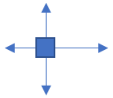
science physics

GCSE P5 – Forces and Motion 1

1. Scalars and Vectors

A physical quantity is something that can be measured.
Scalar quantities only have a magnitude (size) eg. mass and energy
Vector quantities have both magnitude and a direction eg. force and velocity. They are represented by an arrow. The length of the arrow represents the magnitude of the vector.

Free body diagrams are used to describe situations where several forces act on an object.



2. Contact and Non-contact forces

Contact forces act between two objects that are physically touching each other. Eg:

- Reaction force - experienced by an object resting on a surface
- Tension - experienced by an object being stretched
- Friction - experienced by objects sliding past each other
- Air resistance - experienced by objects moving through air

When a contact force acts between two objects, **both** objects experience the same **size** force, but in **opposite** directions.
Force is measured using a Newtonmeter
Non-contact forces act between two objects that are not physically touching each other. Eg:

- Magnetic force - experienced by any magnetic material in a magnetic field.
- Electrostatic force - experienced by any charged particle in an electric field.
- Gravitational force - experienced by any mass in a gravitational field.

Weight is the force acting on an object due to gravity and is measured in newtons (N) with a Newton meter. The weight of an object acts at a single point called its **centre of mass.**
Gravitational field strength (g) is measured in newtons per kilogram (N/kg).

$$W = m g$$

Weight (N) = mass (kg) x gravitational field (N/kg)

3. Work done

Work is done when a force causes an object to move.

$$W = F s$$

Work done (J) = Force (N) x distance (m)

4. Force and elasticity

When a force acts on an object, the object may change shape (bend, stretch or compress)
A change in shape is called **deformation**:

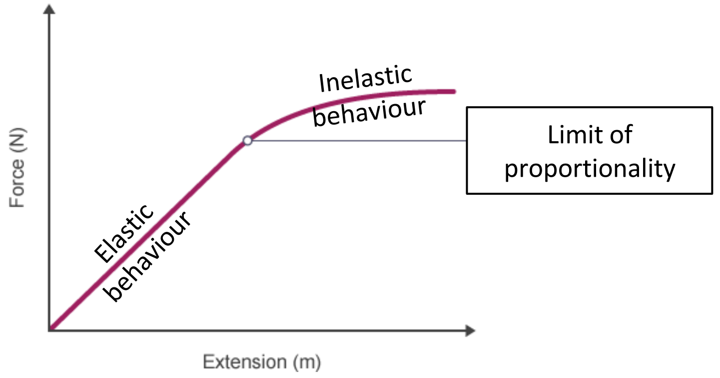
- **elastic** deformation – object returns to original size and shape when force is removed
- **inelastic** deformation - there is a permanent change in shape

Hooke's Law describes the extension of an elastic object (spring)

$$F = k e$$

Force (N) = spring constant (N/m) x extension (m)

Spring constant - a measure of the stiffness of a spring
The limit of proportionality - the elastic limit of a material (the furthest point it can be stretched while still being able to return to its previous shape) Once a material has gone past its elastic limit, its deformation is inelastic.

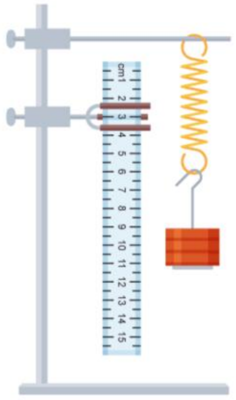


Work is done when a spring is extended or compressed.
Elastic potential energy is stored in the spring:

$$E_e = ½ ke^2$$

Elastic potential energy (J) = ½ x spring constant x extension^2 (m)

5. Required practical – investigating how forces affect the extension of a spring



1. Secure a clamp stand to the bench using a G-clamp or a large mass on the base.
2. Use bosses to attach two clamps to the clamp stand.
3. Attach the spring to the top clamp, and a ruler to the bottom clamp.
4. Adjust the ruler so that it is vertical, and with its zero level with the top of the spring.
5. Measure and record the unloaded length of the spring.
6. Hang a 100 g slotted mass carrier (weight 0.98N) from the spring. Measure and record the new length of the spring.
7. Add a 100 g slotted mass to the carrier. Measure and record the new length of the spring.
8. Repeat step 7 until you have added a total of 1,000 g.
9. For each result, calculate extension = length - unloaded length

Hazard	Consequence	Precaution
Equipment falls off desk	Injury to feet/leg	Secure stand to the desk with a clamp
Spring breaks and sharp end recoils	Damage to eye/skin	Wear goggles. Gently lower the masses when loading onto the spring
Spring breaks and masses fall to the floor	Injury to feet/leg	Gently lower the masses when loading onto the spring and step away

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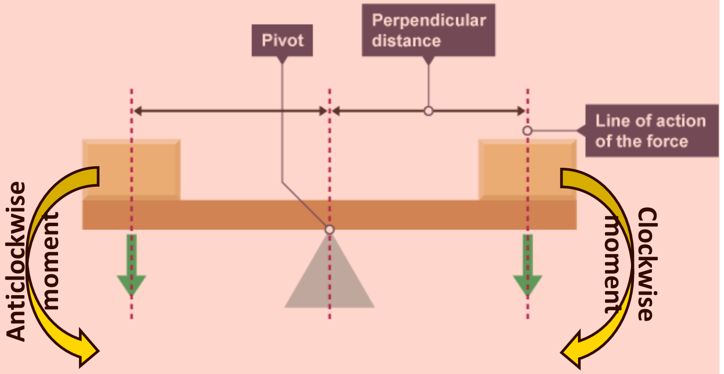
6. Moments

A moment is the turning effect of a force. Moments act about a point in a clockwise or anticlockwise direction.



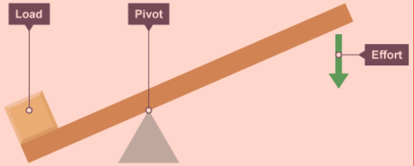
M = F d

Moment (Nm) = Force (N) x distance (m)

If an object is balanced:

total clockwise moment = total anticlockwise moment

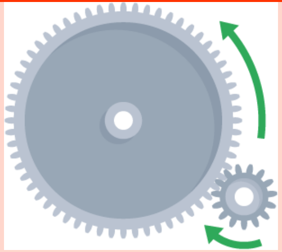
7. Levers



Levers make use of moments to act as a force multiplier: a larger force acts upon the load than is supplied by the effort (it is easier to move heavy objects)

The longer the lever, the further the effort acts from the pivot, the greater the force on the load will be.

8. Gears



As one gear turns, the other gear must also turn. Where the gears meet, the teeth must both move in the same direction.

The forces acting on the teeth are identical for both gears, but their moments are different:

- If the **driven gear** is made **larger** it will rotate more **slowly** but with a **greater moment**. Eg. a low gear ratio on a bike
- If the **driven gear** is made **smaller** it will rotate more **quickly** but with a **smaller moment**. Eg a high gear ratio on a bike

Turning a gear that has double the radius, doubles the turning effect - it is a 2× force multiplier.

9. Pressure in fluids

Pressure = force per unit area. Pressure determines the effect of a force on a surface.

The pressure in fluids (liquids or gases) causes a force that acts at right angles (90°) to the surface.

$$p = F/A$$

Pressure (Pa) = Force (N) ÷ area (m²)

The pressure in a liquid is due to the weight of the column of water above and acts in all directions:

$$p = h\rho g$$

pressure = column height × liquid density × gravitational field strength

(Pa) (m) (kgm⁻³) (N/kg)

An object that is partly, or completely, submerged experiences a greater pressure on its bottom surface than on its top surface.

This resultant force is **upthrust**.

upthrust < weight of the object = the object will sink

upthrust > weight of the object = the object will float.

10. Atmospheric pressure

The atmosphere is the layer of air around the Earth

- it is thin compared to the size of the Earth
- it becomes less dense as the altitude increases

Air molecules colliding with a surface cause atmospheric pressure.

As the altitude increases:

- the number of air molecules decreases
- the weight of the air decreases

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1. Motion in a straight line

Distance = how far an object moves (scalar)
Speed = the distance travelled per unit time (scalar)

$v = s/t$
velocity (m/s) = displacement (m) ÷ time (s)

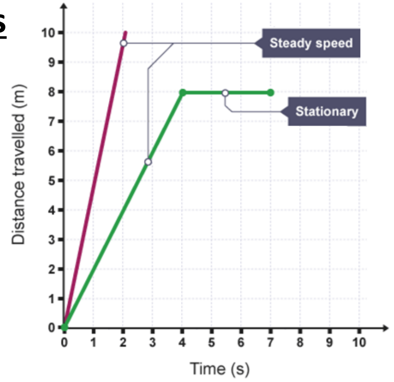
Method of travel	Typical speed (m/s)
walking	1.5
running	3
cycling	6
car	13-30
aeroplane	250

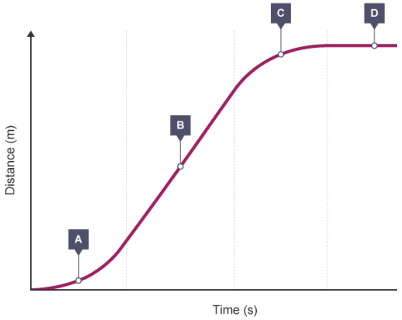
Velocity = speed in a particular direction (vector)
Acceleration = rate of change of velocity (vector)

$a = \Delta v/t$
acceleration (ms^{-2}) = velocity change (m/s) ÷ time (s)

2. Distance-time graphs

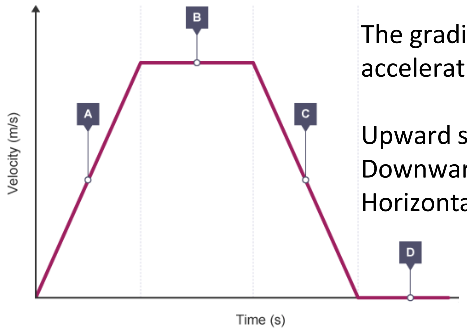
The gradient of the line shows the speed of the object.
The steeper the gradient the faster the object is moving





HIGHER TIER
A curved line shows the object is accelerating or decelerating
The speed at any point can be worked out by drawing a **tangent** to the curve and calculating its gradient

3. Velocity-time graphs



The gradient of the line shows the acceleration of the object.

Upward slope = acceleration
Downward slope = deceleration
Horizontal line = constant velocity

HIGHER TIER
The displacement of an object can be calculated from the **area under** a velocity-time graph.

$$v^2 - u^2 = 2as$$

(final velocity)^2 - (initial velocity)^2 = 2 × acceleration × distance

5. Newton's laws of motion

1st law: an object remains in the same state of motion unless a resultant force acts on it. Eg an object at rest stays at rest, a moving object continues moving at the same speed and direction.

2nd law:

$F = m a$
Force (N) = mass (kg) x acceleration (ms^{-2})

3rd law: when two objects interact, they exert equal and opposite forces on each other.

HIGHER TIER
The tendency of an object to continue in its current state (at rest or in uniform motion) is called **inertia**.

Inertial mass is a measure of how difficult it is to change the velocity of an object

4. Terminal velocity

As an object falls through a fluid:

1. the object accelerates downwards due to the force of gravity
2. as the object's speed increases, frictional forces increase
3. at terminal velocity, the weight of the object is balanced by the frictional forces, and the resultant force is zero

6. Stopping distance

When a force is applied to the brakes, work is done by the friction force between the brakes and the wheels. This reduces the kinetic energy and increases the temperature of the brakes. The greater the speed, the greater the braking force needed to stop it.

Stopping distance (m) = thinking distance (m) + braking distance (m)

Thinking distance	Braking distance
Drugs and alcohol Tiredness Age of driver Distractions (phone)	Quality of Brakes Quality of tyre tread Road conditions (icy/wet)

7. HIGHER TIER - Momentum

All moving objects have momentum

***p* = m v**
Momentum (kgm/s) = mass (kg) x velocity (m/s)

Principle of conservation of momentum:
'in a closed system (where no other forces act), total momentum before is always equal to total momentum after'
Momentum is conserved in collisions and explosions.

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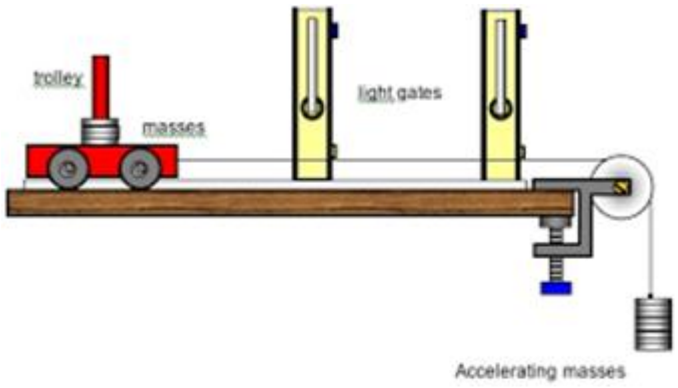
8. Required practical - investigating F=ma



Expt 1: Effect of changing the mass on the acceleration
- Independent = Mass of system (not just the trolley)
- Dependent = Acceleration (change in velocity ÷ time)
- Controls = Force applied, type of trolley, slant of ramp

Expt 2: Effect of changing the force applied on the acceleration
- Independent = Force applied
- Dependent = Acceleration
- Controls = Mass, type of trolley, angle of ramp

Light gates are used as they are more accurate – to measure the velocity at each light gate we do v = s/t

To measure the acceleration, we need to know the change in velocity) between each light gate and the time it takes to get between the two light gates.

Sources of error = friction between the trolley and the ramp and in the pulley system.

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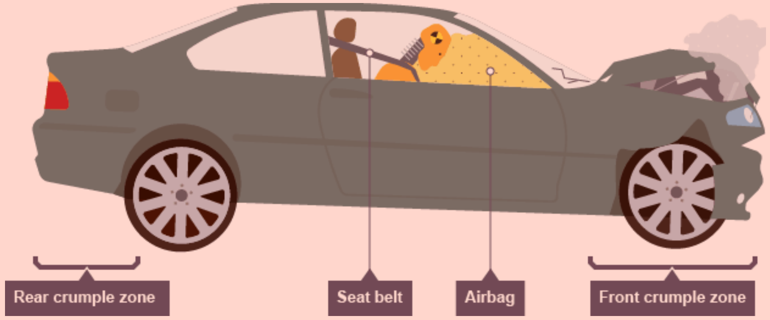
9. Car safety

During a collision there is a change in momentum.
The force of the collision is equal to the rate of change of momentum.

Car safety features such as seatbelts, airbags and crumple zones all work to increase the time taken for the collision and so reduce the force of the collision.



$$F = \frac{m \Delta v}{t}$$

$$\text{Force (N)} = \frac{\text{change in momentum (kgm/s)}}{\text{time (s)}}$$

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