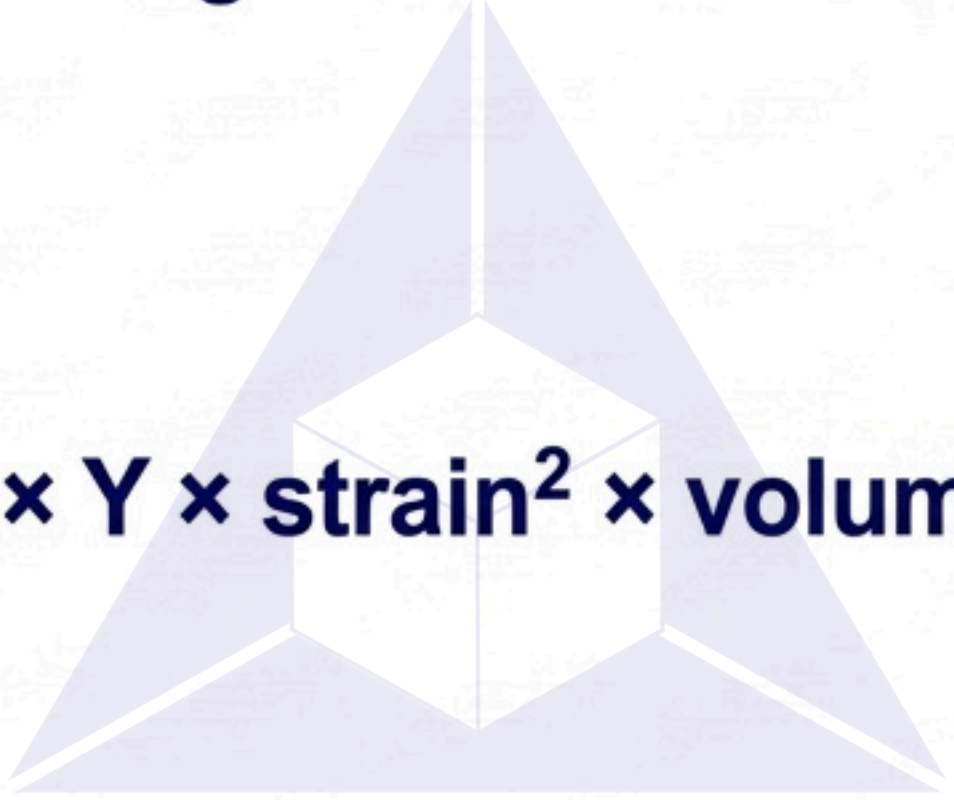
$$W = \frac{1}{2} \left(\frac{Y \cdot A \cdot l^2}{L} \right)$$

This total work W is perfectly converted into stored Elastic Potential Energy (U). Therefore, $W = U$.

The Three Faces of Elastic Potential Energy



The Young's Modulus Form


$$U = \frac{1}{2} \times Y \times \text{strain}^2 \times \text{volume}$$

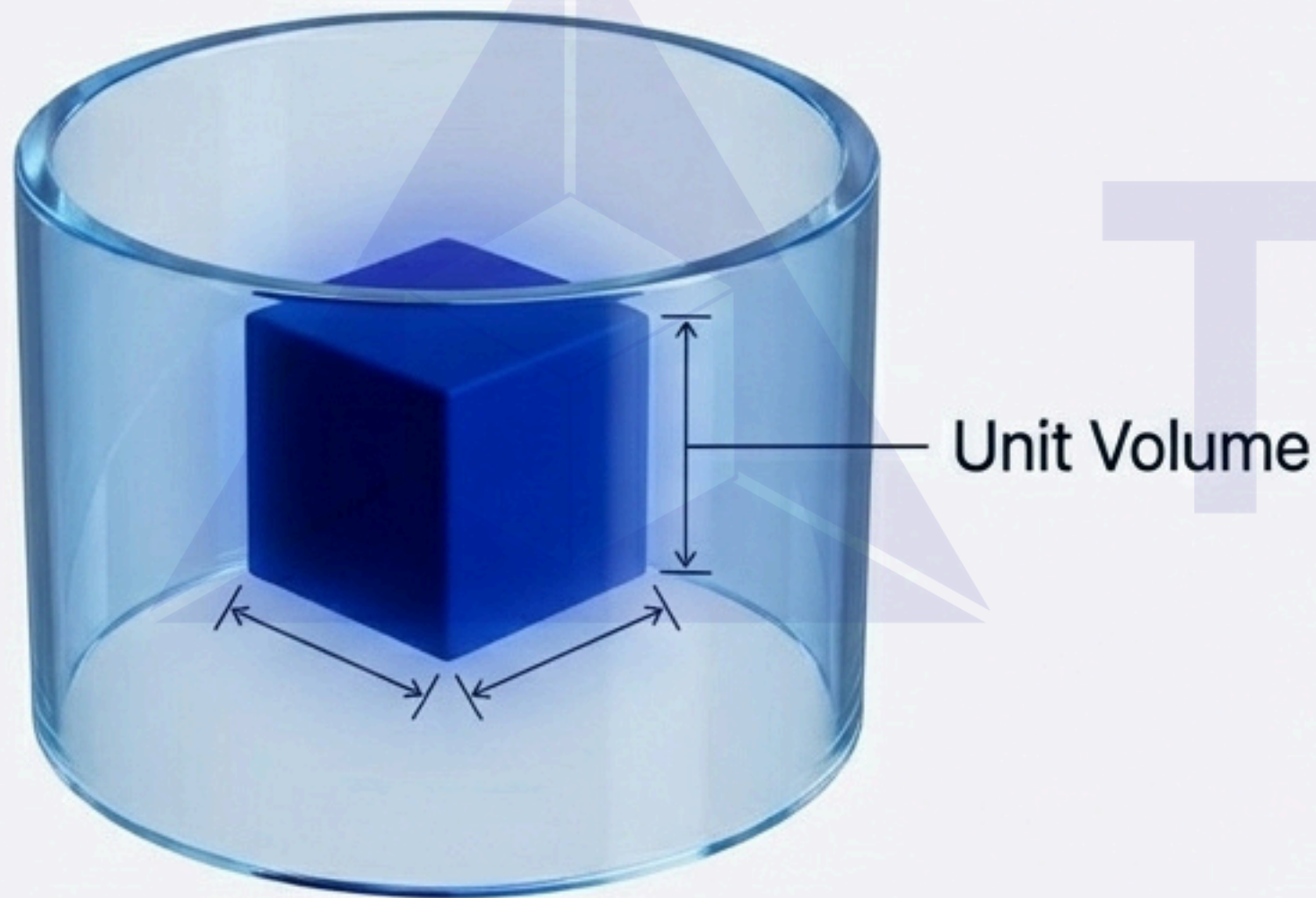
The Stress-Strain Form


$$U = \frac{1}{2} \times \text{stress} \times \text{strain} \times \text{volume}$$

Note: Volume of the wire = $A \times L$. By factoring out (l / L) as strain and (F / A) as stress, we unlock these equivalent, exam-ready forms.

Energy Density (u)

In physics, we often care more about the energy stored in a *specific localized volume* rather than the entire object.



Elastic Potential Energy per unit volume (u) = U / Volume

$$u = \frac{1}{2} \sigma \epsilon$$

Legend: σ = stress, ϵ = strain



Don't confuse the symbols! Capital **U** is total energy (measured in Joules). Lowercase **u** is energy density (measured in Joules/m³).

Chapter Recap: Elastic Potential Energy

✓ **The Origin:** Work is done against inter-atomic restoring forces.

✓ **The Mechanism:** Force changes as the wire stretches, requiring integration
($W = \int F dl$).

✓ **The Triangle Rule:**
 $U = \frac{1}{2} \times \text{stress} \times \text{strain} \times \text{volume}$
mirrors the area of a triangle ($\frac{1}{2} b h$).

EXAM CHEAT SHEET

Total Energy:

$$U = \frac{1}{2} Y \epsilon^2 V = \frac{1}{2} \sigma \epsilon V$$

Energy Density:

$$u = \frac{1}{2} \sigma \epsilon$$



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