# Physics 101H

## General Physics 1 – Honors

Lecture 30 – 10/28/22

Deformable objects

# Summary

**Topics**

**Yesterday: Static equilibrium [chapter 12]**

- Static equilibrium
- Examples

**Today: Deformable objects [chapter 12]**

- Stress and strain
- Elastic modulus

# Deformable objects

The extended objects we have been considering so far have been **rigid**

But we know that not everything is rigid! Some objects can be **deformed**.

- Even apparently rigid objects can be deformed if the applied forces are sufficient

Characterise forces on an object by

- Stress
- Strain

# Elastic modulus

Property of object that measures response to stress

Different situations have different names, but all characterise the response to stress

- Young's modulus
- Shear modulus
- Bulk modulus

**Elastic** objects return to their original shape when the external forces are removed

Above the **elastic limit**, materials become **plastic**, and do not return to their original shape

## Practice in pairs

**Instructions:** Solve the following question with a neighbour. Your answers will not be graded; your discussion is for your own learning.

**Question:** A ladder leans against a wall at a 60 angle (with respect to the horizontal). The floor is *frictionless*, but there is *friction with the wall*. Assume that the coefficient of friction is very large (say = 10). Is it possible for this setup to be in static equilibrium?

**Example:** The Mariana Trench is about 11 km deep, which is very deep. The pressure at this depth is $1.13 \times 10^8$ N/m$^2$, which is a lot. Calculate the change in volume of 1 m$^3$ of seawater carried from the surface to this deepest point. Find the change in density of water at the bottom of the trench. The bulk modulus of water is approximately $0.22 \times 10^{10}$ N/m$^2$.

# Quick quiz

**Instructions:** This quiz is for your own learning. There are three questions and each question has two columns. Write your own solution, without reference to your notes, the textbook, or your neighbour, **in the first column**. Once you have tried to answer all the questions, discuss the questions with a neighbour and fill in any incomplete answers **in the second column**. Keep your sheet for future reference.

# Want more practice?

Try the following problems **Chapter 12** of the textbook:

- Conceptual questions: 1, 5, 7, 9, 13, 15, 17
- Static equilibrium: 25, 27, 31, 37, 41, **75**, **77**, **79**
- Stress and strain: 45, 49, 51, 59, 63

Answers are provided for questions with **blue** numbers (odd numbered)

Click on the number to be taken to the answer.

But make sure you at least **try** the problem first!

# Summary

**Topics**

**Today: Deformable objects [chapter 12]**

- Stress and strain
- Elastic modulus

**Next week: Gravity [chapter 13]**

- Newton's laws and gravitational fields
- Gravitational potential energy and escape velocity
- Kepler's laws of planetary motion

**Announcements**

**Wednesday November 9: Midterm 2**

# PHYSICS 101 - HONORS

## Lecture 30 10/28/22

## Deformable objects (slide 3)

Stress - external force acting on an object per unit cross-sectional area $= \frac{F_\perp}{A}$

- $\frac{\text{force}}{\text{area}}$ has units $N/m^2$ ← a pressure!

Strain - result of a stress

- fractional change in length $= \frac{\Delta L}{L_0}$
- unitless!

↑ tensile forces = compression or stretching

Be careful!

Shear strain $\frac{\Delta x}{L}$

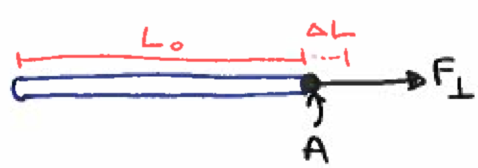
Bulk strain $\frac{\Delta V}{V_0}$

## Elastic modulus (slide 4)

Young's modulus - resistance of a solid to length changes

↖ not relevant to liquids

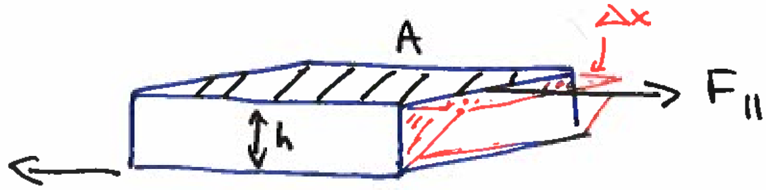
$$Y = \frac{\text{stress}}{\text{strain}} = \frac{F_\perp/A}{\Delta L/L_0}$$



Shear modulus – resistance of a solid to shear forces

← not relevant to liquids

$$S = \frac{\text{stress}}{\text{strain}} = \frac{F_{\parallel}/A}{\Delta x/h}$$

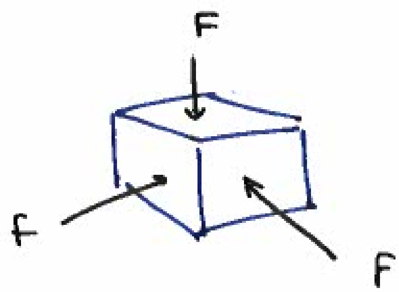



Bulk modulus – resistance to changes in volume

↑ applies to liquids too?

$$B = \frac{\text{stress}}{\text{strain}} = -\frac{F/A}{\Delta V/V} = -\frac{P}{\Delta V/V}$$

↑ minus sign ensures B is positive for ordinary materials




– compressibility is inverse of bulk modulus

$$k = \frac{1}{B} = -\frac{\Delta V/V_0}{P}$$

## Mariana Trench example (slide 6)

$$B = -\frac{P}{\Delta V / V} \Rightarrow \frac{\Delta V}{V} = -\frac{P}{B} \Rightarrow \Delta V = -\frac{P}{B} V$$

The water starts at atmospheric pressure

$$P_{atm} = 1.01 \times 10^{5} \ N/m^2$$

and occupies volume $V = 1 \ m^3$

$$\Delta V = -\frac{1.13 \times 10^{8}}{0.21 \times 10^{10}} \cdot 1 = \underline{-0.054 \ m^3}$$

The change in density can be expressed as

$$\frac{\rho_{deep}}{\rho_{atm}} = \frac{M/V_{deep}}{M/V_{atm}} = \frac{M V_{atm}}{M V_{deep}} = \frac{V_{atm}}{V_{deep}}$$

But $V_{deep} = V_{atm} + \Delta V$

$$\Rightarrow \frac{\rho_{deep}}{\rho_{atm}} = \frac{V_{atm}}{V_{atm} + \Delta V}$$

$$= \frac{1}{1 - 0.054} = 1.0568$$

$\Rightarrow$ increase in pressure of $5.7\%$