Edexcel Physics A-level

Topic 2: Mechanics

Key Points

Scalars and Vectors

Scalar quantities are ones which only have a **magnitude**:

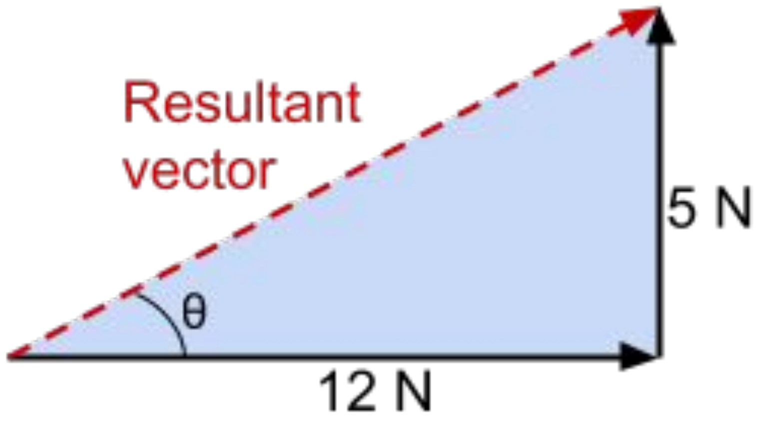
- Mass
- Time
- Energy
- Work
- Length
- Speed

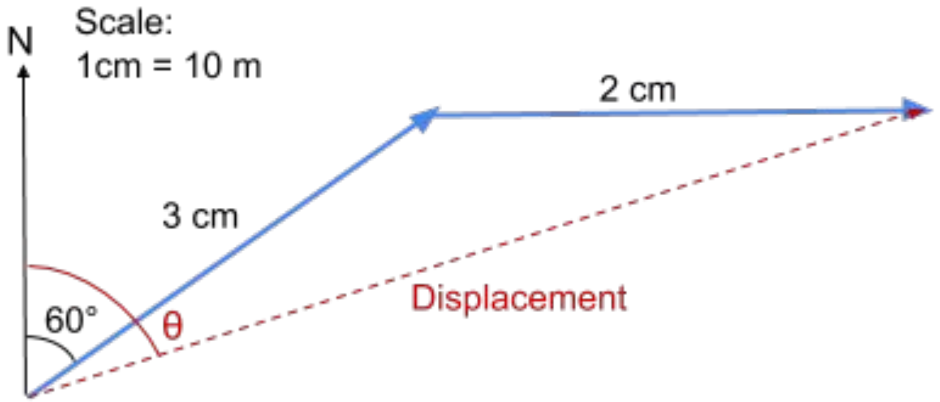
Vector quantities are ones which have a **magnitude and direction**:

- Displacement
- Force
- Acceleration
- Velocity
- Momentum

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, calculations must be used.

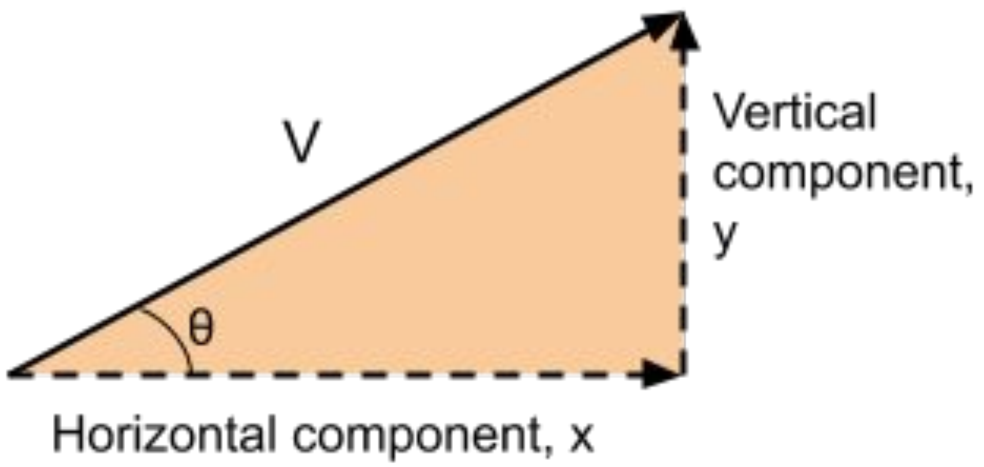




Vector triangles can be used to determine **resultant vectors** as shown above.
If 3 forces form a closed triangle they are balanced and will have a resultant force of 0 N.

Resolving Vectors

Resolving a vector means splitting it up into its **horizontal and vertical** components. Because these components 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 the line of action of the force 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 that both act on the same body and 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**.

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 the motion of an object.

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 its shape.

Terminal Velocity happens when frictional forces equal the driving force, causing a resultant force of 0 N and zero acceleration.

Newton's First Law

Newton's first law of motion states that an object will remain in its stationary or moving state, unless acted on by a **resultant** force. This means:

- If an object is at **rest**, it will **remain at rest** unless there is a resultant force acting on it
- If an object is moving at a given **velocity**, it will continue moving with that **same** velocity (same **speed** and in the same **direction**) unless acted on by a resultant force

Consequently, any time an object **starts** moving, **accelerates**, or changes the **direction** in which is travelling, a resultant force **must** be acting.

Newton's Second Law

Force (N) = Mass (kg) x Acceleration (ms^{-2})

- For an object to accelerate, there must be a **resultant force** acting on it
- The acceleration is **directly** proportional to the resultant force and **inversely** proportional to the mass of the object

Terminal Velocity in a falling object:

1. Initially the weight **>** air resistance, so there is a **resultant** downwards force and the object accelerates
2. As velocity increases, **air resistance** increases
3. When air resistance **=** weight, there is no resultant force and so the object travels at terminal velocity

Newton’s Third Law

Newton’s third law states that every action has an **equal and opposite** reaction. This means that if a force is applied to an object, the object will push back with a force that is equal in **magnitude**, and opposite in **direction**.

One of the consequences of this is that objects resting on a surface will always have an upwards **reaction force** to counteract the weight of the object. This explains why the object doesn’t simply fall through the surface!

Work, Power and Efficiency

$$P = \frac{\Delta W}{\Delta t}$$

$$P = Fv$$

$$W = F\,s\,\cos\theta$$

$$Efficiency = \frac{\text{Useful power output}}{\text{Total power input}}$$

$$Efficiency = \frac{\text{Useful energy output}}{\text{Total energy input}}$$

There are many types of energy: gravitational potential, kinetic, chemical, elastic potential, electrical, sound and more. Energy is transferred when a force is applied across a distance, this is known as the **work done**.

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

Kinetic Energy

Kinetic energy is a form of energy that all **moving** objects have. The **faster** the object is moving, or the **heavier** the object is, the more kinetic energy it must have. It is defined by the equation:

$$E_k = \frac{1}{2} m v^2$$

This means that if the object's velocity **doubles**, the kinetic energy it has will **quadruple**.

When a vehicle brakes to a stop, all the kinetic energy must be transferred to other forms since **energy cannot be created or destroyed**. Most of the energy is used to do work against **friction** between the brake discs and pads, and is transferred to **heat** energy.

Gravitational Potential Energy

When an object is raised to a height, it gains **gravitational potential energy**. This energy is determined by the **gravitational field strength**, the **mass** of the object and the **height** to which it is raised. It is calculated using the equation:

$$G.P.E = m \times g \times h$$

When an object **falls** from a height, the gravitational potential energy it has decreases as it falls. Since energy cannot be created or destroyed, this energy is transferred to **kinetic energy** and **work done** against resistive forces.

Momentum

All moving objects have momentum, the value of which can be calculated using:

Momentum ($kgms^{-1}$) = *Mass* (kg) x *Velocity* (ms^{-1})

A **closed system** is one in which no external forces act. In a closed system the **conservation of momentum** is always observed. This states that the momentum of the system **before** an event must be **equal** to the momentum of the system **after** the event.

$$p_1 = p_2$$

$$m_1 v_1 = m_2 v_2$$

Collisions

For all collisions, the **conservation of momentum** must apply. Whether or not the **kinetic energy** of the system is conserved depends on the type of collision:

- In **elastic collisions**, the kinetic energy of the system is **conserved** and so:

$$E_k\ final = E_k\ initial$$

- In **inelastic collisions**, the kinetic energy of the system is **not conserved** and some kinetic energy is dissipated by being transferred to other forms - to work out the quantity of energy transferred to other forms you can compare the initial and final KE values:

$$\Delta E_k = E_k\ final\ - E_k\ initial$$

Impulse

By combining the equations for **momentum** with **Newton's Second Law**, we can produce a definition for impulse:

$$F = ma$$

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

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

Impulse can therefore be described as the **change of momentum** of an object. It is equal to the **area** under a **Force-Time graph**.

Another useful thing that these equations demonstrate is that the **force** an object experiences is equal to the **rate of change of momentum** - an idea used in vehicle safety.