

# Edexcel Physics A-level

## Topic 2: Mechanics

### Key Points

# Scalars and Vectors

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

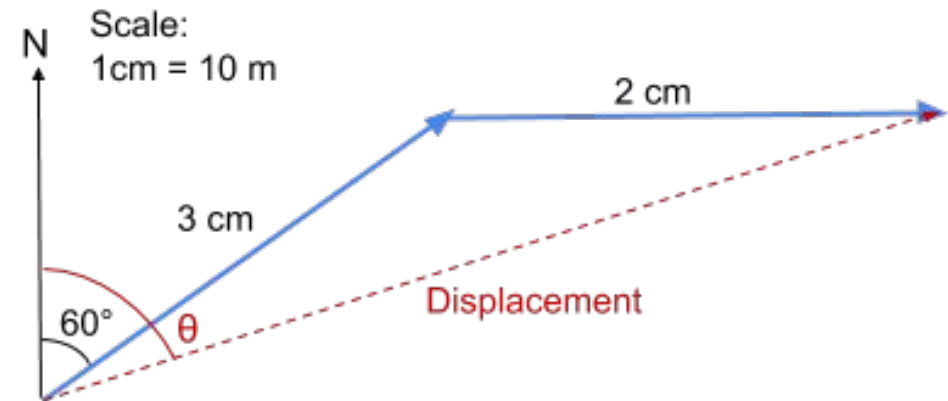
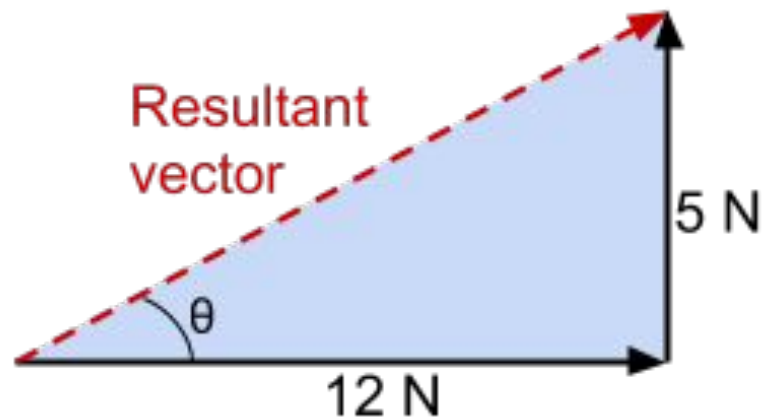
- Mass
- Time
- Energy
- Work
- Length
- Speed

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

- Displacement
- Force
- Acceleration
- Velocity
- Momentum

# Drawing Vectors

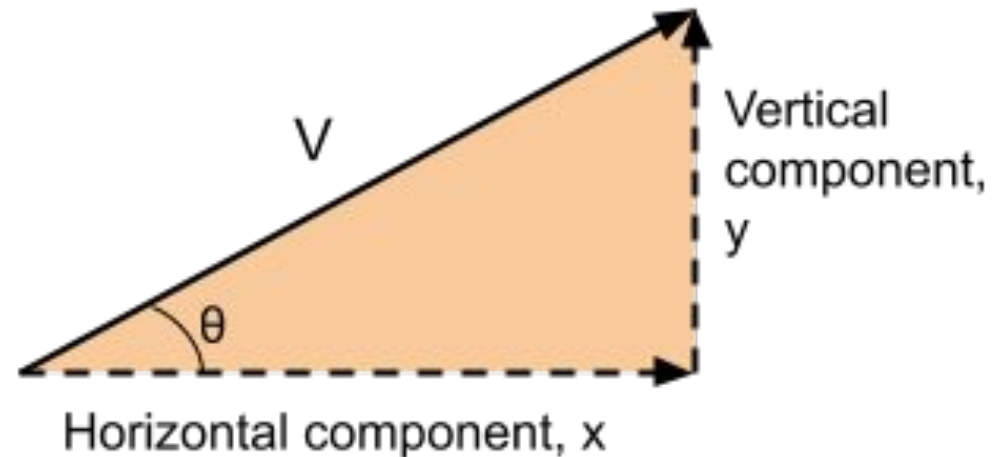
Vectors have both a magnitude and a direction, compared to scalar quantities which only have a magnitude. Vectors can be shown with **arrow** drawings. If they are drawn **to scale** then they can be physically measured. If not, calculations must be used.



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.**

$$\textit{Moment (Nm) = Force (N) x Perpendicular Distance (m)}$$

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:

$$\textit{Total Clockwise Moment = Total Anticlockwise Moment}$$

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.

$$\textit{Moment of a Couple (Nm) = Force (N) x Perpendicular Distance Between Lines of Action (m)}$$

# 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

$$\text{Force (N)} = \text{Mass (kg)} \times \text{Acceleration (ms}^{-2}\text{)}$$

- 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

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

$$P = Fv$$

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

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

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

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:

$$\text{Momentum (kgms}^{-1}\text{)} = \text{Mass (kg)} \times \text{Velocity (ms}^{-1}\text{)}$$

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.

$$p_1 = p_2$$

$$m_1v_1 = m_2v_2$$

# 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:

$$E_k \text{ final} = E_k \text{ initial}$$

- 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:

$$\Delta E_k = E_k \text{ final} - E_k \text{ initial}$$

# Impulse

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

$$F = ma$$

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

$$\text{Impulse} = F\Delta t = \Delta(mv)$$

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.