

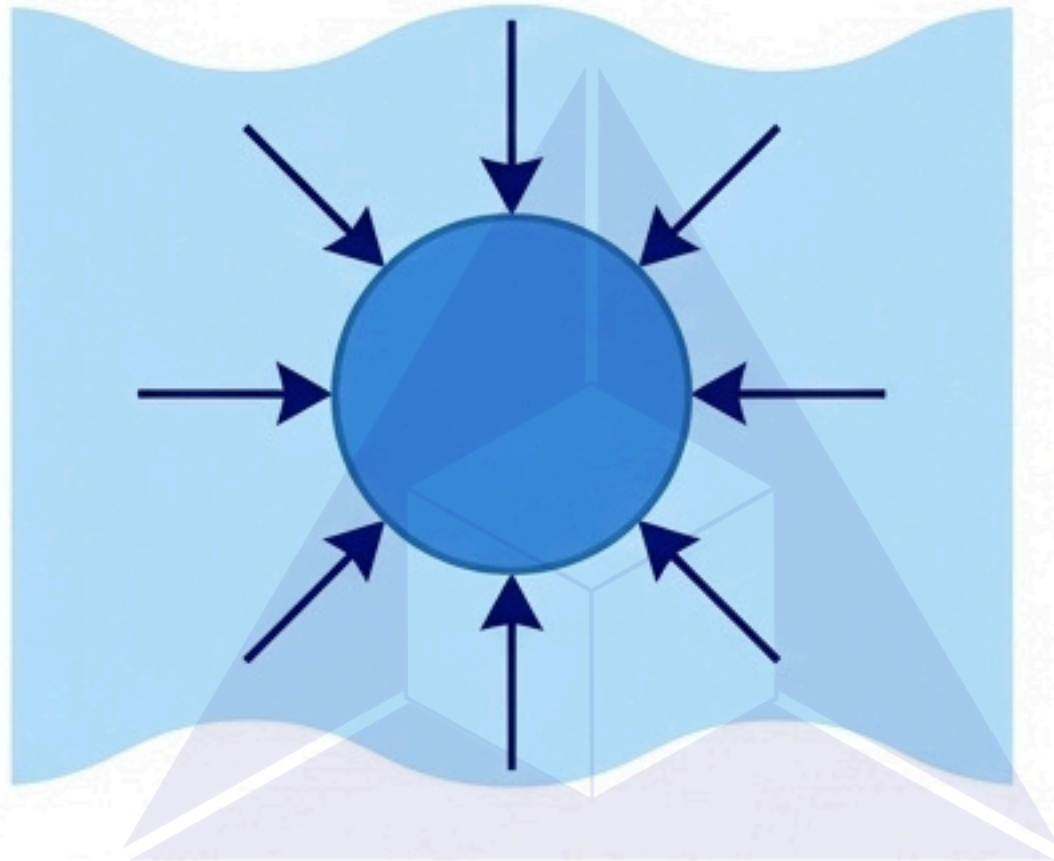


8.5.3 Bulk Modulus

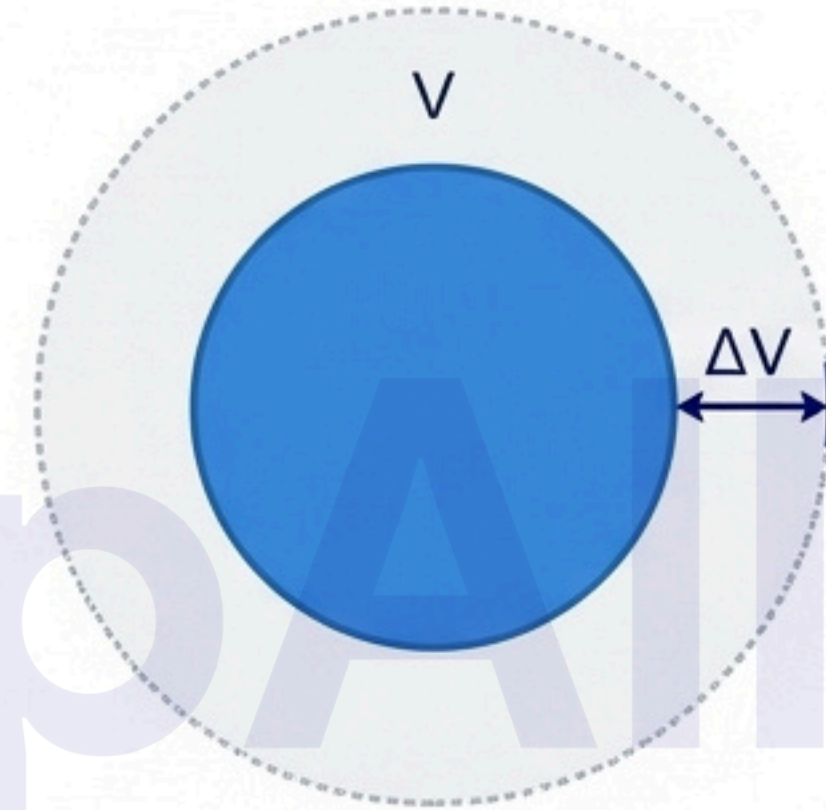
Understanding Hydraulic Stress, Volume Strain,
and Compressibility

Interactive Study Guide

Uniform Pressure Changes Size, But Never Shape



Hydraulic Stress (p): The internal restoring force per unit area equal to the hydraulic pressure of a surrounding fluid.



Volume Strain ($\Delta V/V$): The ratio of the change in volume to the original volume.

Key Idea: The body shrinks uniformly. The geometric shape remains perfectly intact.

The Bulk Modulus Equation



Bulk Modulus
(Ratio of hydraulic stress to volume strain)

Hydraulic Stress / Pressure
(Force per unit area)

$$B = \frac{-p}{\Delta V/V}$$

Volume Strain
(Fractional change in volume)

Exam Takeaway

Since strain ($\Delta V/V$) is a dimensionless ratio, Bulk Modulus inherits the exact same SI Unit as pressure: N m^{-2} or Pascal (Pa).

Decoding the Negative Sign



Caution: Classic Exam Trap

Pressure Increases

p is a positive (+) value.

p ↑



Volume Decreases

ΔV is forced to be a negative (-) value.

ΔV ↓



The Fix

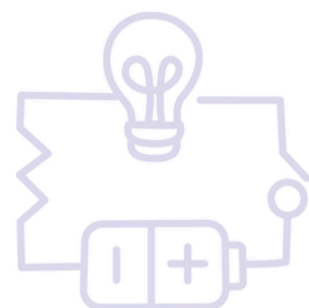
Without a minus sign, the ratio $p / (\Delta V/V)$ would be negative.

The formula artificially adds a minus sign: $B = -p / (\Delta V/V)$. This forces the final Bulk Modulus (B) to always be a positive value for a system in static equilibrium.



You've Learned the Theory. Let's Test Them Now.

$$E=mc^2$$



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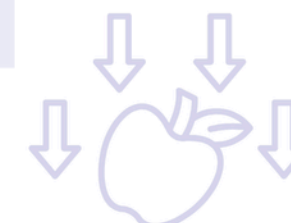
Practice Now



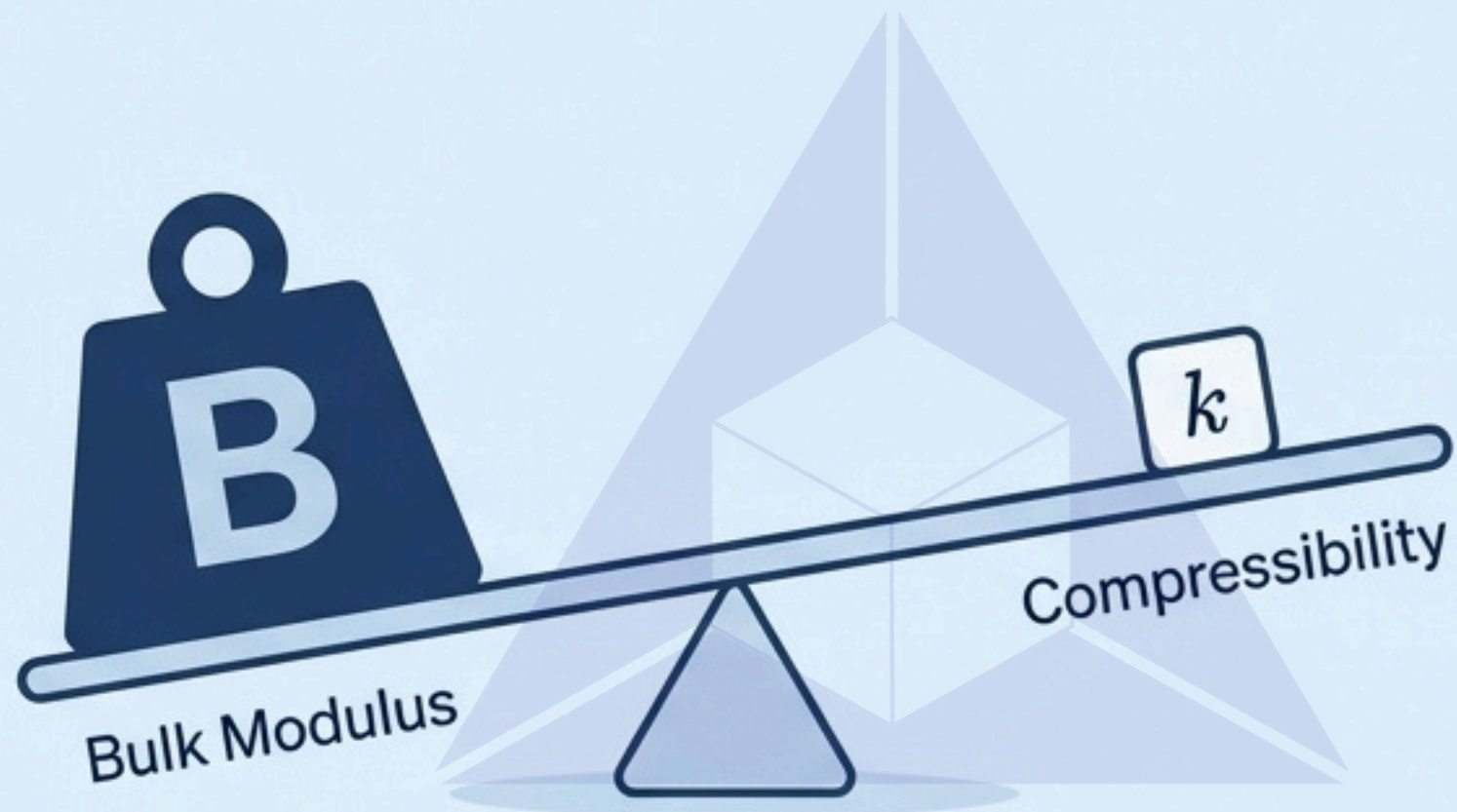
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Key Highlights

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Compressibility is the Exact Inverse



Concept Chip

High Bulk Modulus = Low Compressibility.
If an object is incredibly hard to squeeze, it has a massive B and a tiny k.

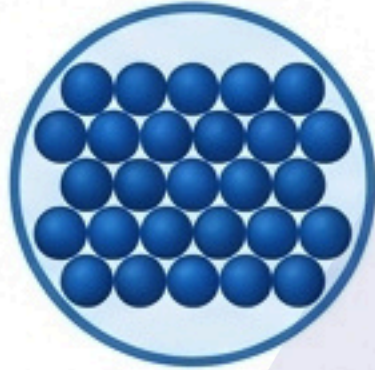
Compressibility (k) is the fractional change in volume per unit increase in pressure.

$$k = \frac{1}{B}$$

$$k = -\frac{1}{\Delta p} \times \frac{\Delta V}{V}$$

Molecular Coupling Defines Compressibility

Solids



Largest Bulk Moduli
(e.g., Steel 160 GPa).
Atoms tightly bound.



Compressibility: **Very Low**

Liquids



Medium Bulk Moduli
(e.g., Water 2.2 GPa).
Molecules bound, but loosely.



Compressibility: **Low**

Gases



Smallest Bulk Moduli
(e.g., Air at STP 1.0×10^{-4} GPa).
Molecules poorly coupled.

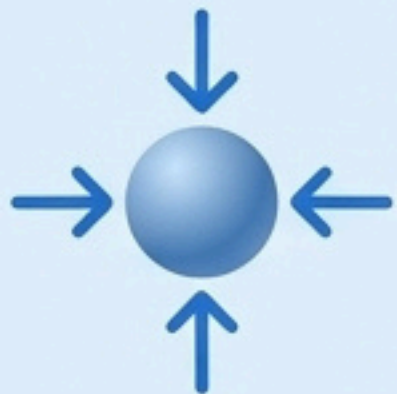


Compressibility: **Extremely High**

“Gases are about a million times more compressible than solids!”

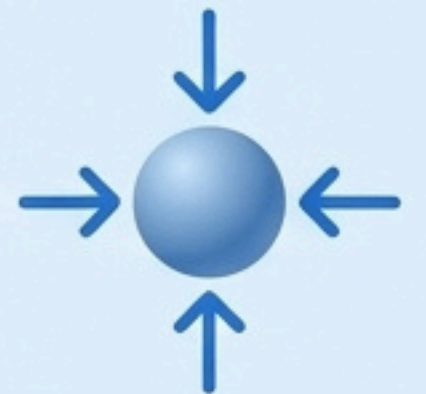
The Master Map of Elastic Moduli

State of Matter:	Solid	Liquid	Gas
Young's (Tensile)	✓	✗	✗
Shear (Tangential)	✓	✗	✗
Bulk (Hydraulic)	✓	✓	✓



Exam Takeaway

Crucial Distinction: Bulk Modulus is the *only* modulus that **applies to all three states of matter**. If a fluid (liquid or gas) is involved, you are always calculating Bulk Modulus.



Chapter 8.5.3 Review

Chapter Revision Complete

✓ **Hydraulic Stress:** Uniform, all-sides pressure from a fluid that shrinks volume without altering shape.

✓ **The Equation:** $B = -p / (\Delta V/V)$.
The minus sign ensures B remains positive.

✓ **Compressibility (k):** The exact reciprocal of Bulk Modulus ($k = 1/B$).

✓ **Matter Comparison:** Solids are incredibly hard to compress; gases are roughly a million times more compressible.

Memory Cue: B is for Bulk, Body, and Bath (applies to fluids!)



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