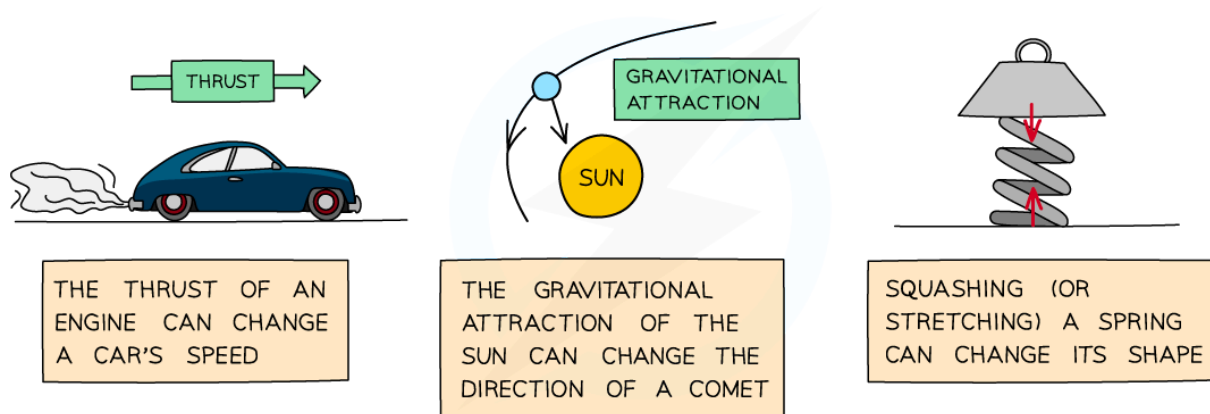


Forces - Basics

- A force is defined as:

A push or a pull that acts on an object due to the interaction with another object

- Forces can affect bodies in a variety of ways:
 - Changes in **speed**: forces can cause bodies to speed up or slow down
 - Changes in **direction**: forces can cause bodies to change their direction of travel
 - Changes in **shape**: forces can cause bodies to **stretch**, **compress**, or **deform**

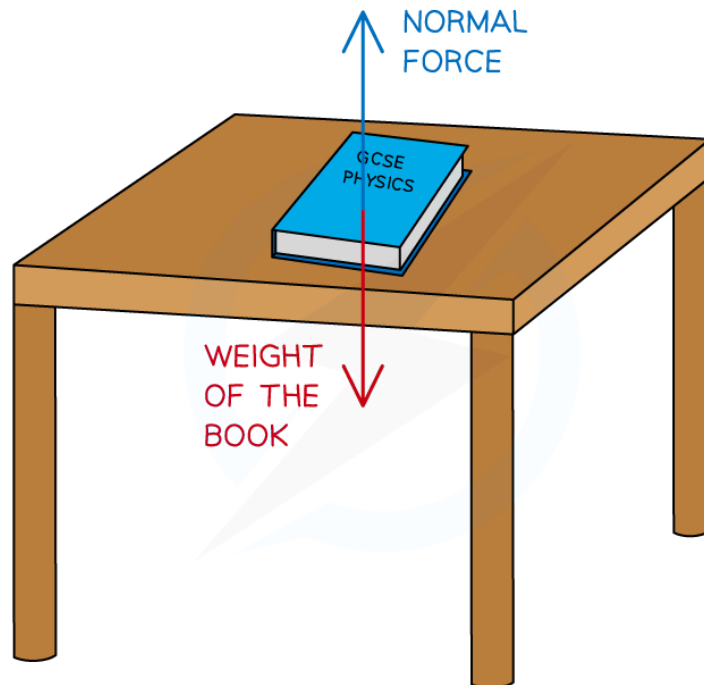


The effects of different forces on objects

Resultant Forces on a Straight Line

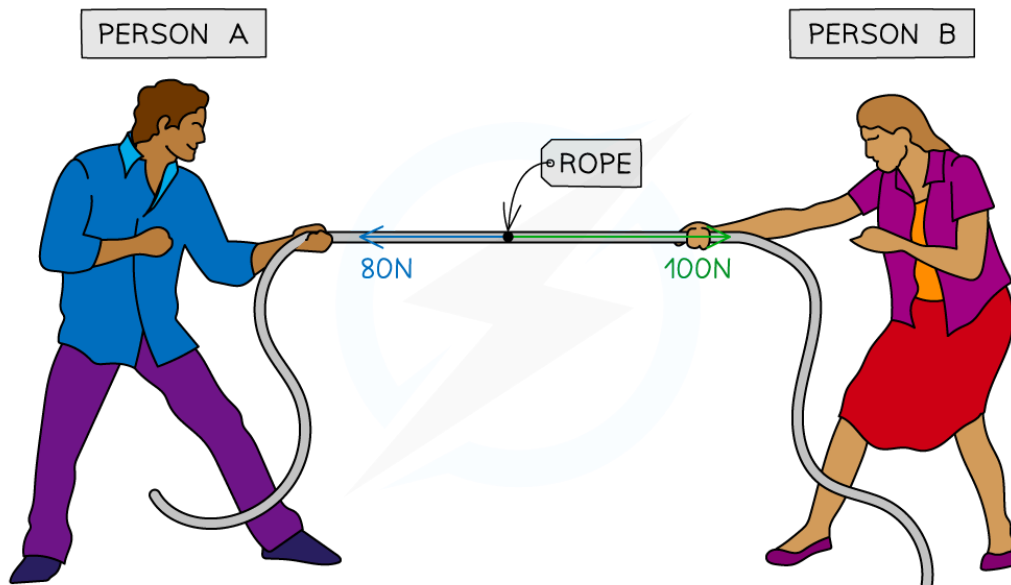
- A **resultant force** is a single force that describes all of the forces operating on a body
- When many forces are applied to an object they can be combined (added) to produce one final force which describes the **combined action** of all of the forces
- This single resultant force determines:
 - The **direction** in which the object will move as a result of all of the forces
 - The **magnitude** of the final force experienced by the object
- The resultant force is sometimes called the **net force**
- Forces can combine to produce
 - **Balanced** forces
 - **Unbalanced** forces
- **Balanced** forces mean that the forces have combined in such a way that they cancel each other out and no resultant force acts on the body
 - For example, the **weight** of a book on a desk is balanced by the **normal** force of the desk

- As a result, **no resultant force** is experienced by the book, the book and the table are **equal** and **balanced**



A book resting on a table is an example of balanced forces

- **Unbalanced** forces mean that the forces have combined in such a way that they do not cancel out completely and there is a **resultant force** on the object
 - For example, imagine two people playing a game of tug-of-war, working against each other on opposite sides of the rope
 - If person **A** pulls with 80 N to the left and person **B** pulls with 100 N to the right, these forces do not cancel each other out completely
 - Since person **B** pulled with more force than person **A** the forces will be unbalanced and the rope will experience a resultant force of 20 N to the right



A tug-of-war is an example of when forces can become unbalanced

- Resultant forces can be calculated by adding or subtracting all of the forces acting on the object
 - Forces working in opposite directions are **subtracted** from each other
 - Forces working in the same direction are **added** together
- If the forces acting in opposite directions are equal in size, then there will be no resultant force – the forces are said to be **balanced**

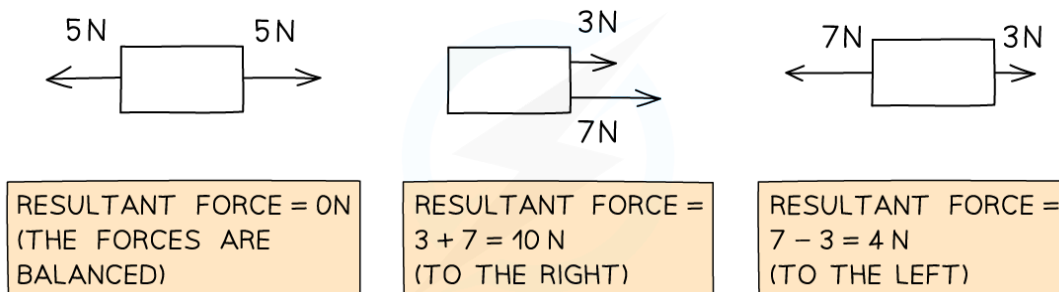


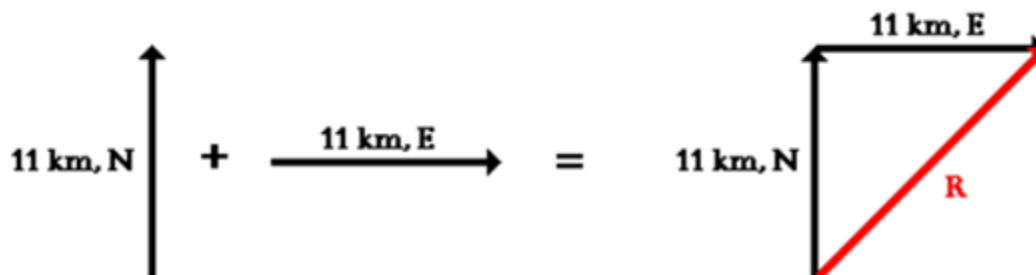
Diagram showing the resultant forces on three different objects

Imagine the forces on the boxes as two people pushing on either side

- In the first scenario, the two people are evenly matched - the box **doesn't move**
- In the second scenario, the two people are pushing on the same side of the box, it moves to the right with their combined strength
- In the third scenario, the two people are pushing against each other and are not evenly matched, so there is a **resultant force to the left**

Head to tail Rule (Triangle law of vector addition)

- This rule can be used to add **2** or more vectors
- Just focus on the name (Head to tail)...i.e. connecting head of one vector to tail of the other vector
- Place the 1st vector
- The head of 1st vector will be connected to tail of 2nd vector
- If there are more than 2 vectors:
 - Head of 2nd connected to tail of 3rd
 - Head of 3rd connected to tail of 4th
 - And son on...
- The resultant vector will start from the tail of the 1st vector to the head of the last vector
 - i.e. tail of the resultant vector is the tail of the 1st vector
 - head of the resultant vector is the head of the last vector



The above can be done in 2 ways.

1. Use a conversion scale to convert the length into forces (e.g 1km=1N). Then draw these vectors using the head to tail rule. Once you have drawn the resultant vector, measure that and use your conversion scale to convert back in km.
2. The other way this could be done is by using the pythagorean theorem, as it is a right angled triangle. No measure means or conversion scale would be required if you do this way.

Direction: It can be found out by measuring/calculating the angle of the resultant.

Newton's First Law of Motion

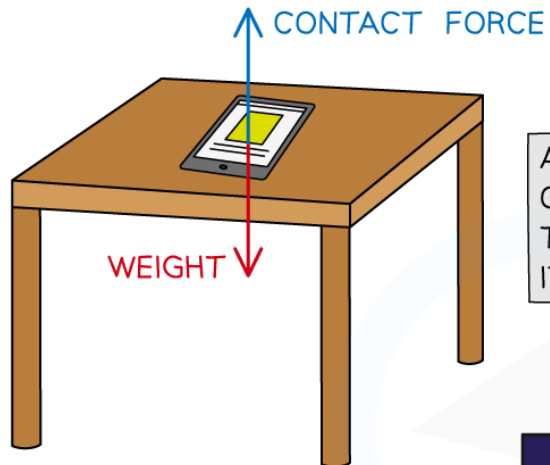
- Newton's **first law of motion** states:

Objects will remain at rest, or move with a constant velocity unless acted on by a resultant force

- This means if the resultant force acting on an object is zero:
 - The object will **remain stationary** if it was stationary before
 - The object will continue to move at the **same velocity** if it was moving
- When the resultant force is **not** zero
 - The **speed** of the object can change
 - The **direction** of the object can change

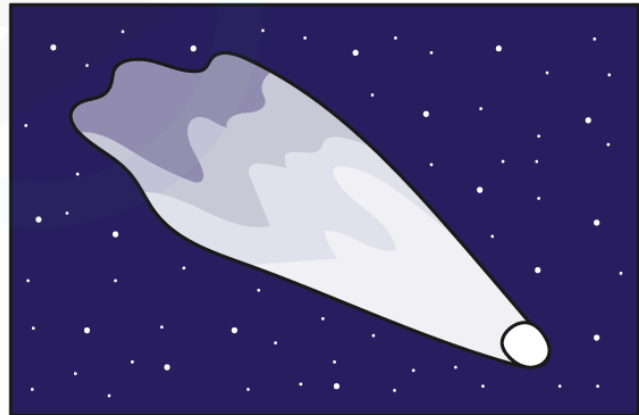
Applying Newton's First Law

- Newton's first law is used to explain why things move with a **constant** (or **uniform**) **velocity**
 - If the **forces** acting on an object are **balanced**, then the **resultant force** is **zero**
 - The velocity (i.e. speed and direction) **can only change** if a **resultant force** acts on the object
- A few examples with uniform velocity are shown below:



A TABLET STAYS AT REST ON A DESK BECAUSE THE TWO FORCES ACTING ON IT ARE BALANCED

A COMET MOVES THROUGH INTERSTELLAR SPACE IN A STRAIGHT LINE AT CONSTANT SPEED BECAUSE THERE ARE NO RESULTANT FORCES ACTING ON IT



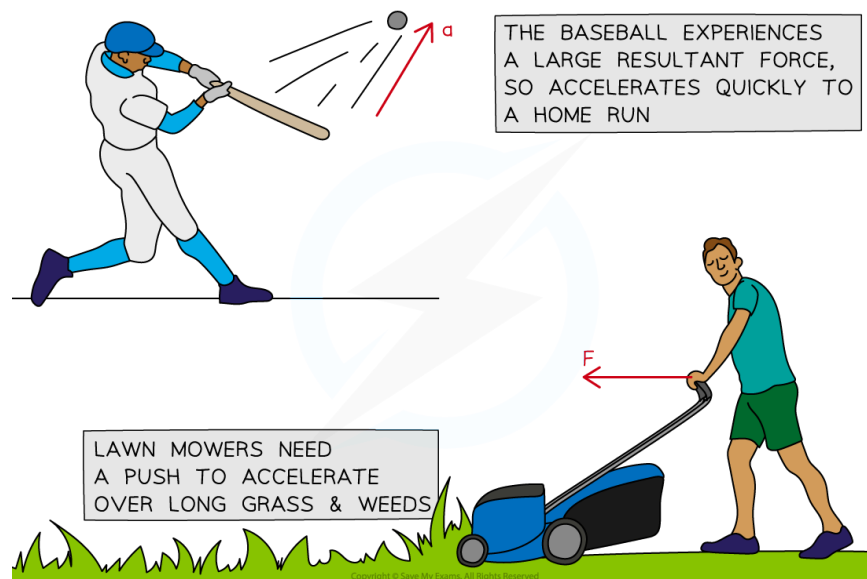
Constant velocity can only be achieved when the forces on an object are balanced - in other words, when the resultant force is zero

Newton's Second Law

- Newton's **second law of motion** states:

The acceleration of an object is proportional to the resultant force acting on it and inversely proportional to the object's mass

- Newton's second law explains the following important principles:
 - An object will **accelerate** (change its velocity) in response to a **resultant force**
 - The **bigger** this resultant force, the **larger** the acceleration
 - For a given force, the **greater** the object's mass, the **smaller** the acceleration experienced
- The image below shows some examples of Newton's second law in action:



Objects like baseballs and lawnmowers accelerate when a resultant force is applied on them. The size of the acceleration is proportional to the size of the resultant force

- Newton's second law can be expressed as an equation:

$$F = ma$$

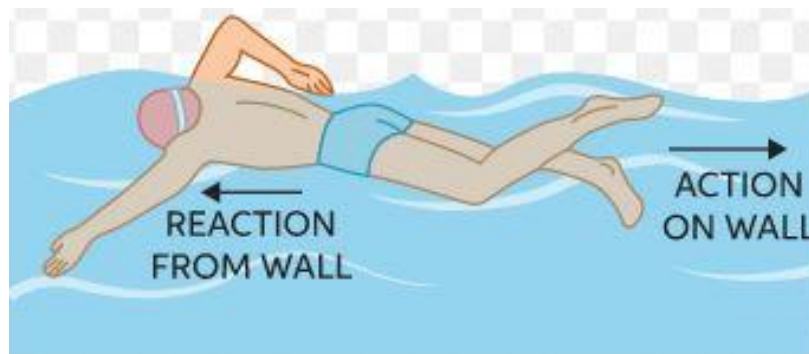
- Where:
 - F = resultant force on the object in Newtons (N)
 - m = mass of the object in kilograms (kg)
 - a = acceleration of the object in metres per second squared (m/s^2)
- The **force** and the **acceleration** act in the **same direction**

Newton's third law:

If an object A exerts a force on object B, then object B must exert a force of equal magnitude and opposite direction back on object A.

This law represents a certain symmetry in nature: forces always occur in pairs, and one body cannot exert a force on another without experiencing a force itself. We sometimes refer to this law loosely as action-reaction, where the force exerted is the action and the force experienced as a consequence is the reaction.

We can readily see Newton's third law at work by taking a look at how people move about. Consider a swimmer pushing off from the side of a pool, as illustrated below.



You can watch the following videos as well;

Newton's 1st law (**Only watch until 4:50**)

▶ Newton's First Law of Motion: Mass and Inertia

Newton's 2nd law

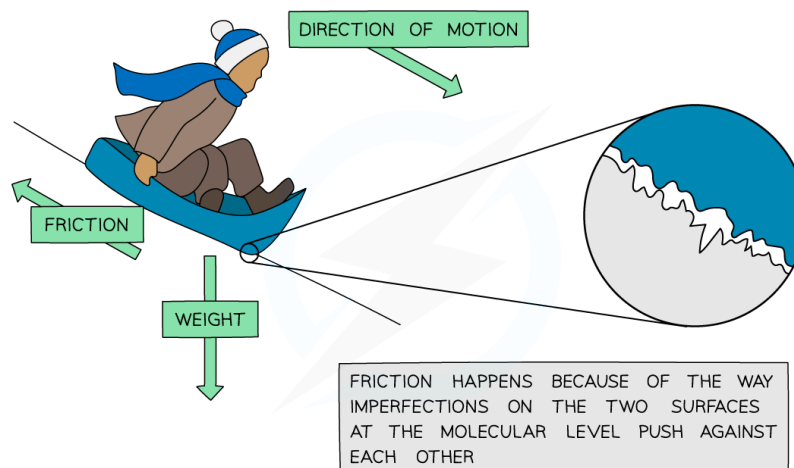
▶ Newton's Second Law of Motion | Physics | Don't Memorise

Newton's 3rd law

▶ Newton's Third Law of Motion: Action and Reaction

Friction in Solids

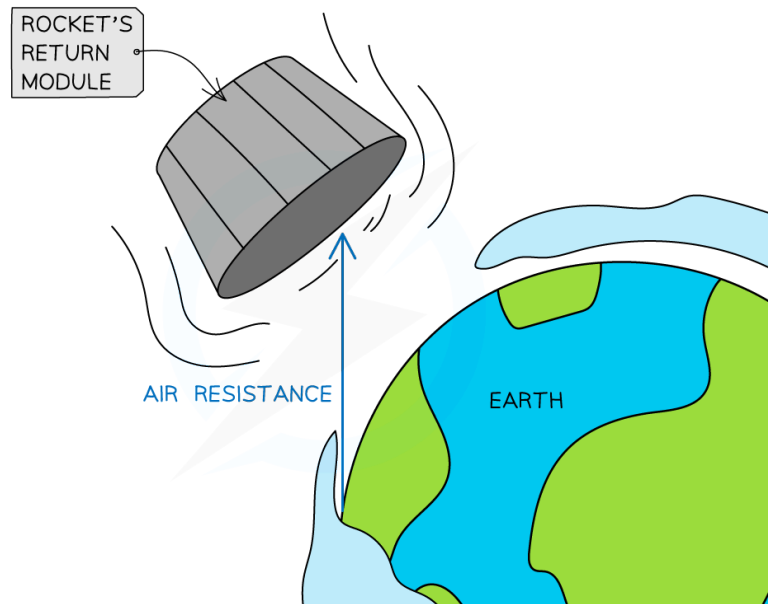
- Friction is a force that works in **opposition** to the motion of an object
 - This slows down the motion of the object
- When friction is present, energy is transferred in the form of **heat**
 - This raises the **temperature** (thermal energy) of the object and its surroundings
 - The work done against the frictional forces causes this rise in the temperature
- **Friction in solids** is caused by **imperfections** in the surfaces of the objects moving over one another
 - Not only does this slow the object down but also causes an increase in **thermal energy**



The interface between the ground and the sledge is bumpy which is the source of the frictional force

Friction in Fluids

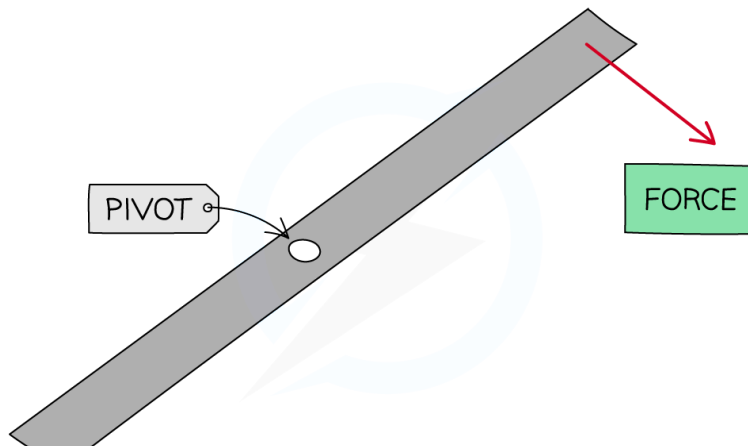
- **Gases** and **liquids** are known as **fluids**
 - Fluids are different to solids because the particles in fluids can move around
- Friction acts on objects moving through gases and liquids as the particles collide with the object
 - This type of friction is called **drag**
- Air resistance is a **type of friction** that slows the motion of an object
- Particles bump into the object as it moves through the air
 - As a result, the object heats up due to the work done against the frictional forces



The return module of a rocket heats up due to the work done by air resistance as it travels a distance through the atmosphere

Moments

- As well as causing objects to speed up, slow down, change direction and deform, forces can also cause objects to **rotate**
- An example of a rotation caused by a force is on one side of a pivot (a fixed point that the object can rotate around)
 - This rotation can be **clockwise** or **anticlockwise**



The force will cause the object to rotate clockwise about the pivot

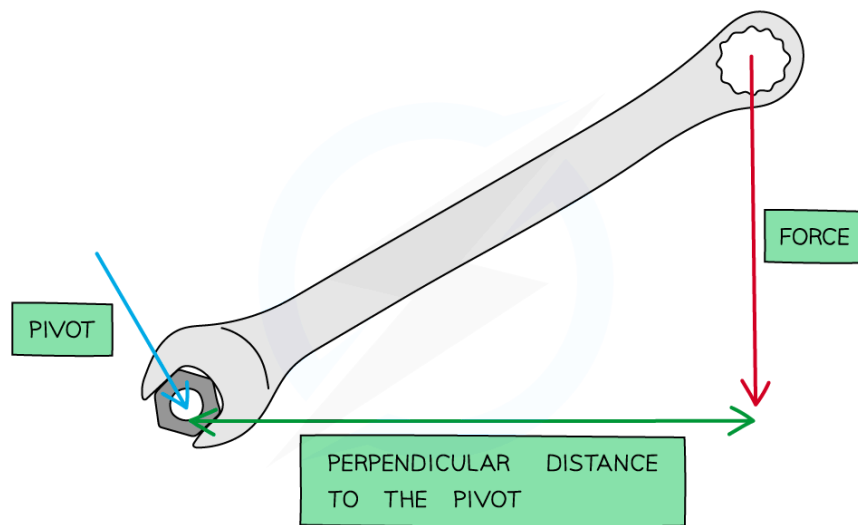
- A **moment** is defined as:

The turning effect of a force about a pivot

- The size of a moment is defined by the equation:

$$M = F \times d$$

- Where:
 - M = moment in newton metres (Nm)
 - F = force in newtons (N)
 - d = perpendicular distance of the force to the pivot in metres (m)



The moment depends on the force and perpendicular distance to the pivot

- This is why, for example, the door handle is placed on the opposite side to the hinge
 - This means for a given force, the perpendicular distance from the pivot (the hinge) is larger
 - This creates a larger **moment** (turning effect) to make it easier to open the door
- Opening a door with a handle close to the **pivot** would be much harder, and would require a lot more **force**
- Some other examples involving moments include:
 - Using a crowbar to prize open something
 - Turning a tap on or off
 - A wheelbarrow
 - Scissors

Principle of Moments

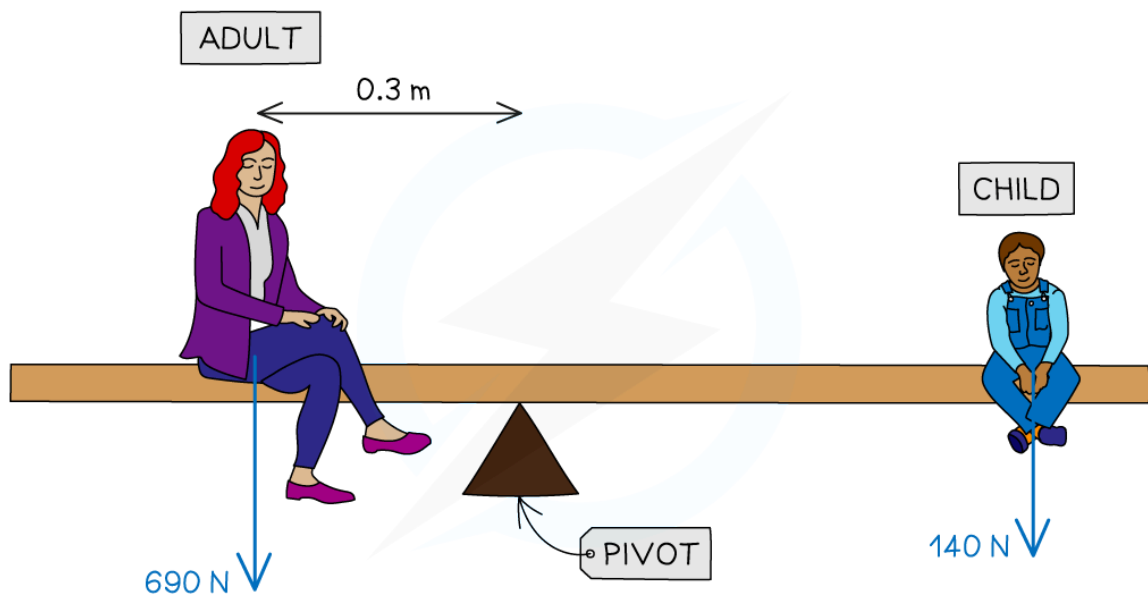
- The principle of moments states that:

If an object is balanced, the total clockwise moment about a pivot equals the total anticlockwise moment about that pivot

- Remember that the moment = **force $\times$ distance from a pivot**
- The forces should be **perpendicular** to the distance from the pivot
 - For example, on a horizontal beam, the forces which will cause a moment are those directed upwards or downwards

→The example below will better help you understand.

A parent and child are at opposite ends of a playground see-saw. The parent weighs 690 N and the child weighs 140 N. The adult sits 0.3 m from the pivot.



Calculate the distance the child must sit from the pivot for the see-saw to be balanced.

Solution:

Step 1: List the know quantities

- Clockwise force (child), $F_{\text{child}} = 140 \text{ N}$
- Anticlockwise force (adult), $F_{\text{adult}} = 690 \text{ N}$
- Distance of adult from the pivot, $d_{\text{adult}} = 0.3 \text{ m}$

Step 2: Write down the relevant equation

- Moments are calculated using:

$$\text{Moment} = \text{force} \times \text{distance from pivot}$$

- For the see-saw to balance, the principle of moments states that

$$\text{Total clockwise moments} = \text{Total anticlockwise moments}$$

Step 3: Calculate the total clockwise moments

- The clockwise moment is from the child

$$\text{Moment}_{\text{child}} = F_{\text{child}} \times d_{\text{child}} = 140 \times d_{\text{child}}$$

Step 4: Calculate the total anticlockwise moments

- The anticlockwise moment is from the adult

$$\text{Moment}_{\text{adult}} = F_{\text{adult}} \times d_{\text{adult}} = 690 \times 0.3 = 207 \text{ Nm}$$

Step 5: Substitute into the principle of moments equation

$$140 \times d_{\text{child}} = 207$$

Step 6: Rearrange for the distance of the child from the pivot

$$d_{\text{child}} = 207 \div 140 = 1.48 \text{ m}$$