6 Forces in Equilibrium

6.1 Vectors and Scalars

- A **vector** is any physical quantity that has a direction as well as a magnitude.
  - Displacement, velocity, acceleration, force.
- A **scalar** is any physical quantity that is not directional.
  - Mass, density, volume, energy.

A vector can be **represented as an arrow** - the length of the arrow represents the magnitude of the vector quantity, the direction arrow gives the direction of the vector.

Distance travelled depends on the route, whereas the **direct distance** is always the same.

- **Displacement** is distance in a given direction.
- **Velocity** is speed in a given direction.

Vector Addition

Vectors can be added using a **scale diagram**.

$$OB = OA + AB$$

Vector addition gives the **overall effect** of the vectors. Adding two forces gives the **resultant** of the forces.

- The **resultant** is the combined effect of two forces.

Vectors can also be added using a **calculator**.

In general, if the two perpendicular forces are F_1 and F_2

- The **magnitude** of the resultant $F = \sqrt{{F_1}^2 + {F_2}^2}$
- The angle θ between the resultant and F_1 is given by $\tan\theta = F_2/F_1$.

Resolving a Vector into Two Perpendicular Components

Is the process of working out the **components of a vector** in two perpendicular directions given the magnitude and direction of the vector.

A force F can be resolved into two perpendicular components

- $F\cos\theta$ parallel to a line at angle θ to the line of action of the force.
- $F\sin\theta$ perpendicular to the line.

6.2 Balanced Force

When two forces act on a **point object**, the object is in **equilibrium** (at rest or moving at constant velocity) only if the two forces are equal and opposite to each other.

- The **resultant** of the two forces is zero.
- The two forces are said to be **balanced**.

When three forces act on a point object, their **resultant** is zero only if the resultant of any two of the forces is equal and opposite to the third force.

6.3 The Principle of Moments

The **moment of a force** about any point is defined as the force $\times$ perpendicular distance from the line of action of the force to the point.

- The unit of the moment of a force is the newton metre (Nm).

$$\text{The moments of a force} = F \times d$$

- An object that is not a point object is referred to as a **body**.
- Such object turns if a force is applied to it anywhere other than through its **centre of mass**.
- The **centre of mass** of a body is the point through which a single force on the body has no turning effect.
  - It is the point where we consider the weight of the body to act when study the effect of forces on the body.

The **principle of moments** states if a body is acted on by more than one force and it is in equilibrium, the **turning effects of the forces** must balance out. Consider the moments of the forces about any point

$$\text{sum of clockwise moments} = \text{sum of anticlockwise moments}$$

6.4 More on Moments

A **couple** is a pair of equal and opposite forces acting on a body, but not along the same line.

The moment of a couple = force $\times$ perpendicular distance between the lines of action of the forces

Note that the total moment is the same, regardless of the point about which the moments are taken.