VP150-RC8

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Elasticity

Elastic Modulus

$$elastic\ modulus\ = rac{stress}{strain}$$

where stress is force per unit area and strain is the fractional deformation due to the stress.

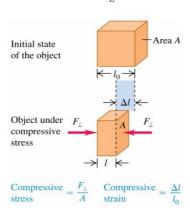
- ullet Young's Modulus (tensile stress) Y
- ullet Bulk Modulus (compressive stress) B
- ullet Shear Modulus (shear stress) S

Shear Modulus is much smaller.

Young's Modulus

Young's modulus is tensile stress divided by tensile strain, and is given by

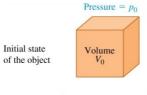
$$Y=rac{rac{F_{\perp}}{A}}{rac{\Delta L}{L}}$$

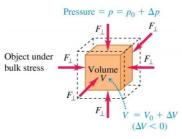


Bulk Modulus

Bulk modulus is bulk stress divided by bulk strain and is given by

$$B = -\frac{\Delta p}{\frac{\Delta V}{V_0}}$$



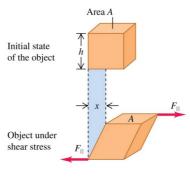


Bulk stress =
$$\Delta p$$
 Bulk strain = $\frac{\Delta V}{V_0}$

Shear Modulus

Shear modulus is shear stress divided by shear strain, and is given by

$$S = rac{rac{F_\parallel}{A}}{rac{x}{h}}$$



Shear stress =
$$\frac{F_{||}}{A}$$
 Shear strain = $\frac{x}{h}$

Fluid

Basic Concepts

Density of Mass

$$ho = \lim_{\Delta V o 0} rac{\Delta m}{\Delta V}$$

Relative Density

$$r=rac{
ho}{1000[kg/m^3]}$$

Pressure

$$p=rac{\Delta F_{\perp}}{\Delta A}$$

Pressure in Liquid

$$\mathrm{d}p = -
ho g \mathrm{y} \ \Delta p = \int_{p_1}^{p_2} \mathrm{d}p \$$

The density of mass ρ and the gravity acceleration g might be a function of depth y.

Pressure with Constant ho and g

$$p = p_0 + \rho g h$$

atmospheric pressure: $1.01 \times 10^5 pprox 1 \times 10^5 [Pa]$

pressure in 1-meter-depth water: $9.8 \times 10^3 \approx 1 \times 10^4 [Pa]$

12.59 • A U-shaped tube open to the air at both ends contains some mercury. A quantity of water is carefully poured into the left arm of the U-shaped tube until the vertical height of the water column is 15.0 cm (Fig. P12.59). (a) What is the gauge pressure at the watermercury interface? (b) Calculate the vertical distance *h* from the top of the mercury in the right-



hand arm of the tube to the top of the water in the left-hand arm.

Pascal's Law

$$\frac{F_2}{F_1} = \frac{A_2}{A_1}$$

*Verify it with:

- the definition of pressure,
- · work-kinetic energy theorem.

Archimedes' Principle

Buoyant Force

$$F_b = \rho_{liquid} V_{immersed} g$$

The buoyant force equals the weight of the fluid displaced by the body in magnitude.

Practically, the density and the gravity acceleration can still be a function of depth y. In this case, solve the buoyant force with integration.

For objects with vertical side surfaces, the buoyant force can be derived with $F_b=(p_2-p_1)A$.

Surface Tension

Origin

The attractive interaction between molecules of the liquid.

Meniscus and capillarity

- adhesion forces dominate ↔ concave liquid surface
- cohesion forces dominate ↔ convex liquid surface

Bernouli's Equation

Requirements and Preparation Equations

- \bullet $\,$ The density of mass ρ is constant, which means the liquid cannot be compressed.
- $\delta W = p_1 dV p_2 dV$
- $dK = \frac{1}{2}\rho(v_2^2 v_1^2)dV$
- $dU_{grav} = \rho g(y_2 y_1) dV$

Equations

$$p+rac{1}{2}
ho v^2+
ho gy=const$$

Viscosity and Turbulence

Definition

- Viscosity is internal friction in a fluid.
- Turbulence is irregular chaotic flow that is no longer laminar.

Application

(a) Motion of air relative to a nonspinning ball

(b) Motion of a spinning ball

(c) Force generated when a spinning ball moves through air



This side of the ball moves opposite to the airflow.



direction of the airflow

or cr

it. So, when air moves past a spinning ball:
On one side, the ball slows the air, creating a region of high pressure.

A moving ball drags the adjacent air with

creating a region of **high pressure**. On the other side, the ball **speeds the air**, creating a region of **low pressure**.

The resultant force points in the direction of the low-pressure side.

Reference

- 1. Wu Yufan, 2022SU VP150 RC.
- 2. Qu Zhemin, 2021SU VP150 RC.
- 3. Mateusz Krzyzosiak, 2023SU VP150 Slides.