Topic 4 - Forces

1 Hooke's Law

A string or wire when stretched is found to obey Hooke's Law up to its limit of proportionality

Hooke's Law states that the extension of a body is proportional to the applied load if the limit of proportionality is not exceeded

$$F = kx$$

Energy stored in the spring = work done in stretching the spring = Area unnder the force-extension graph

$$\text{Energy stored} = \frac{1}{2}Fx = \frac{1}{2}kx^2$$

2 Fluid Statics

2.1 Density

Density of a substance is defined as its **mass per unit volume**

$$\rho = \frac{m}{V}$$

2.2 Pressure

Pressure is defined as the force per unit area, where the force is acting at right angles to the area

generally,

$$p = \frac{F}{A}$$

Pressure in a fluid, or hydrostatic pressure is given by

$$p = \rho g h$$

total pressure at a given depth below the water is thus

$$P = p_{at} + \rho g h$$

2.3 Upthrust

For a cylindrical object of cross sectional area A submerged in a liquid of density ρ

The downward force on the top of the object due to fluid is

$$F_{top} = p_1 A = \rho g h_1 A$$

The upward force on the bottom of the object due to fluid is

$$F_{bottom} = p_2 A = \rho g (h_1 + H) A$$

Since upward force is greater than the downward force, there is thus a net force on the object

$$\begin{aligned} F_{net} &= F_{bottom} - F_{top} \\ &= \rho g A H \\ &= \rho g V \\ &= mg, \text{ since } \rho = \frac{m}{V} \text{ where } m \text{ is the mass of } \textbf{fluid} \text{ displaced} \end{aligned}$$

The force of upthrust is the vertical upward force exerted on a body by a fluid when it is fully or partially submerged in the fluid due to the difference in fluid pressure

Archimedes Principle states that the buoyang force or upthrust is equal in magnitude and opposite in direction to the weight of the fluid that is displaced by a submerged or floating object

3 Viscous force

Viscous forces arise due to the collisions of an object which is moving through a fluid with the molecules of the fluid.
Recall section on air resistance and net force on an object falling due to gravity from Topic 2 - Kinematics

4 Equilibrium of forces

For an object to be in equilibrium, it must be in both translational and rotational equilibrium

The conditions for equilibrium

1. Resultant force on the object is zero
2. Resultant moment on the object about any axis is zero

4.1 1st Condition - Translational Equilibrium

$$\sum F_x = 0$$

$$\sum F_y = 0$$

4.2 2nd Condition - Rotational Equilibrium

Principle of moments:
for any body in rotational equilibrium, the sum of all clockwise moment about any axis must be equal to the sum of all anticlockwise moment about the same axis

Turning effect of a force is called its moment

the **moment** of a force about a point is defined as the produt of the force and the perpendicular distance from the point to the line of action of the force

Torque of a couple

A couple consists of a pair of equal and opposite forces whose lines of action do not coincide
The torque of a couple is the product of one force and the perpendicular distance between the two forces

Note: when only three coplanar forces act on a body in equilibrium, their lines of action must either all be parallel or they meet at a point

5 Center of gravity

The **center of gravity** of a body is the point at which its weight or the resultant of the distributed gravitational attraction on the body appears to act.