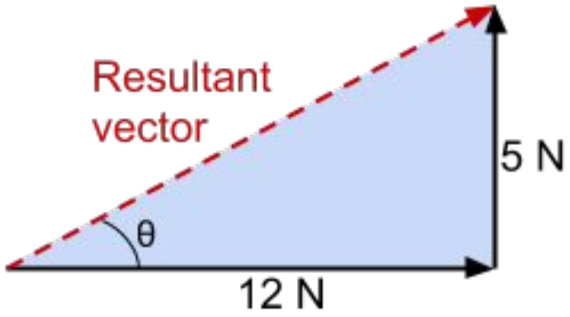
AQA Physics A-level

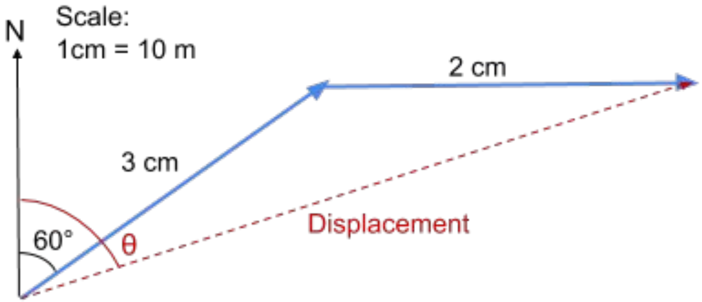
Topic 4: Mechanics and Materials

Key Points

Drawing Vectors

Vectors have both a magnitude and a direction, compared to scalar quantities which only have a magnitude. Vectors can be shown with arrow drawings. If they are drawn to scale then they can be physically measured. If not, maths must be used.

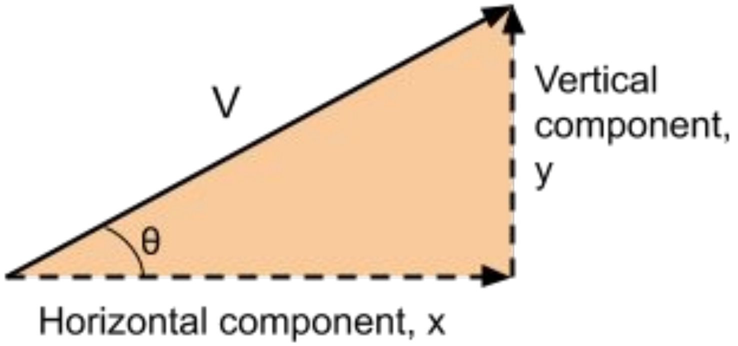




Vector triangles can determine whether the forces are balanced (and with a resultant force of 0N) or not. This is called resultant vectors.

Resolving Vectors

Resolving a vector means splitting it up into its **horizontal and vertical** components. Because horizontal and vertical meet at right angles they can be calculated using **trigonometry**. However, they can also be drawn to scale and found using the **'parallelogram method'**. The key to resolving vectors is putting the vectors **head to tail**.



Moments

The moment of a force about a point is the product of the force and the distance from its line of action to the point.

Moment (Nm) = Force (N) x Perpendicular Distance (m)

Where an object is in **equilibrium**, the moments on it about a point are **balanced**. For example, around a car's wheel axle. You can use this to work out forces and distances because:

Total Clockwise Moment = Total Anticlockwise Moment

A couple is a pair of equal and opposite parallel forces acting on the same body that do not act in the same line.

Moment of a Couple (Nm) = Force (N) x Perpendicular Distance Between Lines of Action (m)

Centre of Mass

The centre of mass is **where the mass of an object can be considered to be concentrated**. The line of action acts from the centre of mass and shows how gravity is acting upon the object.

The centre of mass can be **found by suspending an object by a pin and then using a plum line to draw on the line of action- where they cross is the centre of mass**.

If the line of action falls outside of the width of the base then the object will **topple**.

Newton's Laws of Motion

Newton's first law: *'the velocity of an object will not change unless a resultant force acts upon it'*

Newton's second law: *f=ma (force in N equals mass in kg times the acceleration in ms*$^{-2}$*)*

Newton's third law: *'Every force has an equal and opposite force'*

SUVAT and Projectiles

S= Displacement
U= Initial velocity
V= Final velocity
A= Acceleration
T=Time

In projectile motion, the horizontal and the vertical components are treated **separately**. Acceleration is due to gravity, hence only affects the vertical component and is positive if acting with the object and negative if against it.

Lift, Drag and Terminal Velocity

Friction is a force that opposes motion when moving on a solid.

Drag is a force that opposes motion in a fluid. It usually increases with speed.

Lift is an upward force created on an object as it moves through a fluid due to the shape of an object.

Terminal Velocity happens when frictional forces equal the driving force, causing equilibrium and zero acceleration.

Momentum and Kinetic Energy

In **a closed system**, **momentum is conserved**. This means that the product of velocity and mass must be the same before and after. This occurs in both collisions and explosions.

$$p_1 = p_2$$

$$m_1 v_1 = m_2 v_2$$

In an **inelastic** collision, **kinetic energy is not conserved**. This means we can work out the change in kinetic energy and hence how much energy dissipated into other forms.

$$E_k = \tfrac{1}{2} m v^2 \qquad \Delta E_k = E_k\,final - E_k\,initial$$

In an **elastic** collision **kinetic energy is conserved**. This means we can work out the kinetic energy before and after given smaller pieces of information.

$$E_k\,final = E_k\,initial$$

Impulse

$$F = ma$$

$$F = \frac{\Delta(mv)}{\Delta t}$$

$$F\,\Delta t = \Delta\,(mv)$$

Therefore impulse can be defined as:

'the change in momentum' or the 'product of force and time'

Area under a force-time graph is impulse.

Work, Power and Efficiency

$$P = Fv \qquad W = F\,s\,\cos\theta$$

$$P = \frac{\Delta W}{\Delta t} \qquad Efficiency = \frac{Useful\ Output\ Power}{Input\ Power}$$

There are many types of energy: gravitational potential, kinetic, chemical, elastic potential, electrical, sound and more. **Work** is done when a force is applied across a distance.

Energy is measured in **joules** and power is measured in **watts**, where one watt is equal to one joule per second.

Density

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

$$Density\ (kgm^{-3}) = \frac{Mass\ (kg)}{Volume\ (m^3)}$$

Density is the mass of a material per unit volume.

To find the density of a liquid, its mass and volume can be measured. To find the density of a solid, its mass can be measured as normal and then its volume by measuring the volume of water it displaces.

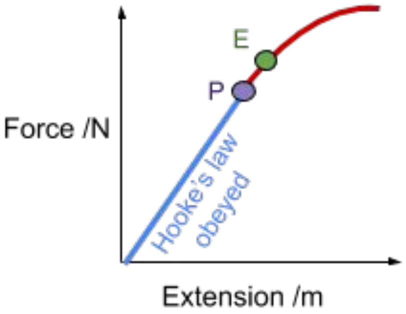
Hooke's Law

Hooke's law says that the force applied is directly proportional to the extension.

$$Force = k\Delta L$$

Force = Spring Constant x Change in Length

The limit of proportionality is the point beyond which Hooke's law no longer applies. The elastic limit is the maximum stress that can be applied without permanent/plastic deformation which is when it does not return to its original shape.



Elastic Deformation: Material returns to original shape and has no permanent extension. Energy is stored as elastic strain energy e.g. an elastic band

Plastic Deformation: Material is permanently stretched because the atoms have physically moved relative to one another. Energy is used to deform it e.g polythene

Stress and Strain

Tensile Stress is the force applied per unit cross-sectional area, measured in Pa or Nm^{-2}

Tensile Strain is the extension per unit original length and has no unit

$$Stress = \frac{F}{A} \qquad Strain = \frac{\Delta L}{L}$$

If enough stress is applied to a material it can fracture. This is called the breaking stress. The maximum stress it can withhold is called the ultimate tensile stress.

A brittle material fractures without showing any plastic behaviour. A ductile material can be stretched into long wires and stays permanently stretched. The strength of a material is its ultimate tensile stress.

Energy Stored

If Hooke's Law is obeyed, energy stored is the area under the graph

$$Work\ Done = ½\ F\ Δ\ L$$

but...

$$Work\ Done = Energy\ Stored$$

so...

$$E = ½\ F\ Δ\ L$$

$$E = ½\ k\ (Δ\ L)^2$$

The energy in a spring can be transformed into kinetic and gravitational potential energy.

Young Modulus

Up to the limit of proportionality, the stress and strain are directly proportional to each other. If you divide stress by strain, you get the young modulus, a constant measure of stiffness.

$$\text{Young Modulus} = \frac{\text{Tensile Stress}}{\text{Tensile Strain}} = \frac{FL}{A\Delta L}$$

The gradient of a stress strain graph is the young modulus.
The area under the graph is the 'strain energy per unit volume' and therefore:

$$\text{Energy per unit Volume} = \tfrac{1}{2} \times \text{Stress} \times \text{Strain}$$