Physics Knowledge Organiser
P8 - Forces in balance

Scalar and vector quantities

Scalar quantities have only a magnitude. Vector quantities have a magnitude and direction.

Scalar	Vector
Distance	Displacement
Speed	Velocity
mass	Acceleration
Temperature	Force
Pressure	Weight
Volume	Momentum
Work	

Representing Forces and other vector quantities

Since forces are a vector quantity, it is useful to show their magnitude (size) and direction using an arrow. The arrow points in the direction that the force acts, and its length shows the magnitude.
For example in the diagram the force acting to the left of the object is larger
Than the fore acting to the right.

Contact and Non-contact Forces

Forces are always the result of objects **interacting** with each other. For instance, the force of gravity keeping this piece of paper on the desk is the result of the interaction between the Earth's mass and the paper's mass. All forces can be classified as contact or non-contact forces.

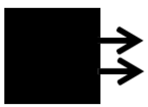
Examples of contact forces: friction, air resistance, tension, the normal contact force.
Examples of non-contact forces: gravitational force, electrostatic force and magnetic force.

Key Terms	Definitions
Quantity	Anything that can be given a numerical value.
Magnitude	Size of a quantity. E.g. a distance of 5 metres has a higher magnitude than 2 metres.
Scalar	Describes quantities that only have a magnitude (size). E.g. speed (how fast something is moving).
Vector	Describes quantities that have a magnitude AND a specific direction. E.g. velocity (speed in a particular direction)
Force	A vector quantity. Forces are pushes or pulls that act on an object. Forces have size and direction. Forces are the result of objects interacting with each other.
Contact forces	For these forces to act, the interacting objects have to be physically touching.
Non-contact forces	For these forces to act, the interacting objects don't have to be touching (they are physically separate).
Resultant force	The single overall force acting on an object. It has the same effect as all the forces acting on the object all together. The resultant force is the vital thing in working out how an object will move. If there is a resultant force, the object's speed will change; or the shape of the object will change; or the direction of the object will change. If the resultant force is nothing (the forces cancel out), the object will keep doing what it was doing – either not moving at all, or moving along at a steady speed.

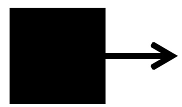
Physics Knowledge Organiser
P8 - Forces in balance

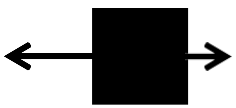
The Resultant Force

In real life, there are usually a few forces acting on any particular object. All the forces can be shown with vectors (arrows – see above). When we take all the forces into account, we can draw just one vector arrow to show a single force, which has the same effect on the object as all the other forces acting at once. This is simplest when the forces are in a straight line:

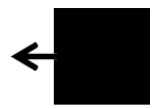


two forces are acting; by adding them we get the resultant force....





this time, the forces are opposite in direction, and are different in magnitude. We subtract one from the other to get the resultant force...



Resultant Force continued

If the forces acting on an object are equal in magnitude and opposite in direction, then the resultant force ends up being ZERO. You can say the forces are balanced. Reading the definition above should make it clear that a resultant force of zero means that an object's movement will not change. So if it was moving to start with, a resultant force of zero means it keeps moving at the same speed. Also, zero resultant force means the direction can't change.

The resultant force is.... nothing!

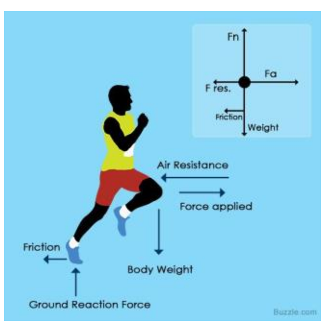
Free body diagrams

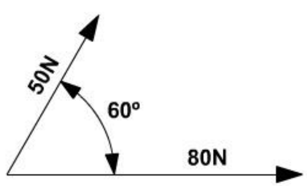
Free body diagrams are used to describe situations where several forces act on an object. Vector diagrams are used to resolve (break down) a single force into two forces acting at right angles to each other

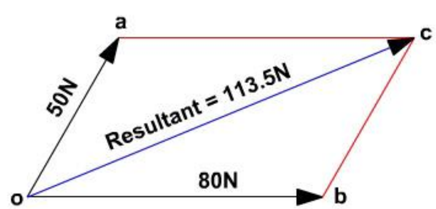
Resultant force – The parallelogram rule (Higher only)

The parallelogram of force is used to find the resultant force when the forces don't act in the same line. To find the resultant force you:

1. Work out the scale
2. Copy out one force to scale so it follows on the other force at the same angle as the original
3. Repeat for the other force. The forces should meet and create a parallelogram.
4. Draw the resultant force between this point and the point the objects act from.
5. Measure the size of this arrow.
6. Use the scale to determine the magnitude of the force







Parallelogram of Forces

Physics Knowledge Organiser
P8 - Forces in balance

Work done and energy transfer

‘Work’ has a particular meaning in physics. If work has been done, energy has been transferred. Work is always done as a result of a force acting on an object. The amount of work can be calculated using W= Fs.

For example, if a force of 1000N makes the car move 200m to the left …

The work done is W= 1000 x 200 = 200 000 J
This means 200 000 J of energy was transferred.

Work done against Frictional Forces

When objects move, they are almost always moving against a frictional force – so the friction arrow is opposite to the direction of motion. Doing work against friction causes an energy transfer to heat (thermal) energy. This raises the temperature of the object and the surroundings.
There are frictional forces even when objects move through the air – air resistance.

The Joule

The joule (J) is the unit for energy, and therefore the unit for work done. It has a particular definition, based on the equation for work done. 1 joule = 1 newton metre. This means that 1 J is the amount of work done when a force of 1 N causes an object to move 1 m. This is because $= F\ s$ and 1 = 1 x 1!

Distance vs. Displacement

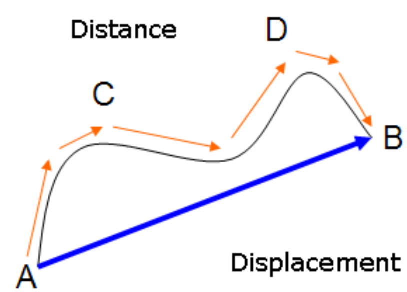
Displacement is different to distance because it involves the direction that an object has moved. The displacement is always measured in a straight line from start to end of a journey, missing out any wiggles along the way.

Key Terms	Definitions
Work done	The measure of how much energy is transferred when a force makes an object. You can say: ‘a force does work on an object when it makes it move’. Doing work always involves the transfer of energy. This is a scalar quantity.
Joule	The unit joule (J) is how the amount of energy transferred by doing work is measured. 1 joule = 1 newton metre (thanks to the equation, below).
Distance	How far an object moves. It does not include direction , so distance is a scalar quantity.
Displacement	The distance an object moves from where it started. This is measured in metres. It is a vector quantity, because it includes the direction an object moved.
Friction	A contact force that results when two objects move past each other. They have to be touching.

Equation	Meanings of terms in equation and units
$W\ = F\ s$ *	*W = work done (joules, J)* *F = force (newtons, N)* *s = distance (metres, m) – aka displacement*

Distance vs. Displacement Diagram

Look how displacement is simply a straight line from A to B.
Distance is the total, with visits to C and D during the journey.



Physics Knowledge Organiser
P8 - Forces in balance

Newton's First Law

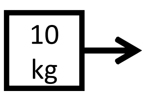
Read the definition. Newton's first law tell us:

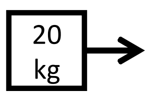
- Vehicles moving at a constant speed have a driving (push) force exactly equal to the resistive forces (like friction);
- Velocity (speed and direction) will only change if there is a resultant force acting (so the resultant force is NOT zero).
- If an object changed direction, it must have been because of a resultant force.

Newton's Second Law

Read the definition. This law follows on very sensibly from the first law. It reminds us that an object will only change in velocity (accelerate) if there is a resultant force acting on it. It also shows that the amount of acceleration depends on the resultant force and the mass of the object.

For instance, if a resultant force of 20 N acts on this object, the acceleration will be 20 / 10 = 2 m/s^2.





But with this object, the same resultant force only causes 20 / 20 = 1 m/s^2 acceleration.

Newton's Third Law

Read the definition. This law is often written as: 'for every action, there is an equal and opposite reaction'. In this version, action means the force exerted by object A on object B, and reaction means the force exerted by object B on object A.

This law explains why pushing **down** with your legs makes you jump **up** (the ground pushes back with the same size force as your push). It also explains why rockets can fly through space: the gases pushing out the back cause the rocket to move forward.

Key Terms	Definitions
Stationary	Not moving. The velocity is 0.
Newton's First Law	The law says that if the resultant force on an object is zero: ➢ Stationary objects stay stationary ➢ Moving objects keep moving at the same velocity (same speed and direction)
HT inertia	Inertia is the tendency of objects to stay at the same speed or stay stationary.
Newton's Second Law	Objects accelerate if there is a resultant force acting on them. The amount of acceleration is proportional to the magnitude of the resultant force and inversely proportional to the mass of the object. (see equation)
Proportional	Just like in maths: if the magnitude of one quantity increases because another quantity increases, they are proportional. The symbol is ∝.
Inversely proportional	The opposite of proportional: if one quantity **decreases** because another one increases, they are inversely proportional.
Newton's Third Law	This law says that when objects interact, the forces they cause to act on each other are equal and opposite.

Equation	Meanings of terms in equation and units
$F = m\,a$ *	*F = resultant force (N)* *m = mass (kg)* *a = acceleration (m/s^2)*

HT only: Inertial mass

Inertial mass measures how difficult it is to change the velocity of an object. It is defined as the ratio of force over acceleration.

For instance, it requires more force to slow down (change the velocity) a lorry compared to a bike. It also requires more force to make a lorry accelerate compared to a car.

Physics Knowledge Organiser
P8 - Forces in balance (Physics only)

Moments

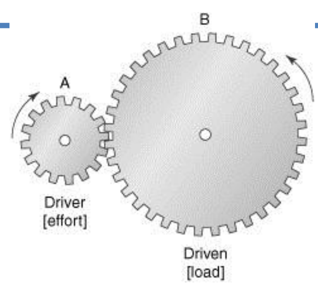
Forces can cause rotation. There has to be a resultant force on a rotating object, because it rotation involves changes in direction! Even when pushing on a door, you are using an applied force to cause rotation of the door. The centre of rotation (the **pivot**) is the hinge of the door. The turning effect is called the **moment** of the force.
If an object is balanced (for example, a see saw or a shelf with stuff on it), in the system the **clockwise moment is equal to the anticlockwise moment**. Notice that this doesn't mean the forces are the same each way (unless the distance from the pivot is the same) – but you can calculate the moment and/or the forces involved using the equation shown.

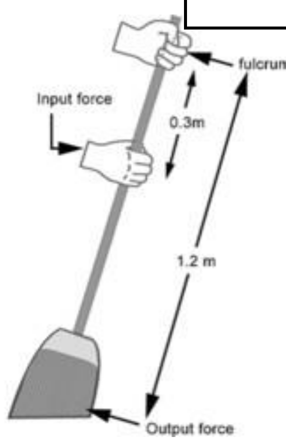
Levers

A lever is a simple system used to transmit a force. Levers can be distance multipliers or force multipliers.
Distance multiplier – this means the lever allows one end of the lever to move much further than where the force is applied, but this does reduce the force at that end. An example is a broom – see diagram.
Force multiplier – this means the lever is used to produce a larger force for the force applied, but this does mean the other end moves a smaller distance. A ring pull on a drinks can is an example – you apply a force at one end of the ring pull, the other end doesn't move as far but there is a big enough force to open the can. The pivot is in the middle.

Gears

Systems with gears are force multipliers or speed multipliers. One gear is the 'driver', which is where the force is applied in the first place. Other gears are driven by this one – they can be connected directly like in the diagram or indirectly, like how gears are joined by a chain on a bike.
Force multipliers – if the driver gear (aka cog) is smaller than the one it drives, the force is multiplied. This is as shown in the example in the diagram.
Speed multipliers – if the driver is larger than the driven gear, the driven gear goes faster. So it's a speed multiplier.





Key Terms)	Definitions
Rotation	Turning motion
Moment	Full name: "moment of a force". This is the turning effect of a force
Pivot	The centre of rotation of a turning object. It stays in a fixed position while other parts move – for example, the hinges of a door.
Line of action	The line along which a force arrow points.
Clockwise moment	The turning effect of a force in the direction hands move around a clock face.
Anticlockwise moment	The turning effect of a force in the direction opposite to the way hands move around a clock face.
Lever	A simple system in which something turns around a pivot, and where a force applied is transmitted to somewhere else.
Gear	A simple system in which wheels transmit the turning effect of a force to somewhere else.

Equation	Meanings of terms in equation and units
$M = F d$ *	*M = moment of a force* (Nm) *F = force* (N) *d = perpendicular distance from the pivot to the line of action of the force* (m)