Physics Knowledge Organiser
Forces (Triple Science)

Scalars and Vectors

All measurable quantities can be assigned a number, we call this number a magnitude. Some also include a direction.

Scalar quantities ONLY have a magnitude.

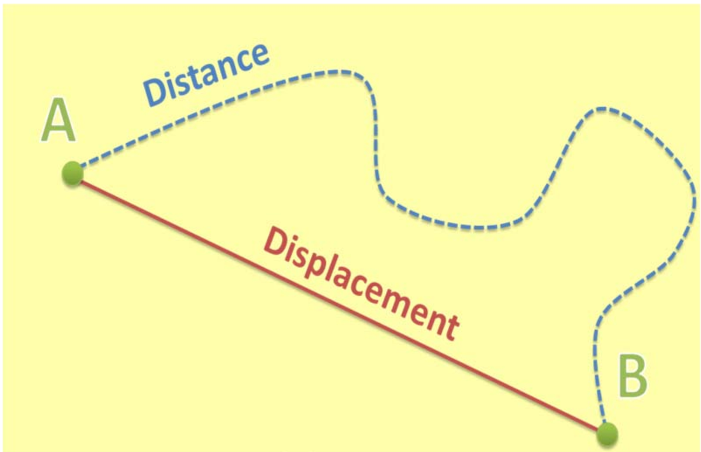
Examples
Distance
Speed
mass

Vector quantities have both a magnitude AND a direction.

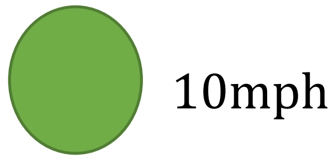
Examples
Displacement
Velocity
Acceleration
Force

Distance is how far something has travelled. It is a scalar.

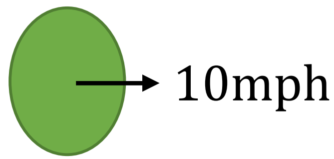
Displacement is how far something has travelled from its starting place. It is a VECTOR.



Speed is how quickly something It is a scalar.



Velocity is speed in a given direction. It is a VECTOR.



Forces

A force is an interaction which will cause an object to change its motion. A force can change an object's speed and/or direction.

Types of forces
Contact forces are where two objects have to touch and apply a force.

Non-contact forces are where objects don't touch but still exert a force on each other.

Scale Vector Diagrams

We can draw forces on objects as scale drawings to represent the size of forces.

Types of Forces

Contact forces are where two objects have to touch and apply a force.

Examples

Friction and tension

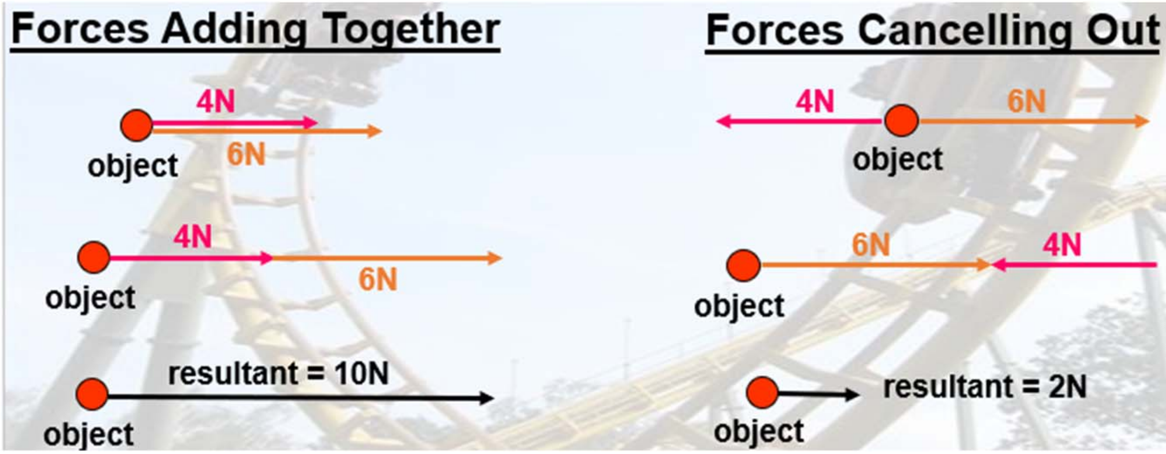
Non-Contact forces are where objects don't touch but still exert a force on each other.

Examples

Gravity and magnetism

Resultant Forces

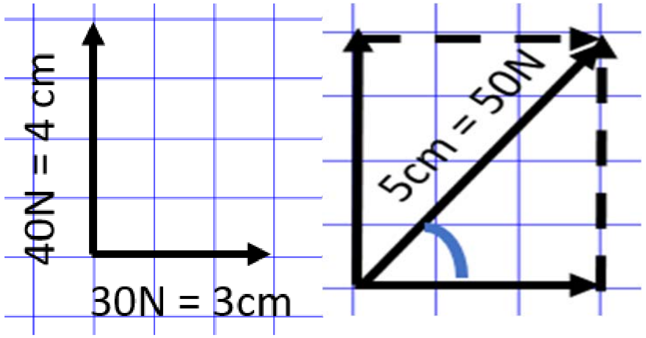
A resultant force is the overall force from all forces acting on an object. It is found by adding all the forces along the same plane.



Resultant forces for non - parallel forces

Some the forces on an object won't be in parallel. Use the parallelogram rule

Drawing vector diagrams to find size and direction of resultant forces (HT only)



Use a ruler to measure the size. A protractor to measure the direction.

Work done Equation

$$W = F \times s$$

W = Work done in Joules (J)
F = Force in Newtons (N)
s = Distance in metres (m)

If a force is applied to an object but it doesn't move, no work is done.

Example for using the weight equation

$W = F \times s$

A crane lifts a load of 5000N up 20m. Determine the work done by the crane.

$$W = F \times s$$
$$W = 5000 \times 20$$
$$W = 100{,}000J$$

Example of rearranging weight equation $W = F \times s$

A car engine moves a car with a force of 20,000N and does 600kJ of work. How far has the car travelled?

$W = F \times s$

Work = 600kJ = 600,000J

$600{,}000 = 20{,}000 \times s$

$\frac{600{,}000}{20{,}000} = s$

$30 = s$

$s = 30m$

Mass and weight

Mass is how much matter there is of something.

Weight is a force that acts downwards due to gravity interacting with an object's mass.

We assume all the mass of the object acts at its centre. This is called the centre of mass.

Weight Equation

$$W = \mathrm{m} \times g$$

W = Weight in Newtons (N)
M = Mass in kilograms (kg)
G - Gravitational field strength in (N/kg)

g on Earth is 9.8 N/kg unless you are told otherwise.

g is different on different planets, the greater the mass of the planet, the higher its gravitational field strength will be.

Example for using the weight equation

$W = \mathrm{m} \times g$

Calculate the weight of a person that has a mass of 80kg (Gravitational field strength = 9.8N/kg).

W = m X g
W = 80 X 9.8
W = 784N

Example for rearranging the weight equation $W = \mathrm{m} \times g$

Calculate the mass of an atas ball which takes 1000N of force to lift it. Give your answer to 3 significant figures.

$$W = m \times g$$

$$1000 = m \times 9.8$$

$$\frac{1000}{9.8} = m$$

$$m = 102.04kg$$
$$m = 102kg$$

Hooke's Law

When a force is applied to an object, this causes the object to extend.

The **extension** of an elastic material is **directly proportional** to the **force** applied to it. This is known as Hooke's Law

Hooke's Law Equation

$$F = k \times e$$

F = Force in Newtons (N)
k = *Spring constant in Newton per metre (N/m)*
e = extension in metres (m)

Spring constant is the stiffness of a spring.

The stiffer the spring, the higher the spring constant.

Elastic and Inelastic materials

An elastic material returns to its **original size** and **shape** when forces on it are removed.

Examples are elastic bands, springs, bungee cord

An inelastic material **stays deformed** after the forces on it are removed.

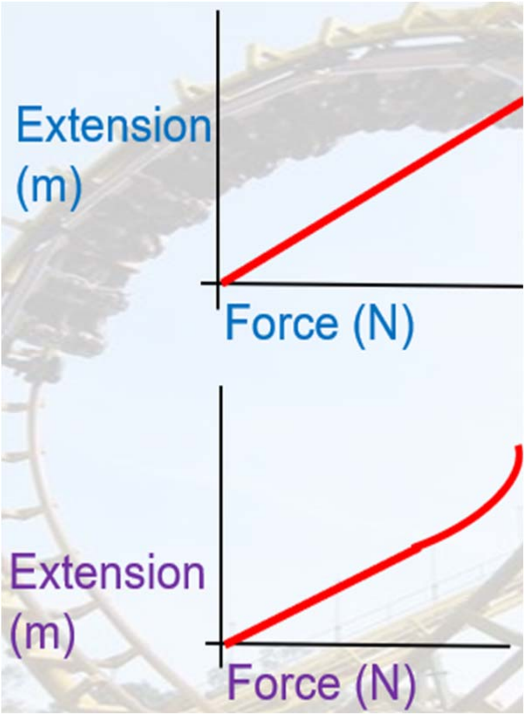
If you apply a force too large then any material will lose its elasticity.

Graphs of elastic and inelastic materials

If the line on a force extension graph remains straight, the object remains elastic (top graph).

If the line on a force extension graph starts to curve, the object becomes inelastic (bottom graph).

This is because the point where the graph becomes curve, it has reached the limit of proportionality.



Example for using the Hooke's Law Equation $F = k \times e$

A spring has a spring constant of 20N/m. Calculate the force on the spring extended from 4m to 7m.

$F = k \times e$

$k = 20$ N/m

$e = 7 - 4 = 3$m

$F = 20 \times 3 = 60$

F= $60N$

Example for rearranging the Hooke's Law Equation $F = k \times e$

A spring has an original length of 9m. When 75N is applied, its length becomes 14m. Calculate the spring constant.

$F = k \times e$

F = 75N

e= 14 - 9 = 5m

$75 = k \times 5$

$\frac{75}{5} = k$

$k = 15\ N/m$

Elastic potential energy

This is the energy stored in the bonds of solids that are stretched or compressed.

The more a material is stretched, the more elastic potential energy it will store.

Equation

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

Given on equation sheet.

E_e = Elastic Potential energy in Joules (J)

k = spring constant in (N/m)

e = extension in metres (m)

Example for using the Elastic potential energy Equation $E_e = \frac{1}{2} \times k \times e^2$

A bow with a spring constant of 500N/m extends by 0.1m. Calculate the elastic potential energy stored in the bow.

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

E_e = 0.5 x 500 x 0.1^2

E_e = 2.5J

Examples of rearranging the equation

Example 2: Rearranging the equation for spring constant, k

A spring stores 5J of elastic potential energy. It extends in length by 0.6m. **Calculate the spring constant of the spring.**

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

$5 = 0.5 \times k \times 0.6^2$

$5 = 0.18 \times k$

$\frac{5}{0.18} = k$

k = 27.7 N/m

Example 3: Rearranging the equation for extension, e

A spring with spring constant of 100N/m has a force of 600N applied to it. Calculate the extension of the spring.

$E_p = ½ \times k \times e^2$

$600 = ½ \times 100 \times e^2$

$600 = 50 \times e^2$

$e^2 = \frac{600}{50}$

$e^2 = 12$

$e = \sqrt{12}$

e = **3.46 m**

Hooke's Law practical (extension of a spring

Practical Set up and data graphs

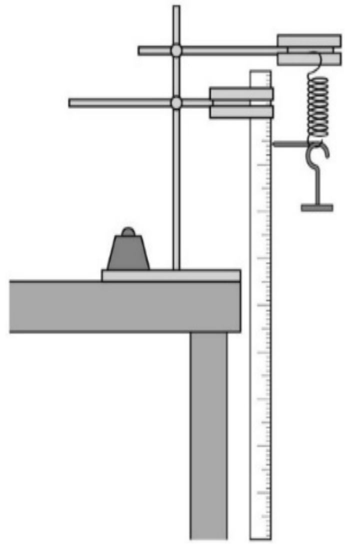


Figure 1: Practical Setup

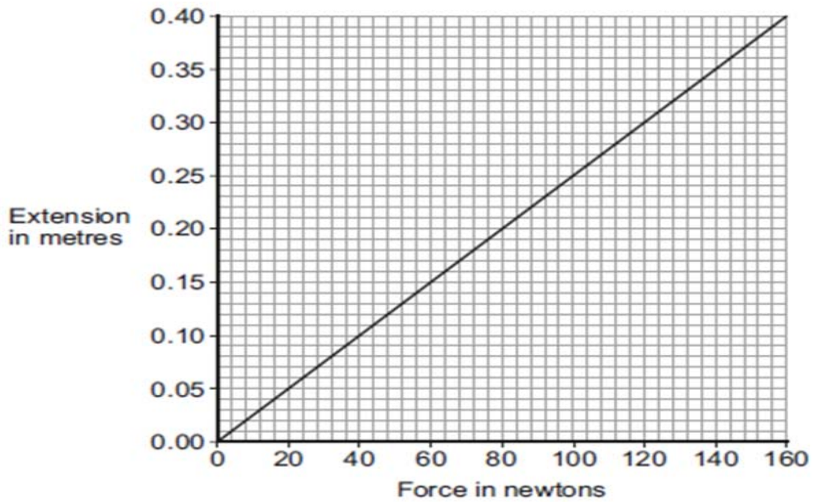


Figure 2: Experimental results

Methods for the different practicals

Method

1) Place a stand on a desk attached with a g clamp. Using two boss and clamps, hang a spring from one clamp and attach a metre ruler to the other parallel to the spring.

2) Measure the original length of the spring using the ruler.

3) Add a 100g mass (1N) to the bottom of the spring. Measure the new length of the spring.

4) Calculate the extension by doing the new length subtracting the original length.

5) Repeat steps 3 – 4 for masses of 200g – 500g (2N - 5N) by adding 100g each time.

6) Plot a graph of extension vs force applied to the spring.

Speed

Speed is how fast an object is moving regardless of its direction.

Examples of typical speeds

Walking = 1.5 m/s
Running = 3 m/s
Cycling = 6 m/s
Speed of sound = 330 m/s

Speed Equation (Triple only)

$$\boldsymbol{s = v \times t}$$

s = Distance in metres (m)
v = Speed in metres per second (m/s)
t = Time in seconds (s)

Example of applying the equation

$$\boldsymbol{s = v \times t}$$

How far did a bullet travel if its speed was 360 m/s and it hit a wall 5.5 seconds after it was fired?

$$Distance = speed \times time$$

$$Distance = 360 \times 5.5$$

$$Distance = 1980m$$

Example of rearranging the equation

$$\boldsymbol{s = v \times t}$$

Calculate the speed of a jumbo jet if it travelled a distance of 1500m in 5.3s. Give your answers to 2 significant figures.

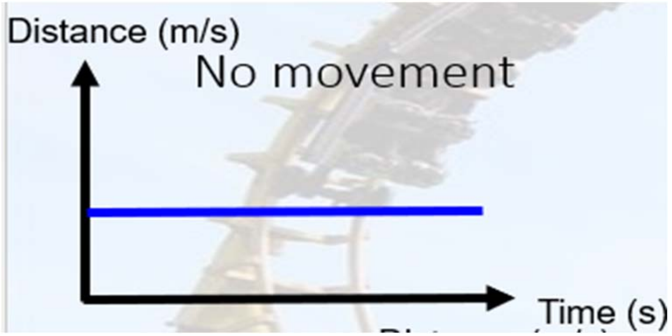
$$Distance = speed \times time$$
$$1200 = speed \times 5.3$$

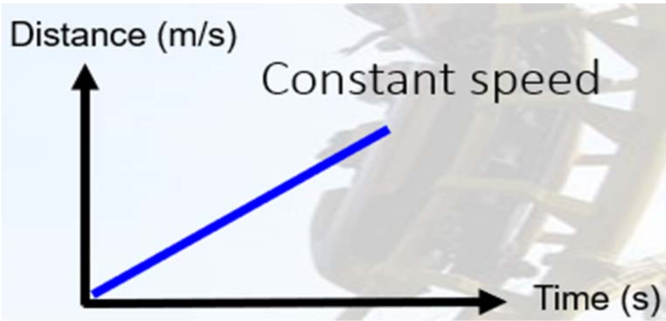
$$\frac{1200}{5.3} = speed$$

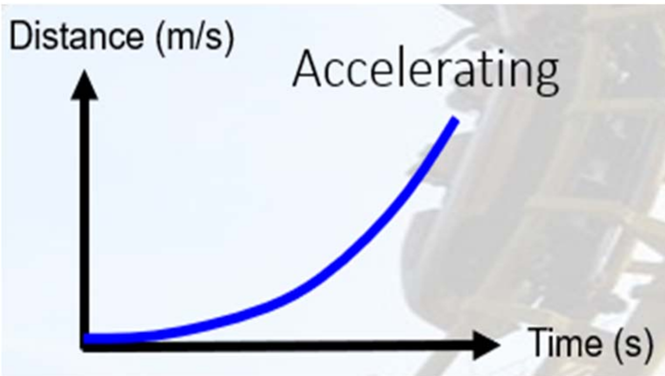
$$speed = 226.415\ m/s$$
Speed = 226 m/s (2sf)

Distance Time graphs

Distance time graphs show the distance covered by an object over time.

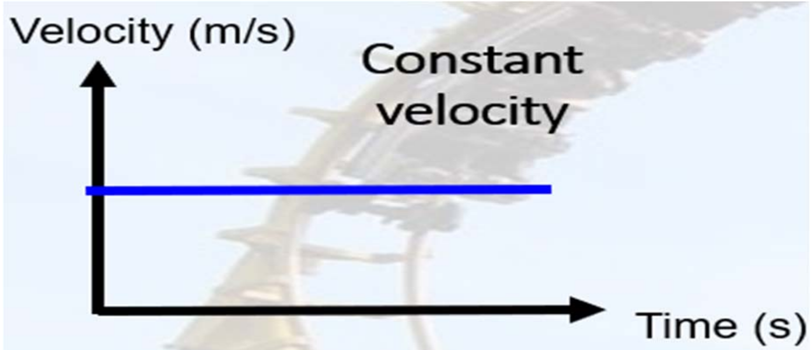


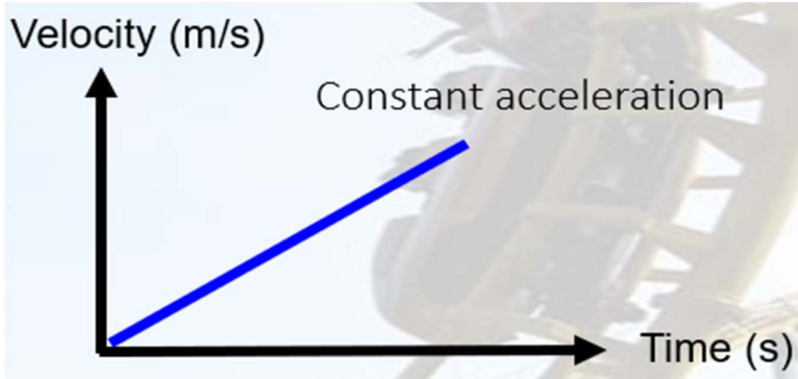


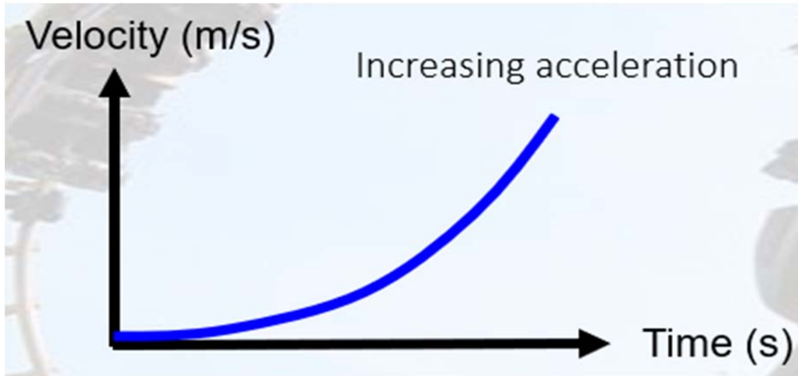


Velocity Time graphs

Velocity time graphs show the velocity of an object over time.







Acceleration Equation

$$a = \frac{\Delta v}{t}$$

Not given on equation sheet

$a = acceleration, m/s^2$
$\Delta v = change\ in\ velocity, m/s$
$t = time, s$

$\Delta v = v - u$

$v = Final\ velocity, m/s$
$u = Initial\ velocity, m/s$

Newton's First Law

No resultant force on an object :

- A stationary object stays stationary
- A moving object continues to move at the same speed and in the same direction (i.e same velocity).

Resultant force on an object
The object will accelerate in that direction.

Inertial Mass

Inertia is the tendency of objects (stationary or moving) to continue in their state of motion.

The greater the mass, the greater the inertia and therefore the harder it is to change its motion.

Examples of using the equation $a = \frac{\Delta v}{t}$

A boat accelerates from a velocity of 9 m/s to 19 m/s in 8.0 seconds. Calculate the acceleration of the boat.

$$a = \frac{v - u}{t}$$

$$a = \frac{(19 - 9)}{8}$$

$$a = 1.25\ m/s^2$$

Examples of using the equation $a = \frac{\Delta v}{t}$

A boat accelerates at 4.5 m/s^2 from a velocity of 3 m/s to 23 m/s. Calculate the time this takes.

$$a = \frac{\Delta v}{t} = \frac{v - u}{t}$$

$$4.5 = \frac{23 - 3}{t}$$

$$4.5t = 23 - 3$$

$$t = \frac{23 - 3}{4.5}$$

$$t = 4.44\ s$$

Acceleration Equation

$$v^2 - u^2 = 2 \times a \times s$$

Given on equation sheet.

$v = Final\ velocity, m/s$
$u = Initial\ velocity, m/s$
$a = Acceleration, m/s^2$
$s = Distance, m$

If an object is initially not moving/ at rest the initial velocity ***u*** = 0 m/s.

If an object is falling on Earth, assume a = m/s^2

Example 1: Applying the equation

A tennis ball accelerates from rest by 12 m/s^2 for a distance of 20m. Calculate the final velocity of the tennis ball.

v= v
u= 0 m/s
a= 12 m/s^2
s= 20m

$$v^2 - u^2 = 2 \times a \times s$$
$$v^2 - 0^2 = 2 \times 12 \times 20$$
$$v^2 = 2 \times 12 \times 20$$
$$v^2 = 480$$
$$v = \sqrt{(480)}$$
$$v = 21.9\ m/s$$

Example 2: Rearranging the equation for a or s

A Jaguar F-Type accelerates from a velocity of 0 m/s to 20 m/s over a distance of 50m. Calculate its acceleration.

v= 20 m/s
u= 0 m/s
a= a
s= 50m

$$v^2 - u^2 = 2 \times a \times s$$
$$20^2 - 0^2 = 2 \times a \times 50$$
$$20^2 = 100 \times a$$
$$400 = 100 \times a$$
$$\frac{400}{100} = a$$
$$a = 4\ \text{m/s}^2$$

Example 3: Rearranging the equation for u

An Ariel Atom accelerates at 12 m/s^2 for a distance of 100m. The final velocity of the Ariel Atom was 65 m/s. Calculate the initial velocity of the Ariel Atom.

v= 65 m/s
u= u m/s
a= 20 m/s^2
s= 100 m

$$v^2 - u^2 = 2 \times a \times s$$
$$65^2 - u^2 = 2 \times 20 \times 100$$
$$4225 - u^2 = 4000$$
$$-u^2 = 4000 - 4225$$
$$u^2 = 4225 - 4000$$
$$u^2 = 225$$
$$u = 15\ \text{m/s}$$

Newton's Second Law

The resultant force applied to an object is directly proportional to its acceleration.

The greater the resultant force applied to an object, the faster it accelerates.

Additionally, acceleration of an object is inversely proportional to its mass.

Equation

$$F = m \times a$$

$F = Resultant\ Force\ in\ Newtons\ (N)$
$m = mass\ in\ kilograms\ (kg)$
$a = acceleration\ in\ m/s^2$

Example of rearranging the equation $F = m \times a$

A tesla semi-truck has a mass of 25,000 kg. Calculate the acceleration is caused by a resultant force of 18kN.

$$F = m \times a$$
$$F = 18kN = 18000$$
$$18{,}000 = 25{,}000 \times a$$

$$\frac{18{,}000}{25{,}000} = a$$

$$a = 0.72\ m/s^2$$

Example of applying the equation

$$F = m \times a$$

An Aston Martin Valkyrie accelerates at 7.8 m/s^2. Its mass of 1,000 kg. Calculate the resultant force it generates.

$$F = m \times a$$

$$F = 1000 \times 7.8$$

$$F = 7800N$$

Newton's Second Law (Acceleration) Practical

Practical Set up and data graphs

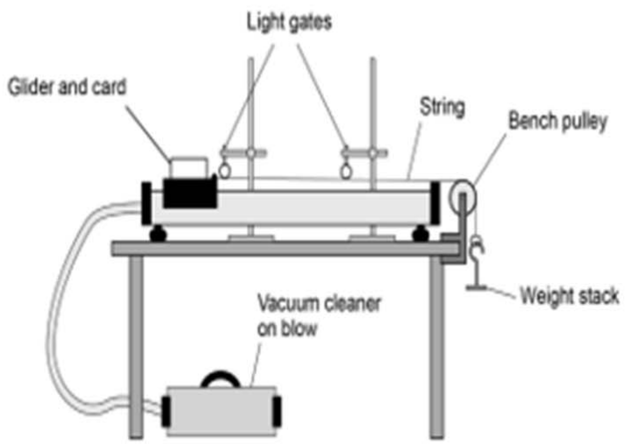


Figure 1: Practical Setup

Resultant force is directly proportional to acceleration

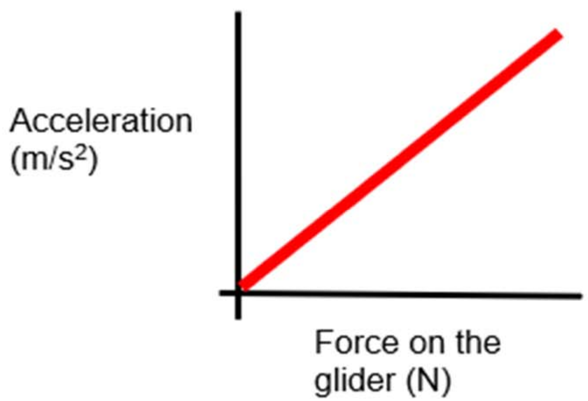


Figure 2: Experimental results for method 1.

Mass of the object is inversely proportional to acceleration

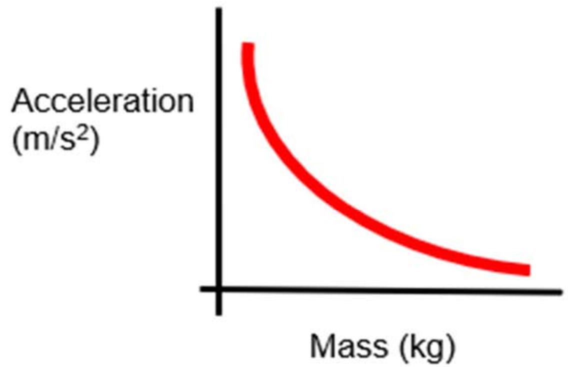


Figure 3: Experimental results for method 2.

Methods for the different practicals

Method 1

Varying the Force

1) Set up a glider attached to a string with masses on the end and a vacuum pump.
2) Add masses for forces of 1N to 5N to the string.
3) Switch on the vacuum cleaner and record the time between the two light gates.
4) Use the time to calculate the acceleration.
5) Plot a graph of force vs acceleration and compare the relationship between these variables.

Method 2

Varying the mass on the glider

1) Set up a glider attached to a string with masses on the end and a vacuum pump.
2) Add masses from 100g to 500g to the glider
3) Add a 100g mass (1N) to the string.
4) Switch on the vacuum cleaner and record the time between the two light gates.
5) Use the time to calculate the acceleration.
6) Plot a graph of mass vs acceleration and compare the relationship between these variables.

Newton's Third Law

When two objects interact with each other, they exert equal forces on each other but in opposite directions.

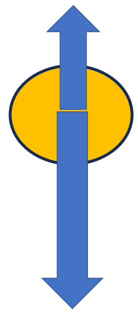
Third law pairs of forces

The forces need to be

- the same type of force (contact, frictional, magnetic, gravitational)
- **the same size;**
- acting in opposite directions.

Forces on falling objects

Air resistance



Weight

As an object is dropped, their weight causes them to accelerate downwards.

As its speed increases, air resistance acting on it increases.

Terminal Velocity Summary table for a skydiver who uses a parachute.

What is happening?	At the start of the fall	As they fall	At terminal velocity	The parachute is released	A few seconds after the parachute is released.	At their new lower terminal velocity
Free body Diagram W =weight A R = Air resistance						
Resultant force	Yes (downwards)	Yes but less	No	Yes (upwards)	Upwards but less	No
Acceleration	Yes	Yes but less	No	Yes (Decelerating)	Yes (Decelerating but less).	No
Speed	Increasing	Increasing at a lower rate	Constant	Decreasing	Decreasing at a lower rate	Constant
Terminal velocity	No	No	Yes	No	No	Yes

Thinking distance

Thinking distance is the distance travelled by a vehicle as the driver reacts to a danger.

Typical reaction times of a person are

between 0.2s – 0.9s.

The following factors can affect a driver's ability to react and **increase their reaction time**. Therefore, increase your thinking distance.

1. Distraction
2. Age
3. Alcohol
4. Drugs
5. *Tiredness*

Braking distance

Braking distance is the distance travelled by a vehicle when braking to a complete stop. Braking distance can be increased by:

1. Wet or icy road surfaces.
2. Condition of road surface.
3. Condition of tyres (heavily worn)
4. Condition of brakes or brake pads (heavily worn)

All these factors **reduce friction between the road and the tyres.**

Additionally, condition of brakes or brake pads (heavily worn) will reduce the braking force (hence friction).

Stopping distance

Stopping distance is the distance travelled by the vehicle before it stops for a danger.

Stopping distance = Thinking distance + Braking distance

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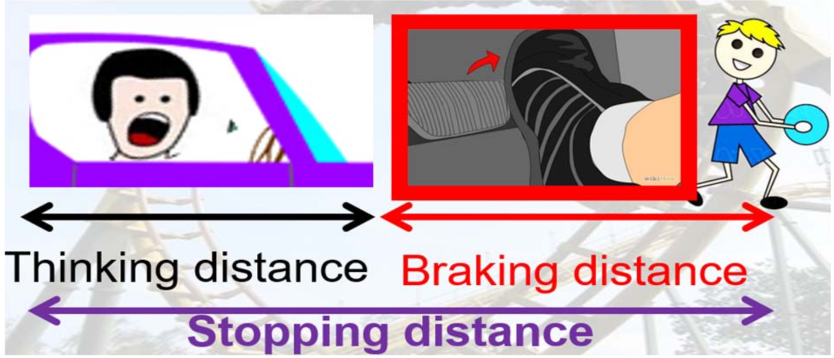

Momentum

Any object that has a mass and velocity has momentum.

$$p = m \times v$$

$p = momentum, kgm/s$
$m = mass, kg$
$v = velocity, m/s$

Conservation of Momentum

In collisions between objects, the momentum is conserved. This means the momentum before is equal to the momentum after the collision.

Examples of using the equation $p = m \times v$

An athlete with a mass of 60kg is running at 10m/s. Calculate the athlete's momentum.

$$p = m \times v$$

$$p = 60 \times 10$$

$$p = 600kgm/s$$

Applying the conservation of momentum

Ice skater A collides with Ice skater B. Ice skater B was stationary.

Explain what happens to each ice skater's velocity. Use the idea of the conservation of momentum.

Total momentum before is equal to the total momentum after the collision.

Therefore ice skater A's velocity will decrease and ice skater B's velocity will increase.