PHYSICS TUTOR
ONLINE

Unit 15 – Forces and Matter

This topic explores how materials respond to forces, focusing on the behaviour of springs and fluids. You'll learn how forces can stretch, compress, or bend objects, and how elastic or plastic deformation occurs. Hooke's Law describes the relationship between force and extension in springs. The unit also covers how fluids exert pressure, how pressure varies with depth and density, and how this leads to **buoyancy**. You'll understand why objects float or sink, and how **atmospheric pressure** changes with altitude.

Springs and Deformation

Stretching, Bending, and Compressing

- To change the shape of an object:
  - More than one force must be applied
- Examples:
  - Compression: Force from opposite sides inward
  - Stretching: One end fixed, the other pulled
  - A spring pulled from one end still experiences two forces (tension and reaction force)

Deformation Types

Type of Deformation	Description	Example
Elastic Deformation	Returns to original shape after force is removed	Elastic band
Plastic Deformation	Permanently distorted; doesn't return to original shape	Overstretched spring

Hooke's Law – Linear Elastic Distortion

Hooke's Law: *The extension of a spring is directly proportional to the force applied*, provided the elastic limit is not exceeded.

$$F = kx$$

Where:

- F= Force (N)
- k= Spring constant (N/m)
- x= Extension (m)

Interpreting a Force–Extension Graph:

Elastic Region (Linear):

- Straight line through origin
- Obeys Hooke's Law
- Gradient = spring constant kkk

Plastic Region (Non-Linear):

- Curve after elastic limit
- Object permanently deforms
- May indicate **ductile** or **brittle** behaviour:
  - **Shallow curve**: Easily stretched (ductile)
  - **Sudden break after straight line**: Brittle material

Work Done on a Spring

Work done in stretching a spring:

$$W = \frac{1}{2}kx^2$$

- Area under the force-extension graph
- Unit: Joules (J)

Atmosphere and Pressure

Atmospheric Pressure:

- Caused by the weight of air above a unit area
- Decreases with altitude:
  - Fewer air molecules above = less weight = less pressure

Pressure in Fluids

- Fluids = **liquids or gases**
- Fluids exert pressure perpendicular to surfaces

$$\text{Pressure} = \frac{\text{Force}}{\text{Area}}$$

Inside a Balloon:

- Gas inside pushes outward
- Atmospheric air pushes inward
- If internal pressure > external, the balloon **expands**
- More gas added → more collisions with walls → **increased internal pressure**

Pressure in Liquids

$$\text{Pressure due to liquid} = h \times \rho \times g$$

Where:

- h= depth of liquid (m)
- ρ = density of liquid (kg/m³)
- g= gravitational field strength (N/kg)

Variable	Effect on Pressure
Depth	Greater depth = higher pressure
Density	Denser fluid = more mass above = more pressure

Buoyancy and Floating

An object floats if it displaces a weight of fluid equal to its own weight.

Principle:

An object will float if the buoyant force (upthrust) is equal to or greater than the object's weight.

Example:

- A ping pong ball floats because its density is less than water's
- Displaces more weight in water than its own mass → resultant upward force

Concept	Key Idea
Buoyant Force (Upthrust)	Equal to the weight of displaced fluid
Object Floats	If weight < upthrust
Object Sinks	If weight > upthrust or can't displace its own weight in fluid
Pressure in a Fluid	Increases with depth and density