P5 – Forces

Scalar and Vector Quantities

Scalar quantities – have **magnitude** only
e.g. temperature, mass and speed.
Vector quantities – have both **magnitude** and **direction**
e.g. velocity. displacement.

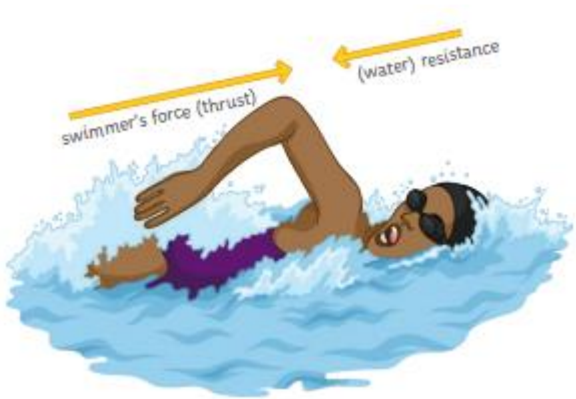
Vectors can be shown using **arrows:**
Size of arrow = magnitude of the quantity
Direction of arrow = direction of quantity

Contact and Non-Contact Forces

Force = a push or pull that acts on an object due to interaction with another object.

All forces are either:
- **Contact forces** – objects are physically touching
e.g. friction, air resistance, tension and normal contact force.
- **Non-Contact forces** – objects are physically separated
e.g. gravitational force, electrostatic force and magnetic force.

- Forces are **vectors** – shown by arrows.



Gravity

Weight = the **force** acting on an object due to gravity.

- Gravity close to Earth is due to the gravitational field.

- Weight of an object depends on the gravitational field strength at the point where the object is.

Weight can be calculated using:

weight = mass x gravitational field strength

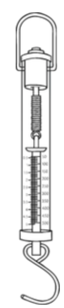
$$W = m \times g$$

Newtons (N) — Kilograms (kg) — Newtons per kilogram (N/kg)

- Earth's gravitational field strength = 9.8 N/kg

- Weight of an object can be considered to act at a single point = object's '**centre of mass**'

- Weight can be measured using a **newton meter**.

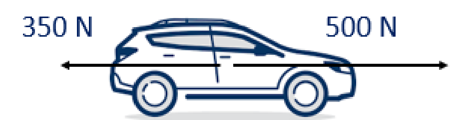


Resultant Forces

Resultant force = The sum of all forces or overall force acting on an object

Bike is being pushed forward with a force of 13N but there are resistive forces of 13N backwards.
Resultant force = 0N

What happens to the motion depends on what the bike was doing before these forces were applied:
- If the bike was stationary, it will stay stationary
- if the bike was moving, it will continue to move at a constant velocity



Car is being pushed to the left by a force of 350N. It is also pushed to the right by 500N.
Resultant force is: 500N – 350N = 150N

What happens to the motion depends on what the car was doing before these forces were applied:
- If the car was stationary, it will **accelerate** to the right
- If the car was already moving to the right, it will move faster **(accelerate)**
- If the car was moving to the left (ie reversing), it will slow down (**decelerate)**

P5 – Forces

Vector Diagrams (HT only)

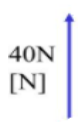
- Used to calculate resultant forces that are not acting directly opposite each other, on a straight line.

Rules (‘tip to tail’):

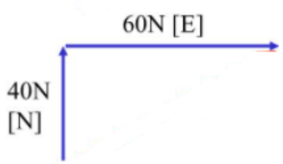
- Draw first vector to scale, in the direction stated
- Draw second vector, from the tip of the first one in the direction stated.
- Join the two lines in a triangle and measure the resulting line
- Convert length to force using your scale – this is the resultant force

Example:
Two forces act on an toy boat - 40N acting north, 60N acting East. Calculate the resultant force and state the direction.

1. Draw the first vector to scale

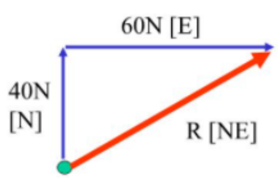


2. Draw 2nd vector from tip of the first one. Again, to scale.



3. Join the two lines. Measure the resulting line.

Resultant force = 72N NE



Work done and Energy Transfer

- When a force acts on an object and makes it move – **work is done**.
Work done = energy transferred

Work done is calculated by:

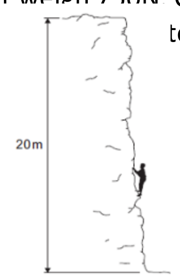
work done = force x distance

W = F x s

Joules (J) → W; Newtons (N) → F; Metres (m) → s

- One joule of work is done when a force of one newton causes a displacement of one metre.
  - 1 joule = 1 newton-metre

e.g A climber and his gear weigh 750N. Calculate the energy transferred … top of the cliff



W = F s
W = 750 x 20m
W = 15000J

- Work done against the frictional forces acting on an object causes a rise in the temperature.

Forces and Elasticity

- When work is done on an elastic object (e.g. stretching or compressing a spring), energy is stored as elastic potential energy.

Elastic deformation:
- When force is applied, object changes shape and stretches.
- When the force is no longer applied, object returns to original shape.

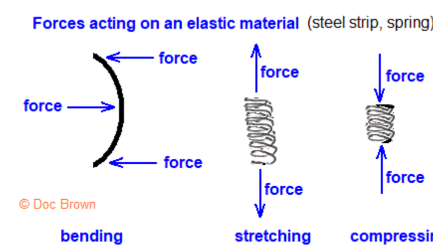
Inelastic deformation = stretched beyond limit – will not return to original shape and size.

Force = spring constant x extension

F = k x e

Newtons (N) → F; Newtons per metre (N/m) → k; Metres (m) → e

Two forces are needed to stretch or compress



Work done in stretching (or compressing) a spring:

elastic potential energy = 0.5 x spring constant x (extension)^2

$$\mathbf{E_e = \frac{1}{2} \times k \times e^2}$$

P5 – Forces

<u>**Required Practical**</u>

Aim: Investigate the relationship between force and extension for a spring (or any elastic object, eg elastic band)

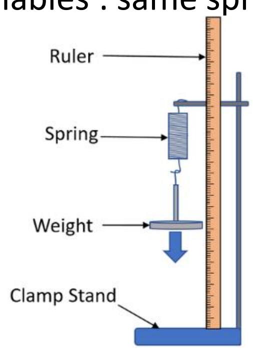
Method

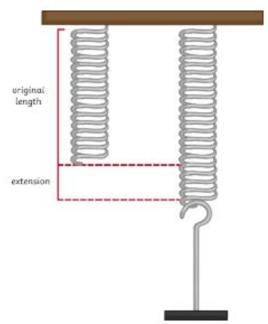
1. Hang a spring from a clamp and stand
2. Measure original length of the spring and record this.
3. Attach a 100g mass – record the new length of the spring.
4. Continue adding 100g masses recording the length each time, up to a total of 500g.
5. Work out the extension for each mass using:

final length – original length

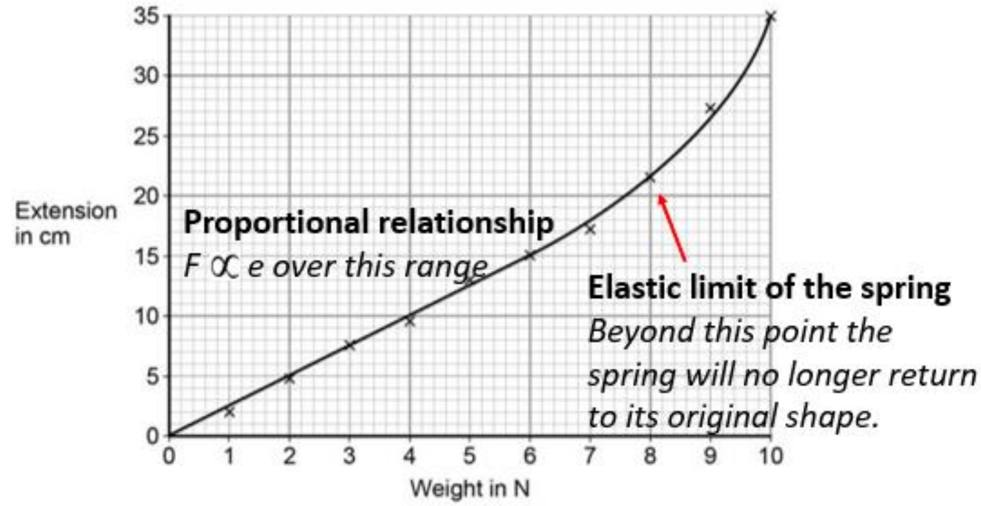
6. Repeat steps 1-5 twice and calculate a mean
7. Plot a line graph with extension (m) on the x-axis and force (N) on the y-axis.

Independent variable : mass on the spring
Dependent variable : extension of the spring
Control variables : same spring

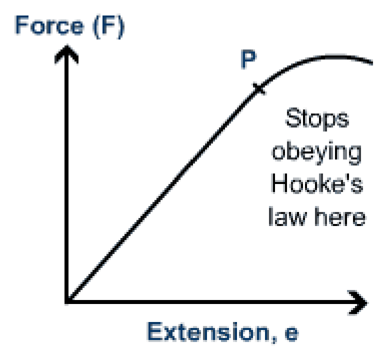




Results :



- There is a proportional relationship (shown by a straight line through the origin) at first.
- This means: **Force ∝ Extension** (F ∝ E)
- However, there comes a point when the 'elastic limit' of the spring is reached. This is also known as the **limit of proportionality**.
- If more force is applied after this, relationship is **no longer proportional**.
- After this point, the spring will not return to its original shape and size when the force is removed.



You may see the graphs with the axes switched – with extension on X and force on Y.

gradient of linear part = spring constant, k, for the spring being used.

P5 – Forces

Distance and Displacement

Distance
- How far an object moves
- Does not involve direction
- Distance = scalar quantity

Displacement
- Includes both the **distance** an object moves, measured in a straight line, from start to finish point and the **direction** of that straight line.
- Displacement = vector quantity

Speed

You should be able to recall the following typical speeds:

Activity	Typical Speed (m/s)
Walking	1.5
Running	3
Cycling	6
A car	25
A train	55
Speed of sound	330

Calculating speed:

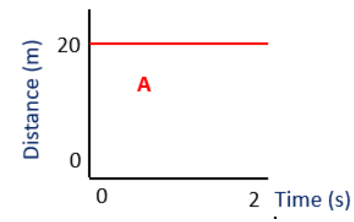
speed = distance x time

E.g. A car travels 100 metres in 3.8 seconds. What is the average speed?

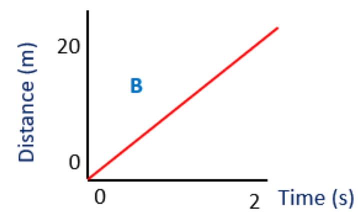
v=s/t
v = 100 m / 3.8 s
v= 26 m/s

Distance time graphs

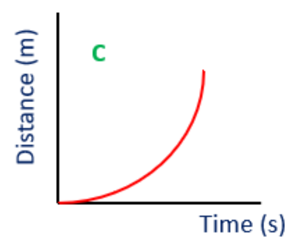
Distance time graphs show the motion of an object
The gradient tells us the speed of the object



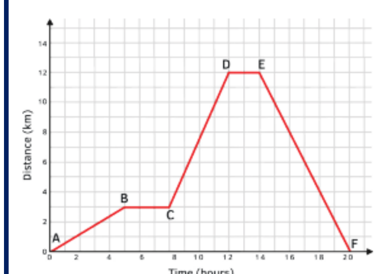
Object is stationary (distance not changing)



Object is travelling at constant speed
v = 20/2
v = 10 m/s



Object is accelerating
(HT only) Speed can be calculated by:
- Drawing a **tangent** and finding the **gradient** of the tangent



A journey generally has different speeds. Average speed can be calculated by using total distance ÷ time

Velocity and Acceleration

Velocity & acceleration = vector quantities
1. Velocity = **speed** in a given **direction**
- positive velocity = forwards (eg +5 m/s)
- negative velocity = backwards (eg -5 m/s)
2. Acceleration is a **change in velocity**
- positive acceleration = speeding up
- negative acceleration = slowing down

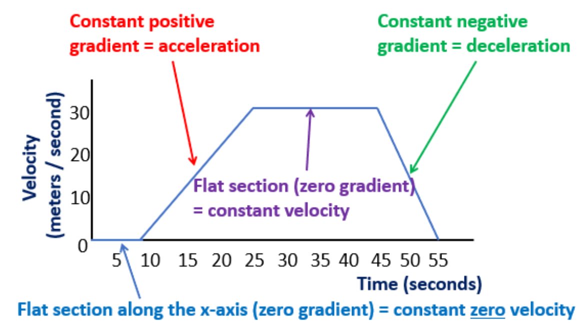
Average acceleration of an object can be calculated using:

acceleration = final velocity – initial velocity / time taken

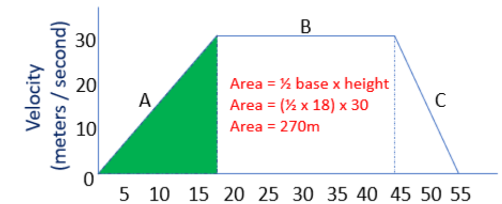
Units for acceleration are m/s^2

Velocity time graphs

Show how velocity changes during a journey
The gradient shows the acceleration



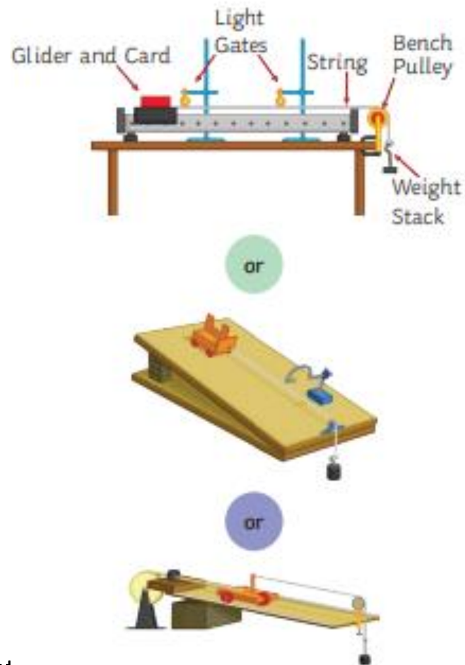
HT only - area underneath a velocity time graph is the distance travelled by an object



P5 – Forces – Required Practical - Acceleration

Aim: To investigate the effect of **varying force** on the acceleration of an object of constant mass.
You may be given any of the following apparatus set-ups to conduct these investigations:

Independent variable = force applied
Dependent variable = acceleration
Control variables = mass of toy car and surface car is on.



Method (using toy car)

1) Place the car on a ramp. Incline the ramp until the car just does not move. This is to remove as much of the effect of friction as possible.

2) Set up a light gate at the end of the ramp

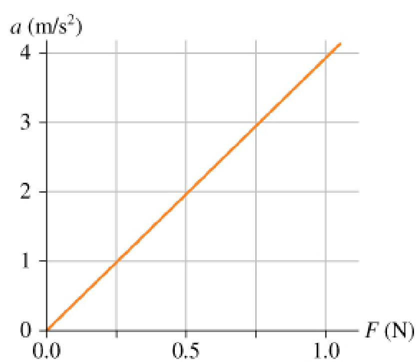
3) Place a 1N weight on the pulley attached to the toy car.

4) Allow the weight to drop and read the acceleration of the car from the light

5) Repeat the experiment several times, decreasing the weight on the pulley each time (e.g. 0.8N, 0.6N, 0.4N etc.) Place the removed mass onto the car to keep the mass of the system constant

Results

Acceleration is proportional to force applied

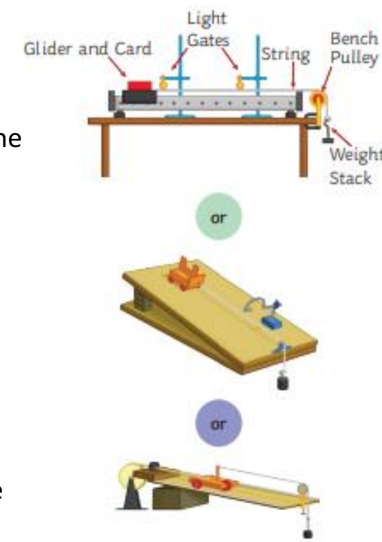


Aim: Investigate the effect of **varying mass** of an object on the acceleration produced by a constant force.
You may be given any of the following apparatus set-ups to conduct these investigations:

Independent variable = mass of glider
Dependent variable = acceleration of glider
Control variables = force applied and surface car is on

Method (using glider)

1) Place the glider on the track. Switch on the air blower and adjust until the glider just doesn't move. This is to remove as much of the effect of friction as possible.



2. Set up a light gate at the end of the air track

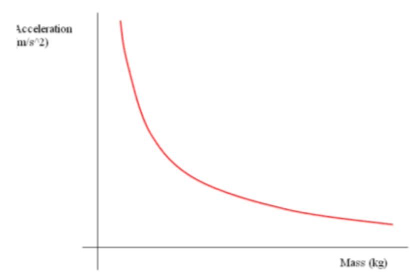
3) Add a 10g mass onto the glider. Place a 1N weight on the pulley attached to the glider and let go.

4) Record the acceleration from the light gate

5) Repeat the experiment several times, increasing the mass on the glider each time (e.g. 20g, 30g, 40g etc.) whilst keeping the weight (1N) on the pulley constant.

Results

Acceleration is inversely proportional to mass



P5 – Forces

Stopping Distance

Stopping distance = thinking distance + braking distance

- Greater the speed of vehicle – greater the stopping distance.

Thinking Distance (reaction time)

Thinking distance = distance travelled before driver reacts and presses brakes.

Reaction times are typically 0.2s to 0.9s

Factors that affect a driver's reaction time:

- Tiredness
- Drugs
- Alcohol
- Age
- Distractions (e.g. phone/music)

Momentum (HT only)

- Defined by the equation:

momentum = mass x velocity

p = m x v

Units:

momentum = kilograms metre per second (kg m/s)

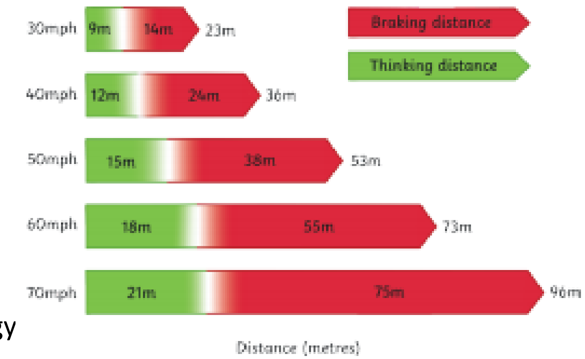
mass = kg

velocity = m/s

- In a closed system, total momentum before an event is equal to the total momentum after the event – this is called **conservation of momentum**.

Braking Distance

Braking distance = the distance travelled by a vehicle once with **brakes are applied** until it reaches a full stop.



It can be affected by:

- wet/icy roads
- poor vehicle conditions (brakes/tyres)

When a force is applied to brakes, **work is done** by the friction between the car wheels and the brakes.

Work done – reduces the **kinetic energy store** and energy is transferred to **the thermal store of the brakes**, increasing their temperature.

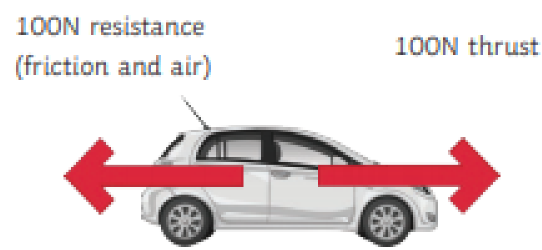
Increased speed = increased force required to stop the vehicle

Very large decelerations can lead to brakes overheating and/or loss of control of the car.

Newton's First Law

If resultant force acting on object is zero:

- Stationary object will remain stationary
- Moving object will continue at a steady speed and in the same direction.



(HT only) Inertia = tendency of an object to continue in a state of rest of uniform motion (same speed and direction)

Newton's Second Law

Acceleration of an object is proportional to resultant force acting on it and inversely proportional to the mass of the object

Resultant force = mass x acceleration

F = m x a

(HT only) Inertial mass = how difficult it is to change an object's velocity. Defined as ratio of force over acceleration.

Newton's Third Law

When two objects interact, forces acting on each other are always equal and opposite.

e.g. a hammer hitting a nail

The hammer exerts a force on the nail, and the nail exerts an equal and opposite force on the hammer.