PiXL KnowIT!

GCSE Physics

AQA Topic – Forces

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The PiXL Club Ltd, Company number 07321607

Overview
Forces

Forces and their Interactions

- Scalar and Vector Quantities
- Contact and Non-contact Forces
- Gravity
- Resultant Forces

Work Done and Energy Transfer

Forces and Elasticity

Moments, Levers and Gears (Physics Only)

Pressure and Pressure Differences in Fluids (Physics Only)

- Pressure in a Fluid 1
- Pressure in a Fluid 2 (HT Only)
- Atmospheric Pressure

Forces and Motion

- Distance and Displacement
- Speed
- Velocity
- The Distance-Time Relationship
- Acceleration

Forces, Accelerations and Newton's Laws of Motion

- Newton's First Law
- Newton's Second Law
- Newton's Third Law

Forces and Braking

- Stopping Distance
- Reaction Time
- Factors Affecting Braking Distance 1
- Factors Affecting Braking Distance 2

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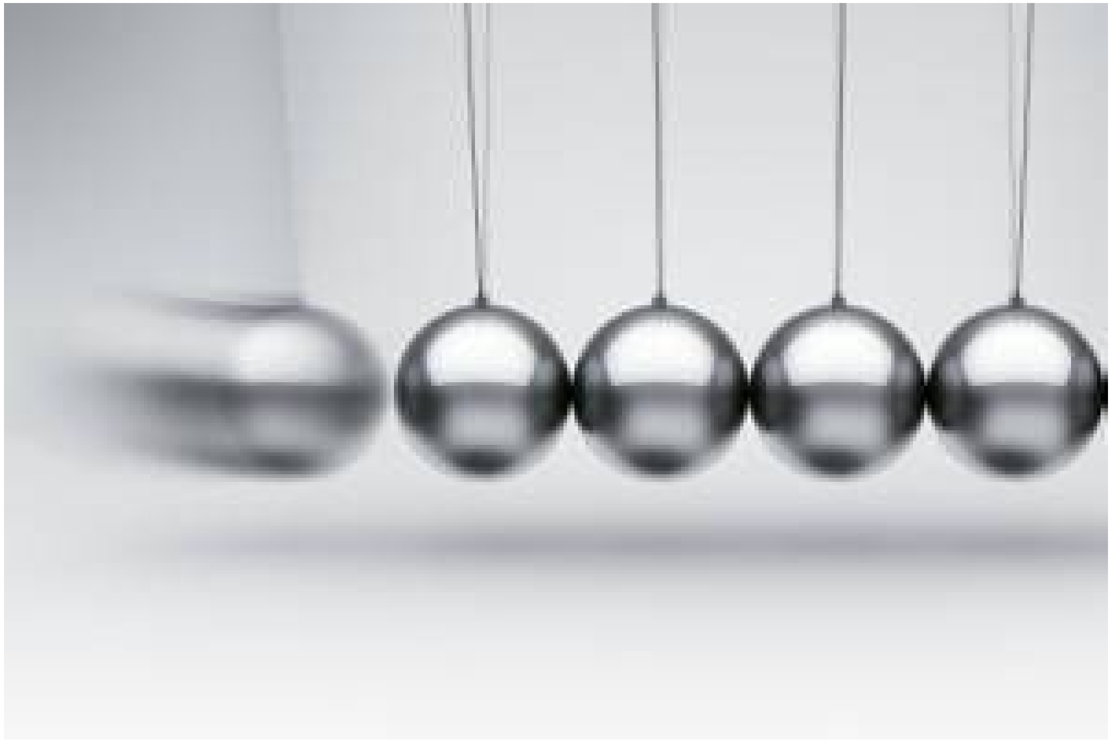
Momentum (HT Only)

- Momentum is a Property of Moving Objects
- Conservation of Momentum
- Changes in Momentum (Physics Only)



LearnIT!
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Forces

- Scalar and Vector Quantities
- Contact and Non-contact Forces
- Gravity
- Resultant Forces

Scalars and Vectors

Materials in a classroom can be grouped into two groups – metals and non-metals.

Things we measure can be put into two groups as well – scalars and vectors.

Scalars: Things that we measure that have a magnitude (size) only are scalars.

Vectors: Things that we measure that have both magnitude and direction are vectors.

Sometimes direction is really important. In a crash the direction, as well as the speed, of the vehicles will determine how much damage is caused.

Examples of Scalars and Vectors

Some examples of scalars and vectors are shown in the table below.

Scalars	Vectors
Time	Forces (including weight)
Mass	Displacement
Temperature	Velocity
Speed	Acceleration
Direction	Momentum

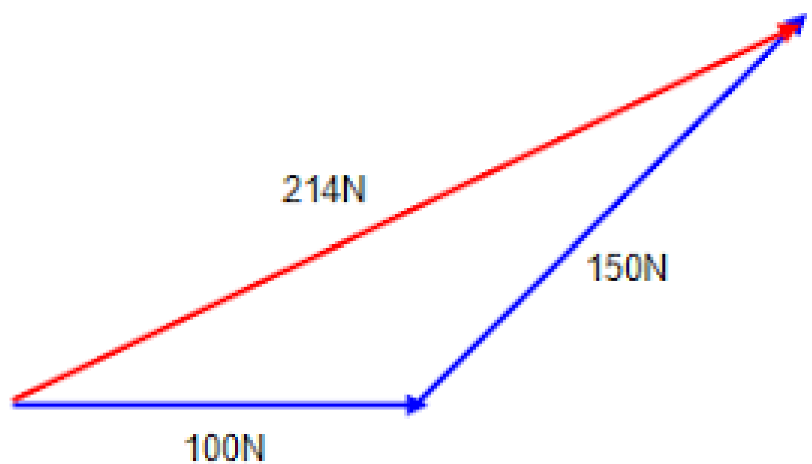
Representing Vectors

Vectors can be shown by arrows.

The length of the arrow shows the size, or magnitude, of the force.

The direction of the arrow shows the direction of the force.

The vector arrows can be added together to show the resultant of two of more vectors.



Contact and Non-contact Forces

Forces can be placed into two groups. There are forces that act on contact and there are forces that act at a distance.

Contact Forces	Non-Contact Forces
Air Resistance	Gravity
Friction	Magnetism
Tension	Electrical Force
Normal Force	Nuclear Force

Gravity

Gravity is a non-contact force.

Gravity is the force responsible for the formation of galaxies, stars and planets.

Weight is the force acting on an object due to gravity. The force of gravity close to the Earth is due to the gravitational field around the Earth.

The weight of an object depends on the gravitational field strength at the point where the object is.

Calculating Weight

The weight of an object can be calculated using the equation:

Weight (N) = Mass (kg) x Gravitational field strength (N/kg)

$$W = m\,g$$

It is useful to note that the gravitational field strength, g, on Earth is about 10 N/kg.
This means that a one kilogram mass would have a weight of 10 N. This can also be found using a calibrated spring balance (a newtonmeter).

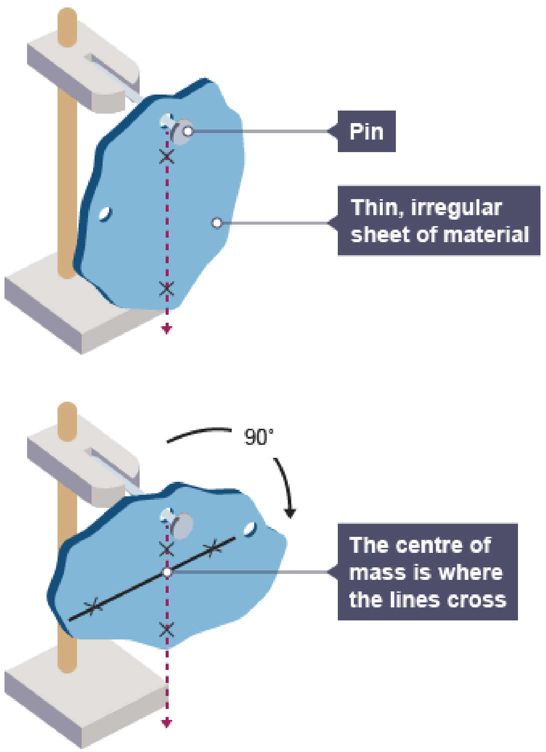
The value of the gravitational field strength will depend on where you are. Your weight on top of a mountain will differ slightly from your weight at sea level. On the Moon your weight will be approximately one sixth of your weight on Earth.

Weight and mass are directly proportional.

Centre of Mass

The weight of an object may be considered to act at a single point referred to as the object's '**centre of mass**'.

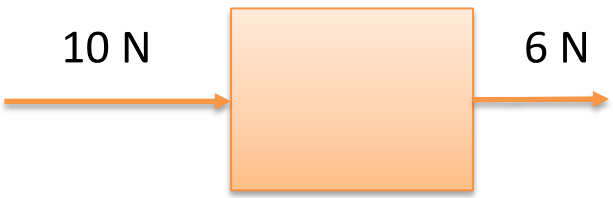
The centre of mass of an irregularly shaped 2-D object can be found by using a pin, some string and a small mass. By pinning the 2-D object up on a board with the string hanging from the pin (with the small mass on the end) the string will go through the centre of mass – mark with a line. Rotate the object and re-hang on the board. Draw a line to show where the string hangs. Where the lines cross is the centre of mass of the shape.



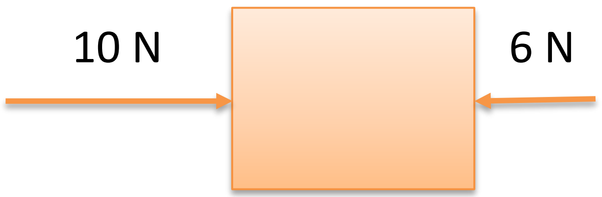
Resultant Forces

A number of forces acting on an object may be replaced by a single force that has the same effect as all the original forces acting together. This single force is called the resultant force.

When two forces act in a line the resultant force is the vector addition of the two vectors. Remember the direction is important.



R = 16 N to the right



R = 4 N to the right

Calculating Resultant Force

Example 1:

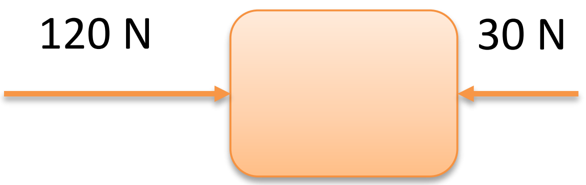
A box is pushed along the floor with a force of 120 N. There is a resistive force of 30 N. Work out the resultant force on the box.

Solution:

Resistive forces act in the opposing direction to motion.

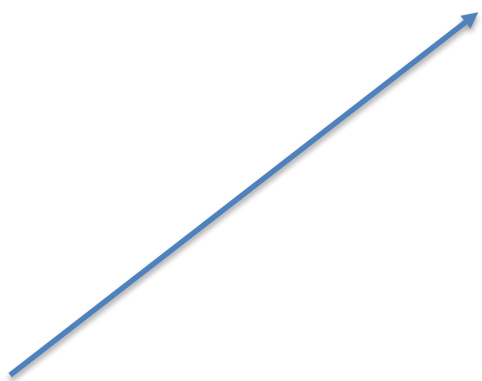
Addition of the forces gives:

120 N + -30 N = 90 N in direction of 120 N force



Calculating Resultant Force… continued

A single force can be resolved into two components acting at right angles to each other. The two component forces together have the same effect as the single force.



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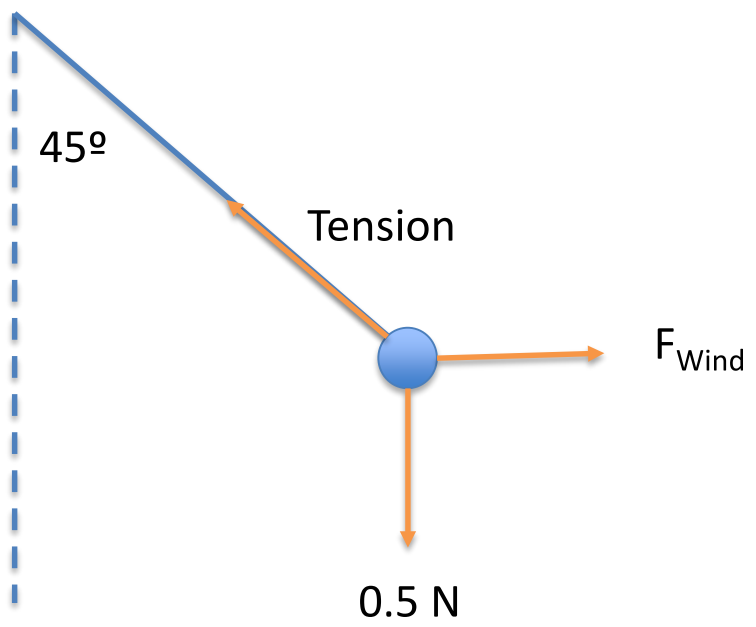
Example

A pendulum has a weight of 0.5 N.

On a windy day the pendulum is hung outside and the pendulum now hangs at an angle of 45º.

Assuming the wind hits the pendulum moving horizontally, draw a free body diagram to represent the forces acting.

Solution



QuestionIT!

Forces

- Scalar and Vector Quantities
- Contact and Non-contact Forces
- Gravity
- Resultant Forces

1. What is a scalar quantity?

2. Explain how a car can be moving at a constant speed but have changing velocity.

3. State whether the following quantities are scalars or vectors:

Acceleration Mass Momentum Time

4. Gravity is a force that acts at a distance.
   Name two other forces that act at a distance.

5. Name three contact forces.

6. A boy has a mass of 40 kg. Calculate the boy's weight.
   Take g = 10 N/kg.

7. Name a piece of scientific equipment that you would use to find the weight of a block in a science laboratory.

8. The object below has two forces acting on it, shown by the arrows.

Draw an arrow to show the resultant force on the object

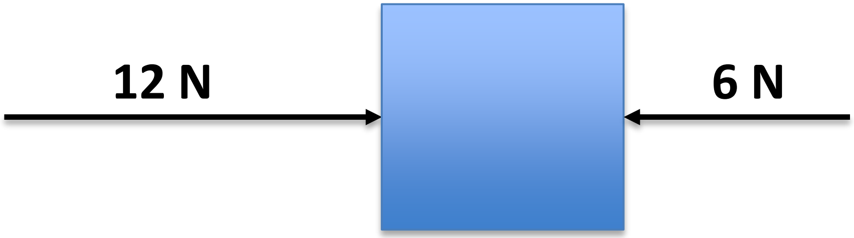
9. On The Moon an astronaut has a weight of 130 N. The gravitational field strength on The Moon is 1.7 N/kg. The gravitational field strength on the Earth is 10 N/kg.

   Calculate the weight of the astronaut on the Earth.

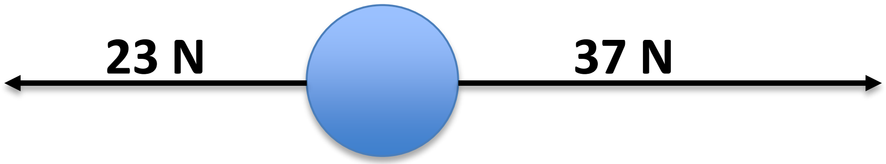
10. A child cuts out a picture of a snowman on a piece of card. How could you determine the centre of mass of the snowman?

11. Calculate the resultant force acting on the objects below:

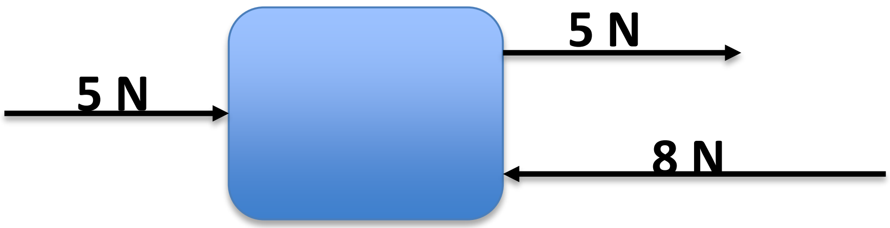
a)



b)



c)



AnswerIT!

Forces

- Scalar and Vector Quantities
- Contact and Non-contact Forces
- Gravity
- Resultant Forces

1. **What is a scalar quantity?**
   Scalars quantities have magnitude ONLY i.e. no direction.

2. **Explain how a car can be moving at a constant speed but have changing velocity.**
   As velocity is a vector if the direction of the car changes the velocity will change, at a constant speed.

3. **State whether the following quantities are scalars or vectors:**

Acceleration	Mass	Momentum	Time
Vector	Scalar	Vector	Scalar

4. Gravity is a force that acts at a distance.
Name two other forces that act at a distance.
Magnetism Electrical Force Nuclear Force

5. Name three contact forces.
Tension Friction (including air resistance) Normal Force

6. A boy has a mass of 40 kg. Work out the boy's weight.
Take g = 10 N/kg.
Using

$$W = mg$$

Substitution gives

$$W = 40 \times 10$$

Answer

$$W = 400\ N$$

7. Name a piece of scientific equipment that you would use to find the weight of a block in a science laboratory.
   A newtonmeter

8. The object below has two forces acting on it, shown by the arrows.

Draw an arrow to show the resultant force on the object

9. **On The Moon an astronaut has a weight of 130 N. The gravitational field strength on The Moon is 1.7 N/kg. The gravitational field strength on the Earth is 10 N/kg.**
Work out the weight of the astronaut on the Earth.

Using W = mg
Mass of astronaut = 130 / 1.7
Mass of astronaut = 76.5 kg

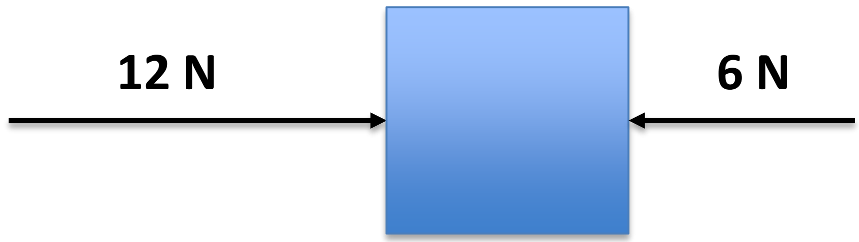
Using W = mg
Weight of astronaut on Earth = 76.5 x 10
Weight of astronaut on Earth = 765 N

10. **A child cuts out a picture of a snowman on a piece of card.**
Describe how you could determine the centre of mass of the snowman.

Hang the picture using a pin so that the shape is free to rotate.
Have a plumb line hanging from the pin.
Mark the path of the plumb line against the picture.
Hang the picture from another point.
Mark the path again.
Where the lines cross is the centre of mass of the picture.

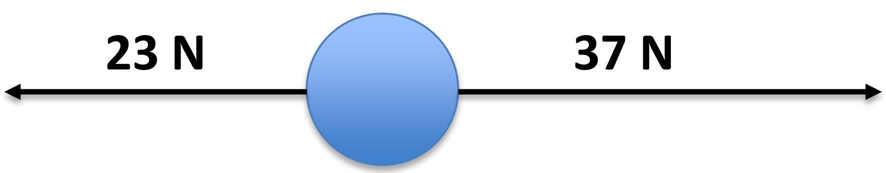
11. Calculate the resultant force acting on the objects below:

a)



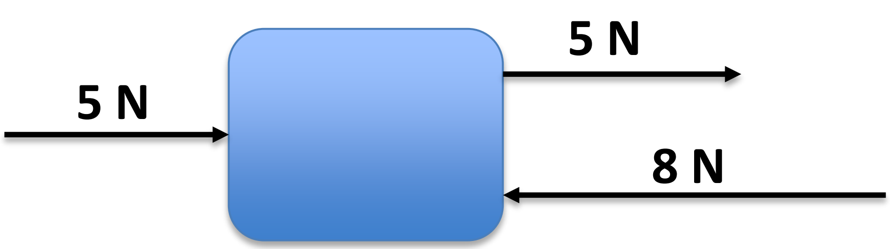
Resultant Force = 6 N Right

b)



Resultant Force = 14 N Right

c)



Resultant Force = 2 N Right

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Work Done and Energy Transfer

Work Done

When a force causes an object to move through a distance work is done on the object. So a force does work on an object when the force causes a displacement of the object.

Work done can be calculated using the equation:

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

W = F s

Note: The distance moved has to be in the direction the force is acting on the object.

Work Done Calculations

A box is pushed 3 m across the floor with a force of 120 N.

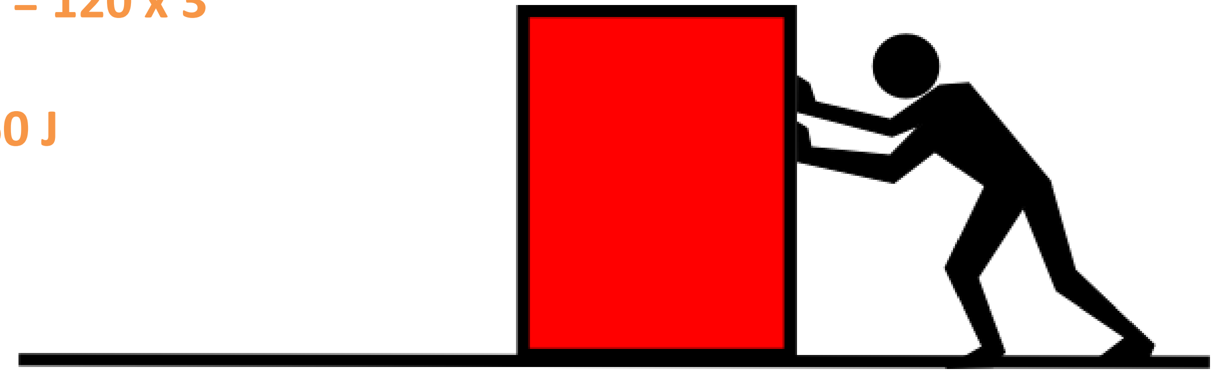
Work out the work done in moving the box.

Solution

Equation: work done = force x distance

Substitution: work done = 120 x 3

Answer: work done = 360 J



Work Done Calculations

A man with a mass of 70 kg gets onto a moving escalator.

The escalator moves 15 m horizontally and 8 m vertically.

Calculate the work done by the motor against gravity.

Take g = 10 N/kg.

Solution

Gravity acts downwards, so the distance moved against gravity is 8 m.
Sine W = mg; the weight of the man is 700 N.

Using: work done = force x distance
work done = 700 x 8
work done = 5600 J

Work Done Against Frictional Forces

When work is done against frictional forces on an object there is a temperature increase of the object.

A bicycle pump gets hot in use as work is done in compressing the gas, causing the pump to get hotter.

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QuestionIT!

Work Done and Energy Transfer

1. A piano is pushed across a wooden floor with a force of 2500 N. The piano moves a distance of 3.5 m. Calculate the work done moving the piano.

2. Work done is usually measured in joules. An alternative unit for work done is (circle the correct answer).

   kg/m^3 Nm W N/m2 N/kg

3. Why does a bicycle pump get hotter when used to pump up a tyre?

4. A box with a weight of 120 N is lifted up 1.8 m onto a shelf. Calculate the work done in lifting the box.

5. When a book is lifted 3 m the work done on the book is 1.2 J. Calculate the weight of the book.

AnswerIT!

Work Done and Energy Transfer

1. A piano is pushed across a wooden floor with a force of 2500 N. The piano moves a distance of 3.5 m. Work out the work done moving the piano.

   Using W = F s

   Work done = 2500 x 3.5

   Work done = 8750 J

2. Work done is usually measured in joules. An alternative unit for work done is (circle the correct answer).

   kg/m^3 Nm W N/m2 N/kg

3. Why does a bicycle pump get hot when used to pump up a tyre?

   Work is done in compressing the air

   Causing the molecules to increase the frequency of their collisions

   Causing frictional heating and an increase in the temperature.

4. A box with a weight of 120 N is lifted up 1.8 m onto a shelf.
Calculate the work done in lifting the box.
Using Work done = force x distance
Work done = 120 x 1.8
Work done = 216 J

5. When a book is lifted 3 m the work done on the book is 12.6 J.
Calculate the weight of the book.
Using
Work done = force x distance
Rearranging gives
Force = work done / distance
Substitution gives
Force = 12.6 / 3
Answer
Force = 4.2 N

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Forces and Elasticity

Springs

Springs are used in many everyday objects. Springs are found in beds, in motorcycle and bike suspension, weighing scales and trampolines.

Springs can either be used in tension (where the spring is stretched) or compression (where the spring is squashed).

Springs have a store of elastic potential energy when they have changed shape.

Not all springs are cylindrical in shape.

Uses of Springs

Some common uses of springs, in compression and tension, include:

Uses of Springs in Compression	Uses of Springs in Tension
Ball Point Pen	Trampolines
Beds (mattresses)	Garage Doors
Suspension Springs (bikes)	Newtonmeter
Electrical Switches	Exercise Equipment (Chest Expander)

Elastic and Inelastic Deformation

To stretch a spring at least two forces are required – otherwise the whole spring will move.

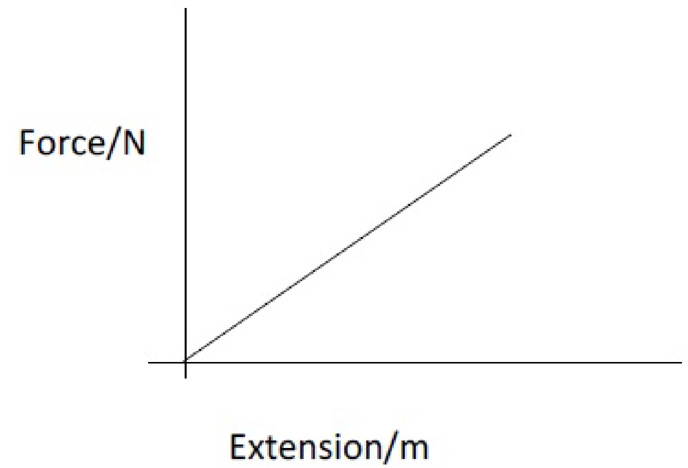
When a spring is stretched, the spring may return to it's original shape. In this case the deformation of the spring is said to be elastic.

If the spring is stretched too far then the spring will never return to it's original length. The deformation is said to be inelastic.

Limit of Proportionality

The extension (the length of a spring minus the original length) of a spring is directly proportional to the force applied – provided that the limit of proportionality is not exceeded.

This means that if the force on the spring is doubled then the extension of the spring will be doubled too.



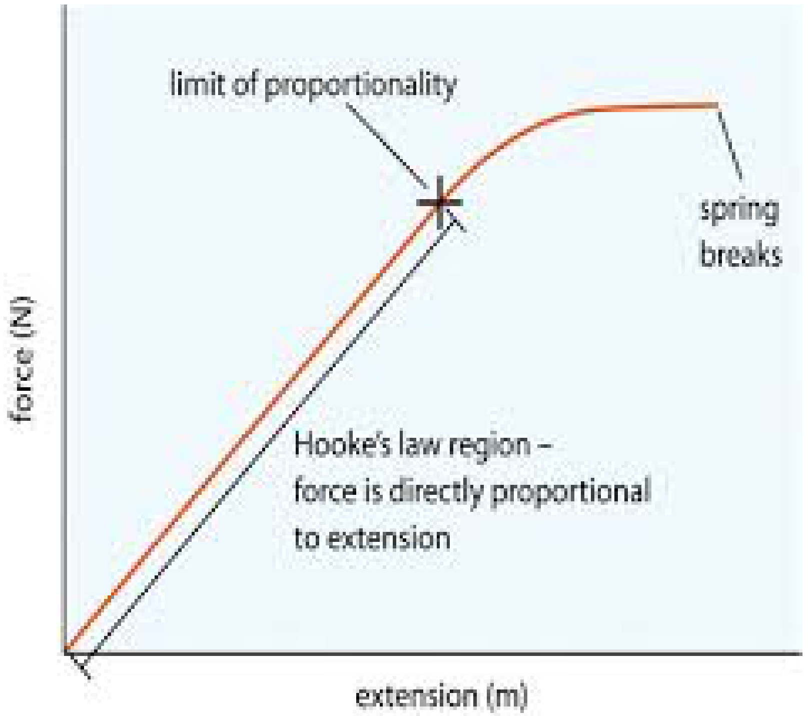
A graph of force against extension for a spring that has not been stretched beyond the limit of proportionality.

Permanent Deformation of a Spring

If the force applied to a spring is too great the the spring will be **inelastically deformed**.

A graph showing force against extension for a spring stretched beyond it's **limit of proportionality will no longer be a straight line through 0,0**.

The graph opposite shows the force – extension graph for a spring stretched beyond it's **limit of proportionality**.

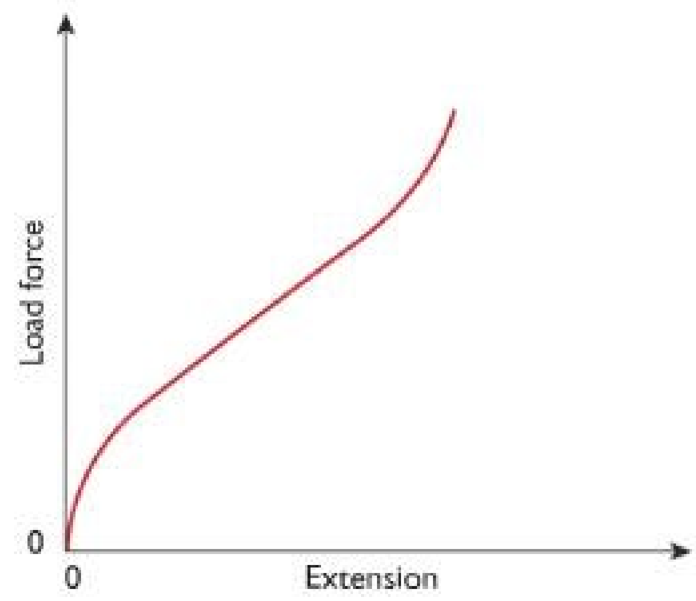


Stretching Other Materials

Objects and materials other than metal springs can be stretched.

An elastic band is an example of a material that can be stretched and stores elastic potential energy.

The extension of an elastic band is not directly proportional to the force applied. A graph of extension against length for an elastic band will produce a curve, yet the material may still go back to it’s original shape.



Spring Constant

The amount a spring stretches depends on the force applied to the spring and also to the spring constant of the spring.

The spring constant of a spring is measured in newtons per meter (N/m). The higher the spring constant the greater the force required to produce a given extension, in metres.

The spring constant can be found using the equation:

Force (N) = Spring Constant (N/m) x Extension (m)

$$F = k\,e$$

This relationship can be applied to springs in both compression and tension, as long as the limit of proportionality is not exceeded.

Spring Constant Calculation

Example:

A trampoline spring has a spring constant of 2200 N/m.

Work out the extension of the trampoline spring if a weight of 600 N is applied.

Solution:

Using the equation

$$F = k\,e$$

Substitution gives

$$600 = 2200 \times e$$

Rearranging

$$600 / 2200 = e$$

Answer:

$$0.27 \text{ m}$$

Energy Stored in a Spring

To stretch or compress a spring you must do work on it. This means that you have transferred energy to the spring, so the spring now has a store of elastic potential energy. Provided the spring is not inelastically deformed the work done in stretching the spring is equal to the elastic potential energy stored in the spring.

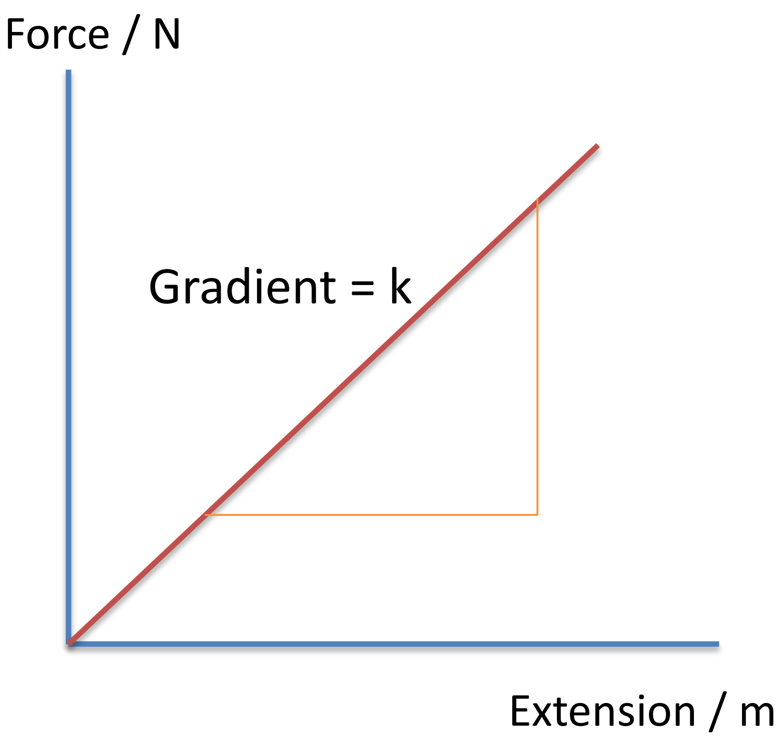
To calculate the amount of energy stored in a spring you need to use the equation:

Elastic Potential Energy (J) = 0.5 x spring constant (N/m) x (extension)^2 (m)

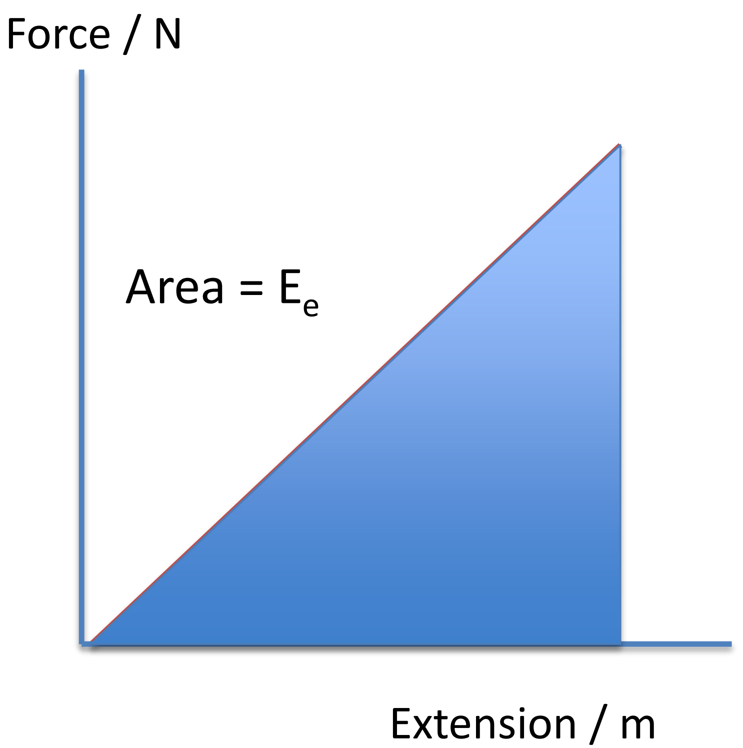
$$E_e = \frac{1}{2} k e^2$$

Graphs of Force Against Extension

The gradient of a force against extension graph gives you the spring constant of the spring.



The energy stored as elastic potential energy is the area under a force against extension graph.



Energy Stored in a Spring Calculations

Example:

A trampoline spring has a spring constant of 1400 N/m.

The spring has a 50 N load added to the spring.

Work out the amount of elastic potential energy stored in the spring when the 50 N load is added to the spring.

Solution:

Step 1: Determine the extension of the spring using F = k e

Extension = 50 / 1400
Extension = 0.0357 m

Step 2: Calculate the energy stored in the spring using $E_e = ½ k e^2$

$$E_e = ½ \times 1400 \times 0.0357^2$$
$$E_e = 0.9 \text{ J}$$

QuestionIT!

Forces and Elasticity

1. What type of energy is stored in a stretched spring?

2. What is the least number of forces required to stretch a spring?

3. A student investigates the stretching of a spring. The student adds weight to the spring and measures the extension.

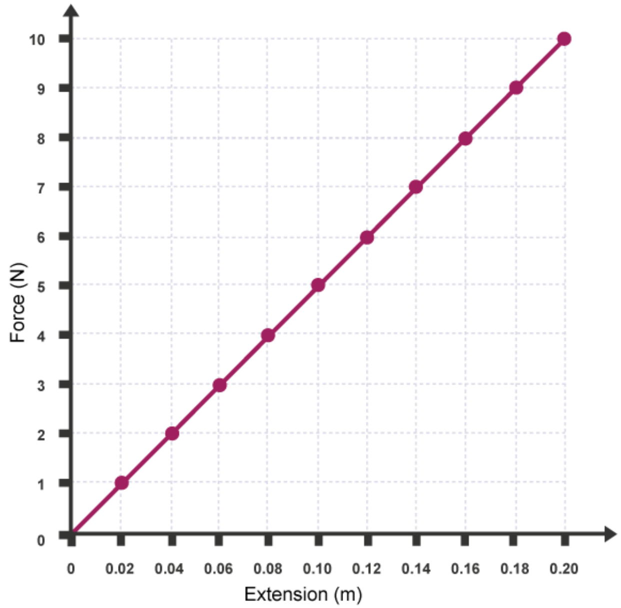
   Sketch the force – extension graph the student would expect for the spring.

4. A spring is stretched beyond its elastic limit. Describe the effect that this would have on the spring.

5. Explain how the extension of a spring is determined.

6. Motorcycles use springs for their suspension. The spring is compressed when the motorcycle rides over bumps.
   A force of 240 N compresses the spring 2 cm.
   Calculate the spring constant of the motorcycle spring.

7. The graph below shows the force-extension graph for a spring.



a) Calculate the spring constant of the spring.

b) Calculate the energy stored in the spring when it is stretched 50 cm.

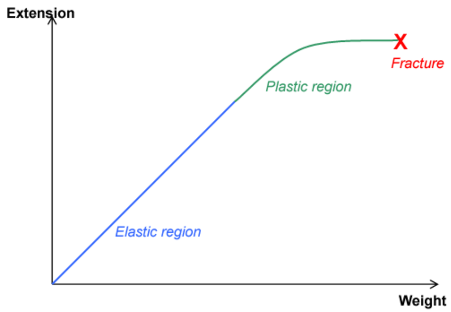
AnswerIT!

Forces and Elasticity

1. What type of energy is stored in a stretched spring?
   Elastic Potential Energy

2. What is the least number of forces required to stretch a spring?
   2

3. A student investigates the stretching of a spring. The student adds weight to the spring and measures the extension.
   Sketch the force – extension graph the student would expect for the spring.

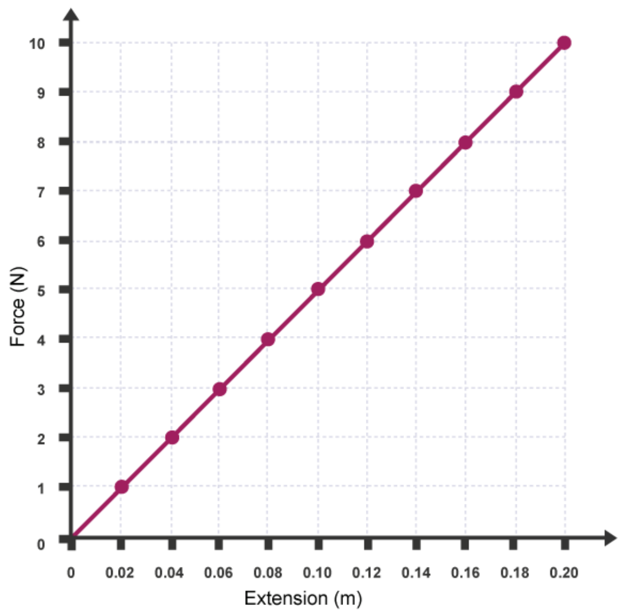


4. A spring is stretched beyond its elastic limit. Describe the effect that this would have on the spring.
   The spring would be inelastically deformed
   so would not return to its original shape

5. Explain how the extension of a spring is determined.
   The length of the extended spring
   minus the original length

5. Motorcycles use springs for their suspension.
   The spring is compressed when the motorcycle rides over bumps.
   A force of 240 N compresses the spring 2 cm.
   Calculate the spring constant of the motorcycle spring in N/m.
   Using $F = k e$
   Rearranging gives $k = F/e$
   Substitution gives $k = 240 / 0.02$
   Spring constant is 12 000 N/m

7. The graph below shows the force-extension graph for a spring.



a) Calculate the spring constant of the spring.

Using k = F / e k = 7 / 0.14 spring constant = 50 N/m

b) Calculate the energy stored in the spring when it is stretched 50 cm.

Using $E_p = ½ k e^2$ $E_p = 0.5 \times 50 \times (0.5)^2$

Elastic Potential Energy = 6.25 J

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Moments, Levers and Gears (Physics Only)

Moments

A force or a system of forces may cause an object to rotate.

Everyday examples of force causing a rotation motion include door handles, steering wheels and see-saws.

The turning effect of a force is called the moment of the force. The size of the moment is determined by the equation:

Moment of a force (Nm) = Force (N) × Distance (m)

$$M = F\,d$$

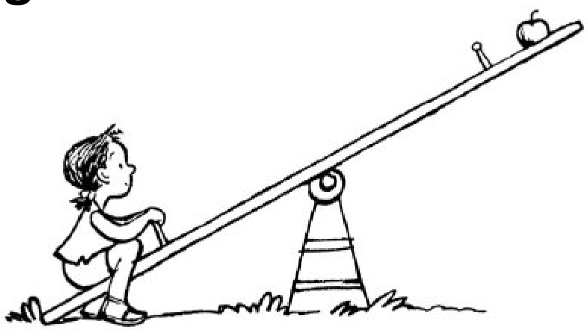
The distance, d, is the **perpendicular distance** from the pivot to the line of action of the force.

Moment Calculations

Example:

A child with a weight of 400 N sits on see-saw. The child sits a distance of 1.2 m from the pivot.

Work out the moment of the turning force.



Solution:

Using:

$$M = F\,d$$

Substitution gives:

$$M = 400 \times 1.2$$

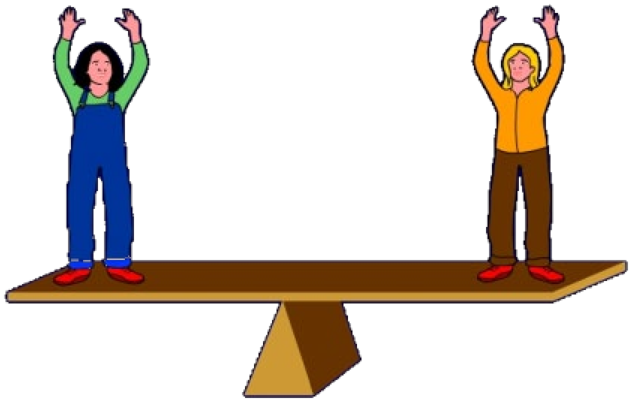
Answer:

$$M = 480 \text{ Nm}$$

Balanced Moments

When two children are on a see-saw the see-saw may be balanced and the children will not move.

In this case the **clockwise moment is balanced by the anti-clockwise moment** – so the two moments are equal.



As both the clockwise and anti-clockwise moments are balanced:

$$F_c\, d_c = F_a\, d_a$$

Where the subscript denotes the direction (clockwise or anti-clockwise).

Balanced Moments Calculations

Example:

A see-saw has two children sat either side of the pivot.

The child on the left-hand side has a weight of 370 N and site 1.3 m from the pivot.

The child on the right sits 2.0 m from the pivot.

Work out the weight of the child on the right-hand side of the pivot if the see-saw is balanced.

Solution:

As both the clockwise and anti-clockwise moments are balanced:

$$F_c\ d_c = F_a\ d_a$$

$$370 \times 1.3 = F_a \times 2.0$$

$$481 / 2.0 = F_a$$

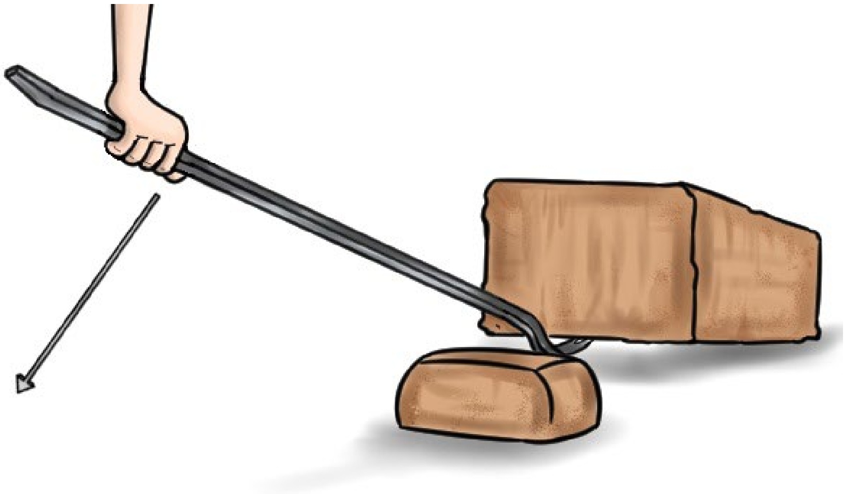
$$F_a = 240.5\ \text{N}$$

Levers

Levers are used to increase the force applied to an object, usually to lift it up from a surface.

A crowbar is an example of a lever. Crowbars can be used to lift up floorboards that have been nailed down.

Levers must have a pivot to rotate around and will work on the principle of moments.



By pushing down on the crowbar the object is lifted upwards.

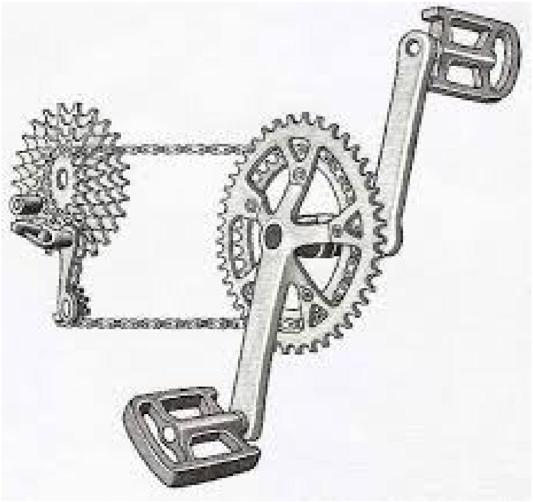
Gears

A gear is a wheel that has teeth on it (also known as a cog), as shown in the diagram opposite. For gears to do work you need at least two gears.

Gears are used to transmit rotational forces from one place to another.

On a bicycle the gears are connected through a chain, though gears can be connected together so that the teeth of the gears interlock.

When the large gear rotates once the smaller gear may rotate many times.

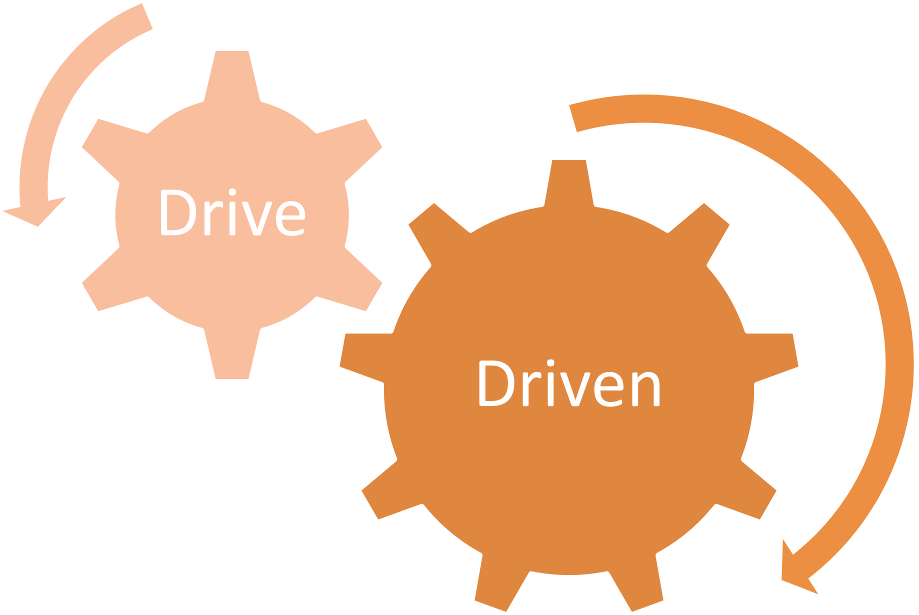


Sometimes gears are connected by a chain.

Rotating Gears

When two cogs are in contact with their teeth interlocking, the driven cog will rotate in the opposite direction to the drive cog.

If the drive cog in a gear spins clockwise then the driven cog will spin anti-clockwise.

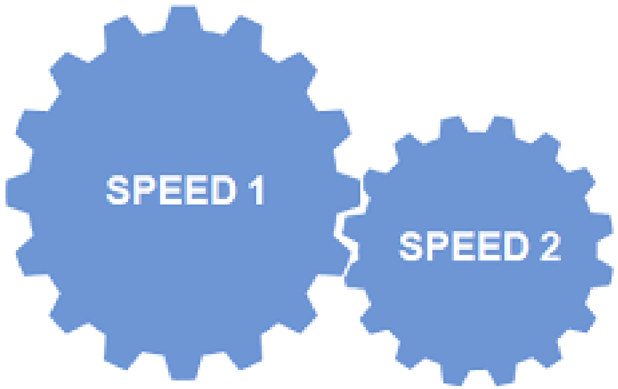


Speed of Gears

When a large cog is driving a small cog, then the small cog will rotate faster than the large cog.

Halving the number of teeth on the small cog will double the speed of the small cog.

Going from a large cog to a smaller cog will increase the speed of rotation.



Speed 2 will be faster than Speed 1 as there are fewer teeth on the cog.

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QuestionIT!

Moments, Levers and Gears
(Physics Only)

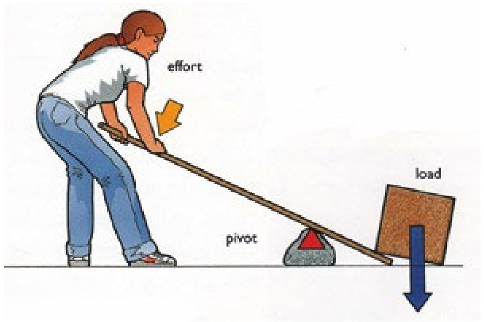
1. State the equation used to find the moment of a force.

2. A 30 cm long spanner is used to undo a nut. A force of 20 N is applied to the end of the spanner.
   Calculate the moment of force applied to the spanner.

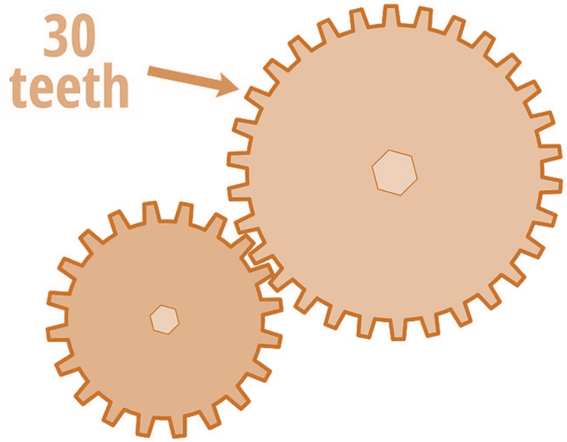
3. Two children sit on a see-saw on opposite sides of the pivot. One child has a weight of 340 N and sits 1.2 m from the pivot. If the other child has a weight of 420 N how far does this child need to sit from the pivot for the see-saw to be balanced?

4. A crowbar is used to lift up a floor board. The crowbar has a length of 40 cm from the pivot to the end of the crowbar, and the distance from the bend to the lifting point is 12 cm.
If the force applied to the end of the crowbar is 300 N, work out the size of the force applied to the floor board.

5. A box with a weight of 400 N is raised using a lever 2 m long. The lever rotates around a pivot 50 cm from the lifting end of the lever. Work out the force applied to the end of the lever.

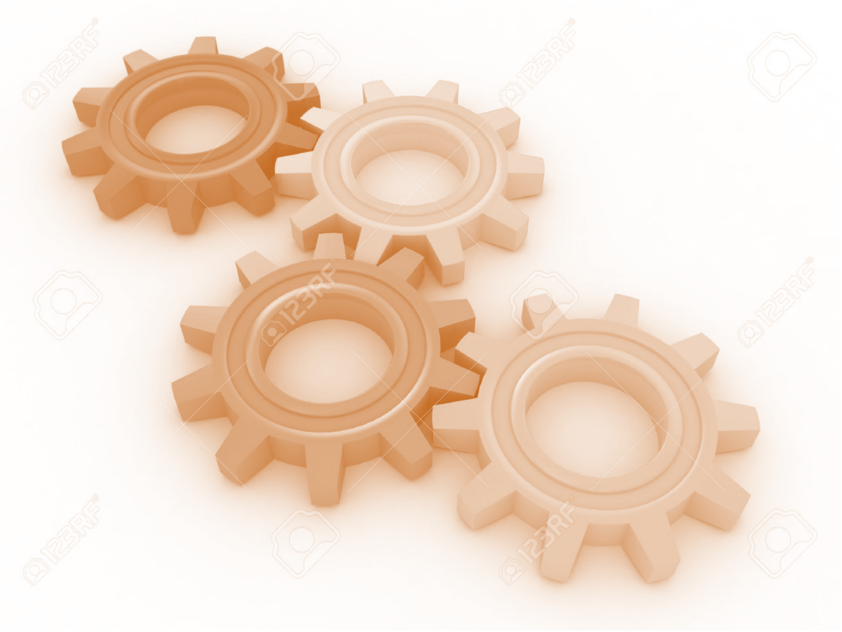


6. The 30 tooth large cog is made to rotate in a clockwise direction. In which direction will the smaller cog rotate?



7. In the gear system shown above, the 30 tooth cog rotates once every 5 seconds. The smaller cog has 20 teeth. Calculate how long it will take to the smaller cog to complete one revolution.

8. Look at the following gear system. In which direction will the yellow cog rotate if the red cog is made to rotate anti-clockwise?



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AnswerIT!

Moments, Levers and Gears (Physics Only)

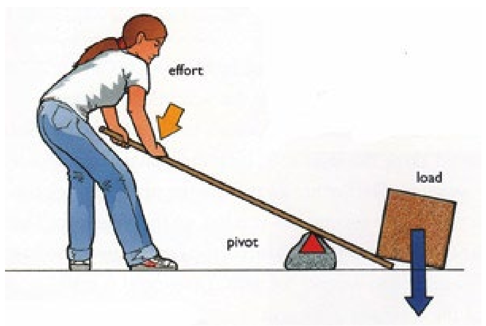
1. **State the equation used to find the moment of a force.**
   Moment = force x distance

2. **A 30 cm long spanner is used to undo a nut.**
   A force of 20 N is applied to the end of the spanner.
   Work out the moment of force applied to the spanner.
   Moment = force x distance
   Moment = 20 x 0.3
   Moment = 6 Nm

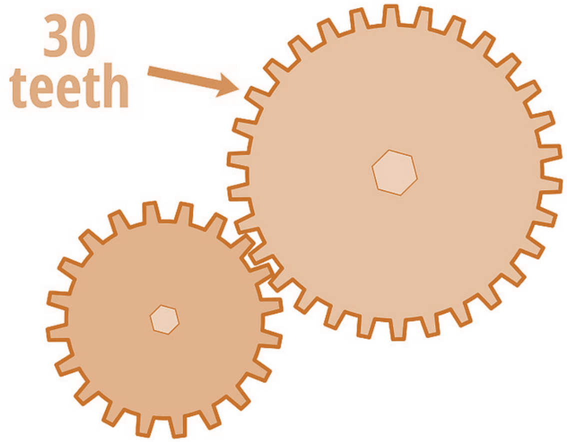
3. **Two children sit on a see-saw on opposite sides of the pivot.**
   One child has a weight of 340 N and sits 1.2 m from the pivot.
   If the other child has a weight of 420 N how far does this child need to sit from the pivot for the see-saw to be balanced?
   Clockwise and anti-clockwise moments must be balanced
   so, 340 x 1.2 = 420 x distance from pivot
   so, distance from pivot = 0.97 m

4. A crowbar is used to lift up a floor board. The crowbar has a length of 40 cm from the pivot to the end of the crowbar, and the distance from the bend to the lifting point is 12 cm.
   If the force applied to the end of the crowbar is 300 N, work out the size of the force applied to the floor board.
   As the moment on either side of the pivot is equal
   300 x 0.4 = force x 0.12
   So, force applied to the floor board = 1000 N

5. A box with a weight of 400 N is raised using a lever 2 m long. The lever rotates around a pivot 50 cm from the lifting end of the lever. Work out the force applied to the end of the lever.
   As the moment on either side of the pivot is equal
   Force Applied x 1.5 = 400 x 0.5
   Force applied = 133.3 N



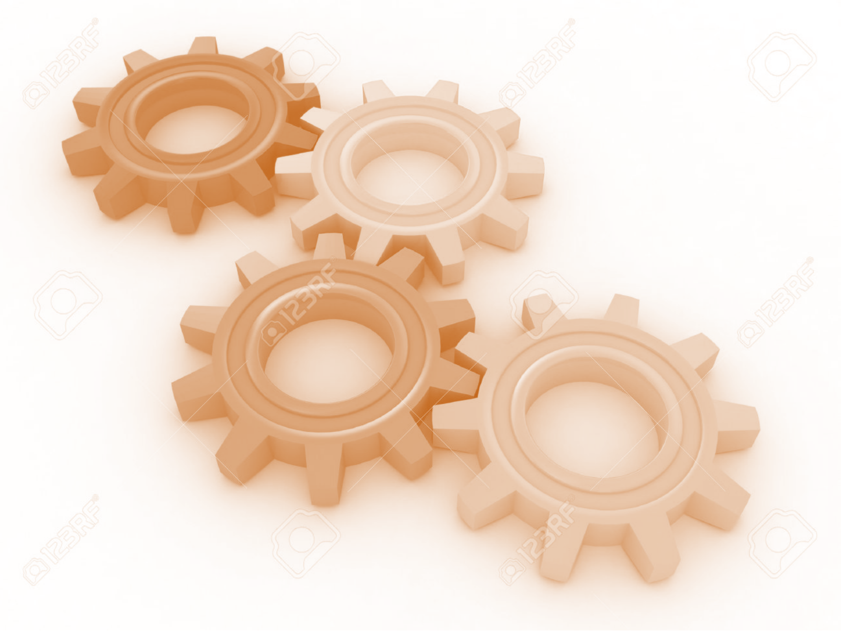
6. The 30 tooth large cog is made to rotate in a clockwise direction. In which direction will the smaller cog rotate?



Anti-clockwise

6. In the gear system shown above, the 30 tooth cog rotates once every 5 seconds. The smaller cog has 15 teeth. Calculate how long it will take to the smaller cog to complete one revolution.
2.5 seconds
As there are half the number of teeth the cog will spin twice as fast.

8. **Look at the following gear system.**
In which direction will the yellow cog rotate if the red cog is made to rotate anti-clockwise?



Clockwise

If red spins anti-clockwise then the green will spin clockwise, blue anti-clockwise making the red cog spin clockwise.

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LearnIT!
KnowIT!

Pressure and Pressure Differences in Fluids (Physics Only)

- Pressure in a Fluid 1
- Pressure in a Fluid 2 (HT Only)
- Atmospheric Pressure

Pressure in a Fluid 1

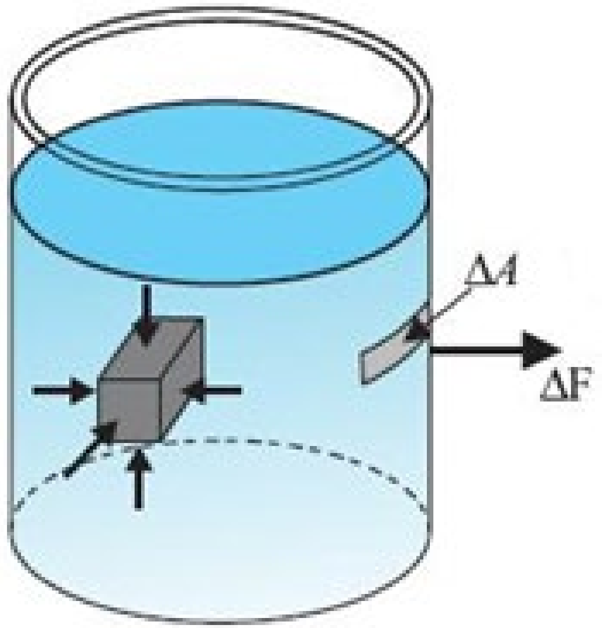
Fluids are substances that flow. Liquids and gases are both fluids.

When there is a pressure in a fluid a force is produced at right angles to the surface containing the fluid.

The size of the force acting at the surface of a fluid can be calculated using the equation:

$$\text{Pressure (Pa)} = \frac{\text{Force normal to a surface (N)}}{\text{Area of that surface (m}^2\text{)}}$$

$$p = \frac{F}{A}$$



The pressure in a fluid produces a force at right angles to the surface .

Pressure in a Fluid 1: Equations

Example:

Work out the pressure in a fluid when the fluid applies a force of 12 N on a surface of area 0.02 m^2.

Solution:

Using the equation:

pressure = force / area

Substituting:

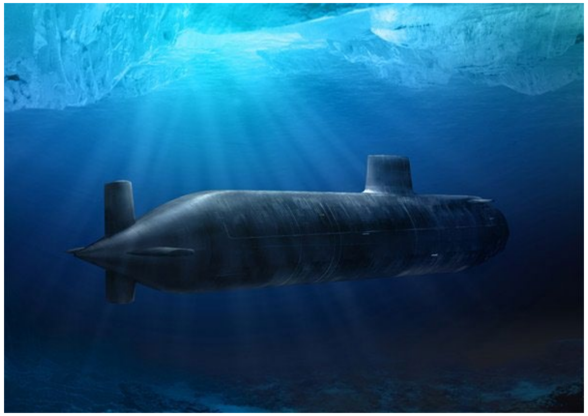
pressure = 12 / 0.02

Answer:

pressure = 600 Pa

Pressure in a Fluid 2

When a submarine is underwater there is a pressure acting. The pressure depends on the depth of the submarine, the density of the water it is in (salt water is more dense than fresh water) and on the gravitational field strength.



The equation that links pressure, gravitational field strength, density and height of column is:

Pressure (Pa) = Height of column (m) x Density of liquid (kg/m³) x Gravitational field strength (N/kg)

$$p = h \rho g$$

Pressure Differences

When a 2 litre bottle has holes drilled into the sides and is then filled with water leaks out. The water that escapes out the bottom of the bottle comes out faster than the water from the top hole – so it travels further.

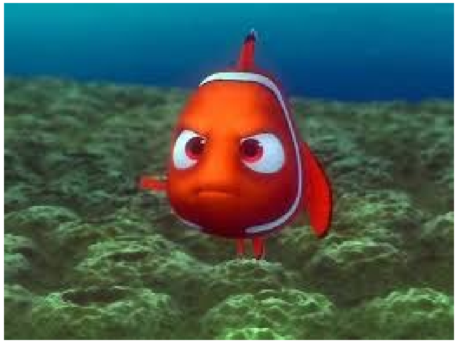
This is due to the pressure at the bottom of the bottle being greater than the pressure at the top of the bottle – there is a greater height of the column of water above the hole at this point, so there is more weight pushing down per unit area.

Floating

A submarine can float mid-water. This happens when the weight of the submarine equals the upthrust from the water.

The upthrust on the submarine depends on the pressure difference between the top of the submarine and the bottom of the submarine. When the pressure difference between the top and the bottom of the submarine equals the weight of the submarine then it will float.

Submarines can adjust the depth they float at by adding or removing water from ballast tanks. Scuba divers use air in a jacket to control their depth. Fish have swim bladders which serve a similar purpose.



Pressure Calculations

Example:

The top of a submarine is 50 m underwater. The density of seawater is 1030 kg/m^3. Work out the pressure on the top of the submarine.
Take g = 10 N/kg.

Solution:

Using the equation	**$p = h \rho g$**
Substitution gives	**$p = 50 \times 1030 \times 10$**
Answer	**pressure = 515 000 Pa**

Upthrust Calculations

Example:

Calculate the upthrust on a submarine that has a height of 15 m and is submerged at a depth of 60 m (to the top of the submarine). The submarine has a surface area of 100 m^2 on the top and on the bottom of the submarine.

Take the density of sea water to be 1100 kg/m^3 and the gravitational field strength of the Earth to be 10 N/kg.

Solution:

The difference in pressure between the top and bottom of the sub is due to a difference in height of the column of water of 15 m.

So, using the equation: $p = h \rho g$

$P = 15 \times 1100 \times 10$

$P = 165{,}000$ Pa

Since Pressure = force / area

force (upthrust) = 165 000 x 200 = 33 000 000 N

The Earth's Atmosphere

The Earth's atmosphere is a very thin (relative to the size of the Earth) layer of gas. The density of this layer of gas gets lower as you go higher.

The weight of air pushing down on a surface decreases with height. With fewer particles the higher up you go there will be fewer collisions, per unit time, with a surface. This means that the atmospheric pressure decreases with height.

When air molecules collide with a surface it creates air pressure. The more molecules that collide with a surface in a given time, the greater the pressure on that surface.

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QuestionIT!

Pressure and Pressure Differences in Fluids (Physics Only)

- Pressure in a Fluid 1
- Pressure in a Fluid 2 (HT Only)
- Atmospheric Pressure

1. In a bath full of water a force of 1250 N acts on an area of 0.5 m^2 at the bottom of the bath.
   Calculate the pressure acting on the bottom of the bath.

2. A pressure of 4000 Pa acts in a hydraulic brake fluid. The surface of the slave cylinder inside the brake system has a surface area of 0.03 m^2.
   Calculate the force acting on the slave cylinder.

3. A beaker is filled to a depth of 10 cm with water. Water has a density of 1000 kg/m^3. Calculate the pressure acting at the bottom of the beaker.
   Take g = 10 N/kg.

4. A scuba diver is diving in the sea. The pressure acting on the scuba diver is 267 800 Pa. Salt water has a density of 1030 kg/m^3.
   Calculate the depth of the scuba diver.

5. A boat floats in sea water (density = 1030 kg/m^3). The boat has a surface area of 15 m^2 in contact with the water and has a pressure of 4120 Pa acting on it.
   Find the depth the boat floats at.
   Take g = 10 N/kg.

6. Explain why the atmospheric pressure on the top of Mount Everest is lower than the atmospheric pressure at sea level.

AnswerIT!

Pressure and Pressure Differences in Fluids (Physics Only)

- Pressure in a Fluid 1
- Pressure in a Fluid 2 (HT Only)
- Atmospheric Pressure

1. In a bath full of water a force of 1250 N acts on an area of 0.5 m^2 at the bottom of the bath.
   Calculate the pressure acting on the bottom of the bath.

   Pressure = Force / Area
   Pressure = 1250 / 0.5
   Pressure = 2500 Pa

2. A pressure of 4000 Pa acts in a hydraulic brake fluid. The surface of the slave cylinder inside the brake system has a surface area of 0.03 m^2.
   Calculate the force acting on the slave cylinder.

   Pressure = Force / Area
   Force = Pressure x Area
   Force = 4000 x 0.03
   Force = 120 N

3. A beaker is filled to a depth of 10 cm with water. Water has a density of 1000 kg/m^3. Calculate the pressure acting at the bottom of the beaker. Take g = 10 N/kg.

Convert 10 cm into standard units: 10 cm = 0.1 m

Pressure = height of column x density x gravitational field strength

Pressure = 0.1 x 1000 x 10

Pressure = 1000 Pa

4. A scuba diver is diving in the sea. The pressure acting on the scuba diver is 267 800 Pa. Salt water has a density of 1030 kg/m^3.
Calculate the depth of the scuba diver.

Pressure = height of column x density x gravitational field strength

Rearranging gives

Height of column = Pressure / (density x gravitational field strength)

Height of column = 267 800 / (1030 x 10)

Height of column = 26 m

Therefore the scuba diver is at a depth of 26 m.

5. A boat floats in sea water (density = 1030 kg/m^3). The boat has a surface area of 15 m^2 in contact with the water and has a pressure of 4120 Pa acting on it.
   Find the depth the boat floats at.
   Take g = 10 N/kg.

   Pressure = height of column x gravitational field strength x density
   4120 = height of column x 10 x 1030
   4120 / (10 x 1030) = height of column
   Height of column = 0.4 m
   Therefore the depth of the boat is 0.4 m.

6. Explain why the atmospheric pressure on the top of Mount Everest is lower than the atmospheric pressure at sea level.

   At sea level there is more air above you
   This gives a greater weight of air pushing on you per unit area
   Increasing the pressure

LearnIT!
KnowIT!

Forces and Motion

- Distance and Displacement
- Speed
- Velocity
- The Distance-Time Relationship
- Acceleration

Definitions

Distance: How far an object has travelled. Distance is a scalar quantity.

Displacement: How far an object has travelled in a straight line from the starting point to the finishing point and the direction of that line. Displacement is a vector quantity.

Examples:

A runner runs around a track. The track is 400 m long.

After completing one complete circuit of the track the runner has travelled a distance of 400 m. After the one complete circuit the runner ends up at their starting point. This means that their displacement is 0 m.

Calculations

For an object moving at a constant speed the distance travelled in a specific time can be calculated using the equation:

Distance travelled (m) = Speed (m/s) x time (s)

$$s = v\,t$$

Definitions

Speed is the rate of change of distance. This can be found using the equation:

$$\text{speed} = \frac{\text{distance travelled}}{\text{time taken}}$$

Speed is a scalar quantity which means that it has magnitude but no direction.

Velocity is the rate of change of distance. Velocity is found using the equation:

$$\text{velocity} = \frac{\text{displacement}}{\text{time taken}}$$

Velocity is a vector quantity which means that is has magnitude and direction.

Speed Calculations

Example 1:

A bike travels 800 m in 160 seconds. Calculate the speed of the bike.

Solution 1:

Using the equation: Speed = distance / time

Speed = 800 / 160

Speed = 5 m/s

Example 2:

A car travels a distance of 300 miles at an average speed of 50 mph. Calculate how long it will take to complete the car journey.

Solution 2:

Rearranging the speed equation gives: time = distance / speed

time = 300 / 50 = 6 hours

Velocity Calculations

Example 1:

A track runner runs around a 400 m athletics track 4 times in 3 minutes and 10 seconds.

Work out:

a) The speed of the track runner

Speed = distance / time
Speed = 1600 / 190
Speed = 8.4 m/s

b) The average velocity of track runner.

As the displacement at the end of the run is 0 m (they end up where they started after four loops of the track) their average velocity is 0 m/s.

Typical Speeds

These are the typical speeds of everyday situations that you should know for your exam.

Situation	Typical Speed/ m/s
Walking	1.5
Running	3
Cycling	6

The speed of sound in air is 330 m/s (though this does changes with temperature and pressure).

Average and Instantaneous Speed

Average speed is the speed of an object over the entire journey. The average speed is found by using the total distance travelled divided by the total time taken.

$$\text{average speed} = \frac{\text{total distance travelled}}{\text{total time taken}}$$

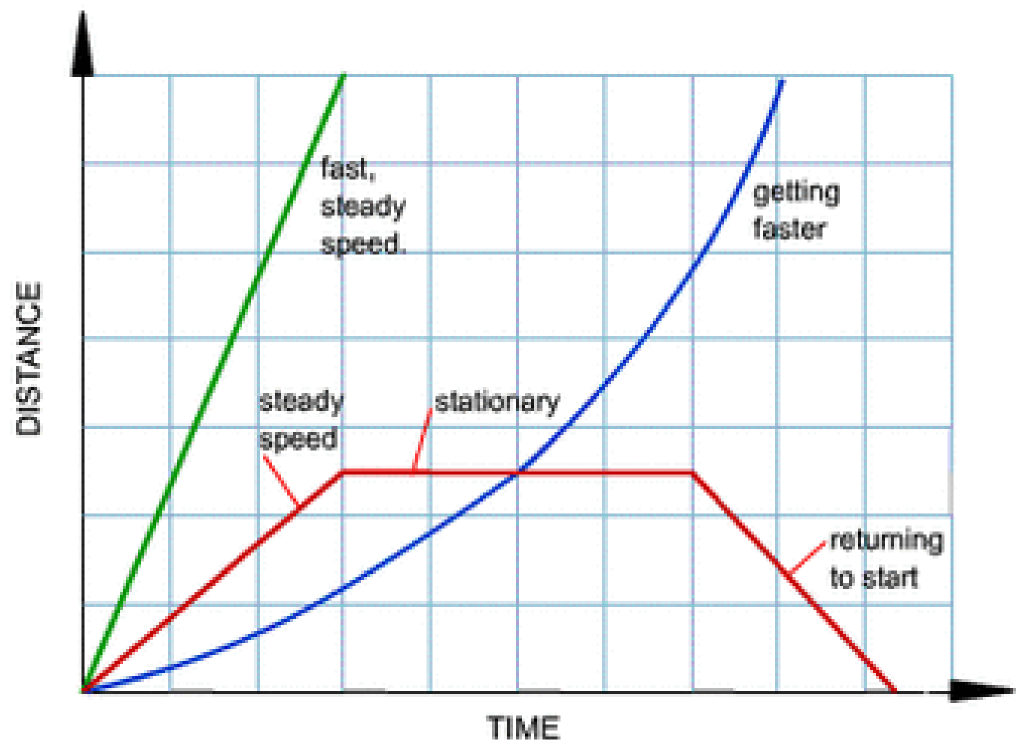
Instantaneous speed is the speed of an object at a given moment in time. The speedometer in a car gives the instantaneous speed of the car.

Distance-Time Graphs

Distance-time graphs can be used to represent the motion of an object.

The different gradients (steepness) of line on the graphs show different motions of the object.

The shapes of line that you need to know are shown opposite.



Calculating Speed from a Distance-Time Graph

From the shapes of distance-time graphs it is possible to compare the speeds of different objects. The steeper the gradient of a line on a distance-time graph the faster the object is travelling.

The gradient of the line on a distance-time graph is the speed of the object.

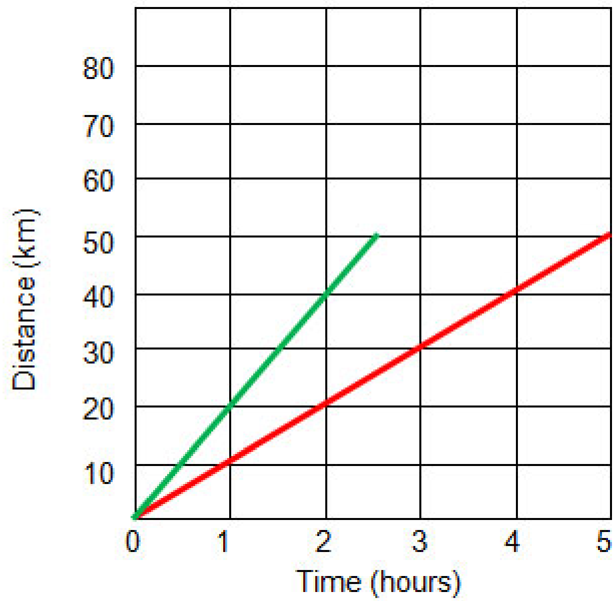
Example:

Work out the speed of the objects shown by the red and green line.

Solution:

Red = distance / time = 30 / 3 = 10 km/h

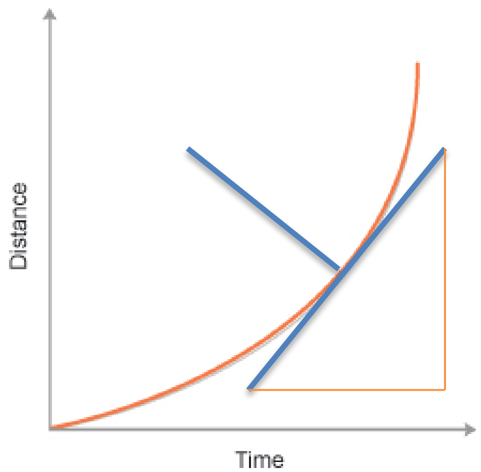
Green = distance / time = 40 /2 = 20 km/h



Calculating Instantaneous Speed

Higher Tier Only
When an object is accelerating the line on a distance-time graph is curved.
To find the instantaneous speed of the object at any point along the curve the tangent to the line must first be found – then the gradient of the tangent shows the speed.

To draw the tangent of a curve you should draw a line perpendicular to your curve to start with, then draw a straight line at right-angles to this across your curve – this is your tangent. The longer the line that you draw at this point the easier and more accurate your speed calculation will be.



Acceleration

When objects accelerate they can be changing speed or changing direction or changing both speed and direction.

Acceleration is the rate of change of velocity, and since velocity is a vector so is acceleration.

The average acceleration of an object is found using the equation:

$$\text{Acceleration (m/s}^2\text{)} = \frac{\text{change in velocity (m/s)}}{\text{Time taken (s)}}$$

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

An acceleration of 3 m/s^2 means that an object is getting 3 m/s faster every second.

Equivalent units for acceleration are: m/s/s and ms^{-2}.

Negative Acceleration

As acceleration is a vector the direction is important.

When a moving object has a negative acceleration it can either be slowing down (often just called decelerating) or it could be increasing speed in the opposite direction.

If a car is moving along a straight motorway at 70 mph and then has a negative acceleration the car will slow down.

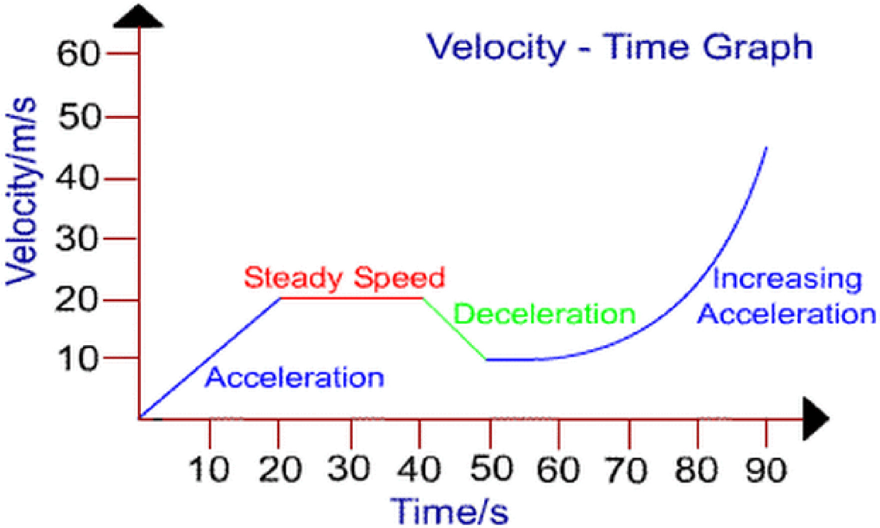
On the on the other hand if the positive direction is chosen to be upwards then a ball that is dropped will have a negative acceleration (as it is in the opposite direction) and will continue to speed up (accelerate) in the opposite direction.

Velocity-Time Graphs

A velocity-time graph gives more information than a distance-time graph. As well as speed, distance travelled and time, a velocity-time graph will give the acceleration of the object.

Although the line shapes look the same as a distance-time graph, as the axes are different the line meanings are different.

Below are the line shapes for velocity-time graphs.



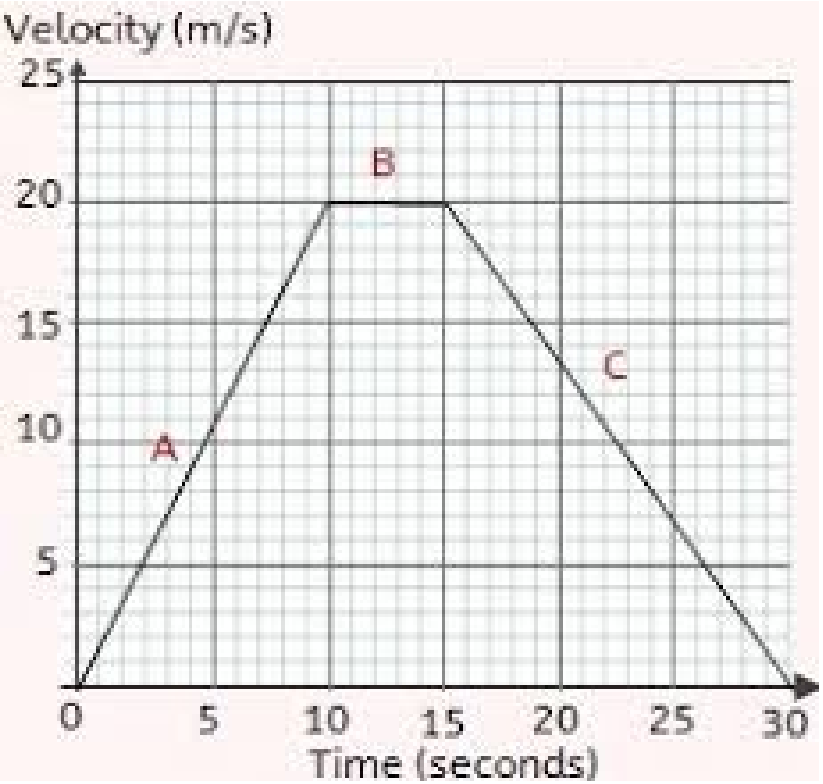
Velocity-Time Graph Calculations

The following information can be gathered from a velocity time graph:

The velocity: From reading off the axes on the graph.

The acceleration: Found from the gradient of the line on the velocity-time graph.

The distance travelled: The area under the line on a velocity-time graph is the distance travelled.

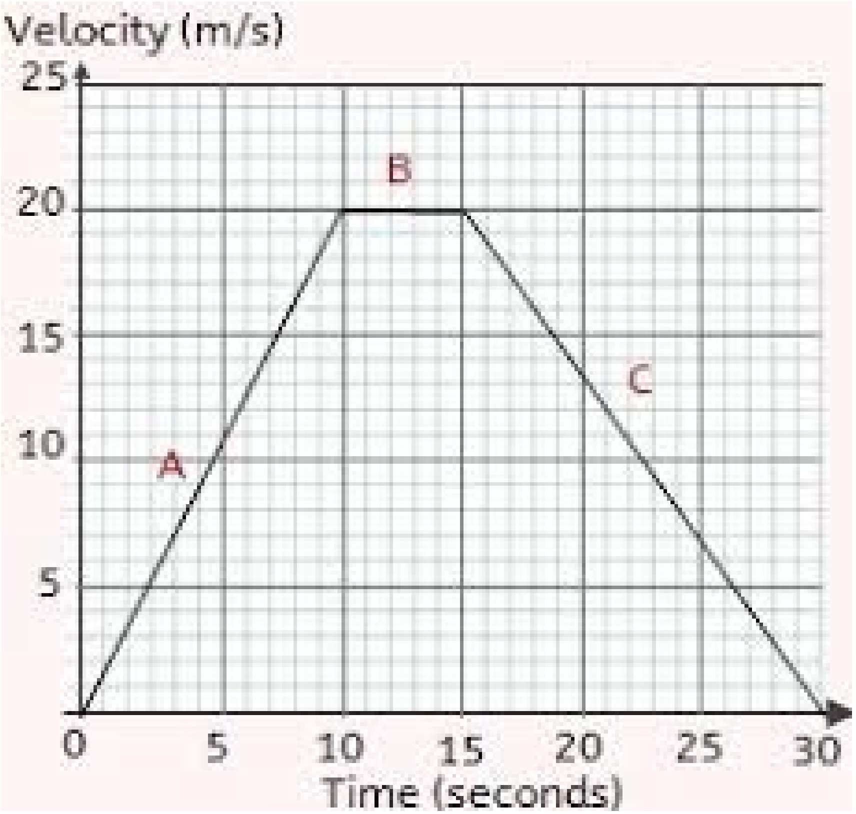


Interpreting Velocity-Time Graphs

Example:
Describe fully the motion shown in the velocity-time graph.

Solution:

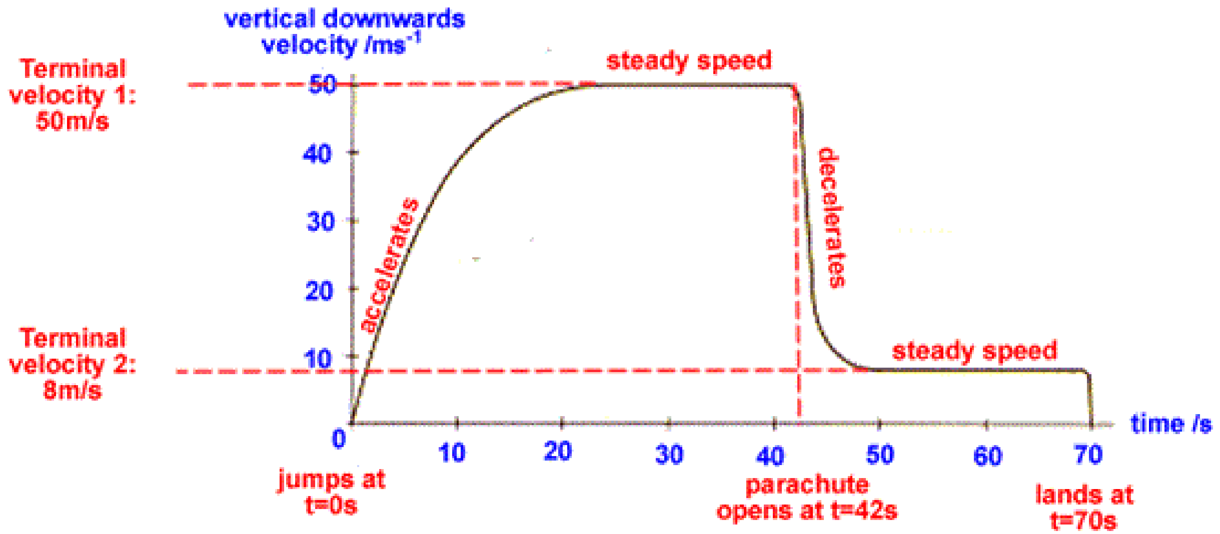
From 0 to 10 s: Constant rate of acceleration of 2 m/s^2.
From 10 to 15 s: Constant speed of 20 m/s.
From 15 to 30 s: Constant rate of deceleration of 1.33 m/s^2.
Distance-travelled is the area under the line = 100 m + 100 m + 150 m = 350 m



Terminal Velocity of Falling Objects

When a skydiver jumps out of a plane they may reach terminal velocity.

At terminal velocity the pull of gravity (the skydiver's weight) is equal in size and opposite in direction to the air resistance on the skydiver. As there is no resultant force there is no acceleration and the skydiver will fall at a steady speed.



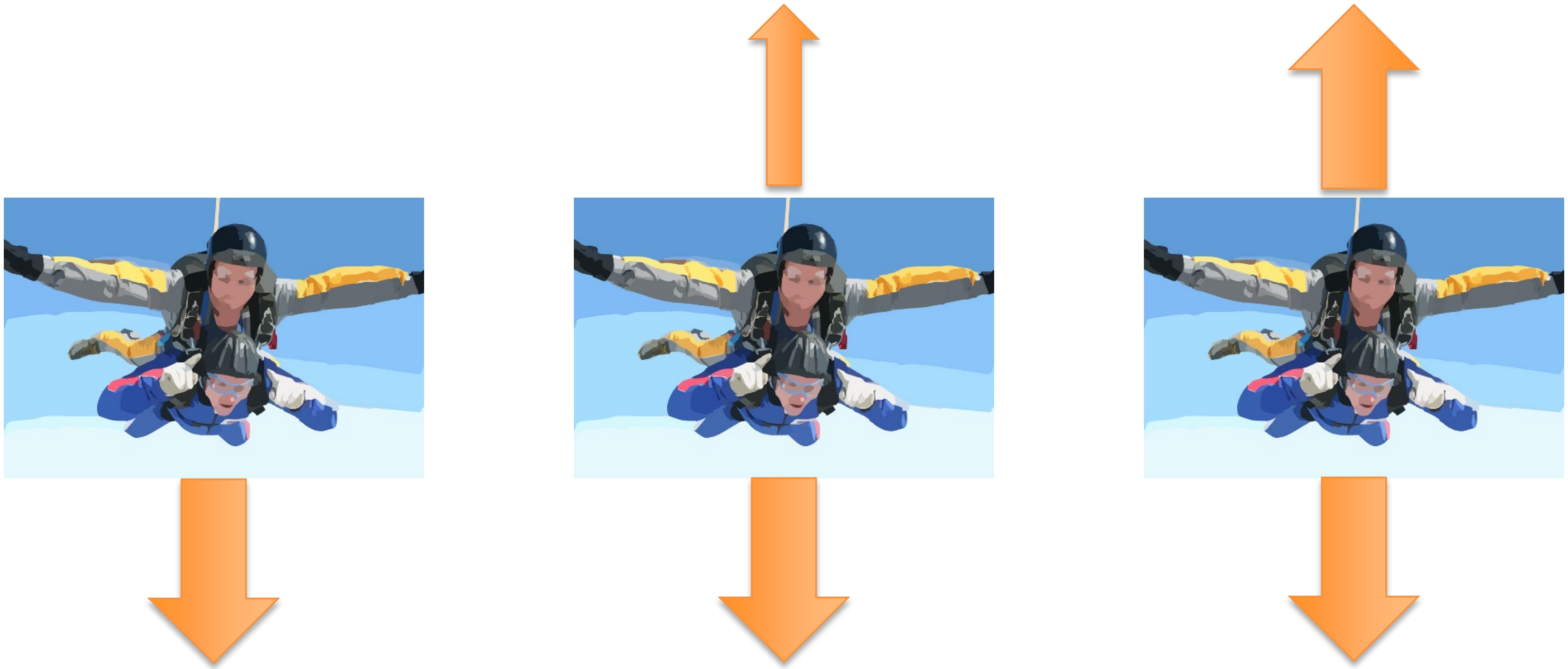
Forces acting on a Skydiver

During the course of a skydive the weight of a skydiver will not change. As a result of this the skydiver will have a constant pull downwards caused by the gravitational attraction of the Earth.

Also acting on the skydiver is air resistance, or drag. As the skydiver moves through the air faster the skydiver will experience more drag.

Drag reduces the acceleration the skydiver experiences, from 10 m/s^2 when they have just jumped out of the plane to 0 m/s^2 when they reach terminal speed.

More Forces acting on a Skydiver



As the skydiver falls faster the amount of drag experienced increases, reducing the skydiver's acceleration, until weight and drag are equal in size. At this point the skydiver will be falling with terminal velocity.

Uniform Acceleration

The equation for uniform acceleration is:

(Final velocity)^2 – (Initial velocity)^2 = 2 x Acceleration x Distance
(m/s) (m/s) (m/s^2) (m)

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

This equation is often used when an object is falling under gravity and assumes the acceleration due to gravity to be constant (so ignoring air resistance).

The acceleration of an object due to gravity is taken to be about 9.8 m/s^2. This is often rounded up to 10 m/s^2.

Uniform Acceleration Calculations

Example:

A stone is dropped off a 30 m high cliff.
The stone falls under gravity ($g = 9.8\ m/s^2$).
Work out the speed of the stone as it hits the floor.

Solution:

As the stone is dropped the initial speed is 0 m/s.
Using

$$v^2 - u^2 = 2\ a\ s$$
$$v^2 = 2\ a\ s + u^2$$
$$v^2 = 2 \times 9.8 \times 30 + 0^2$$
$$v^2 = 588$$
$$v = \sqrt{588} = 24.2\ m/s$$

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QuestionIT!

Forces and Motion

- Distance and Displacement
- Speed
- Velocity
- The Distance-Time Relationship
- Acceleration

1. State the typical speed of a person

   a) Walking

   b) Cycling

2. State the equation that links speed, distance and time.

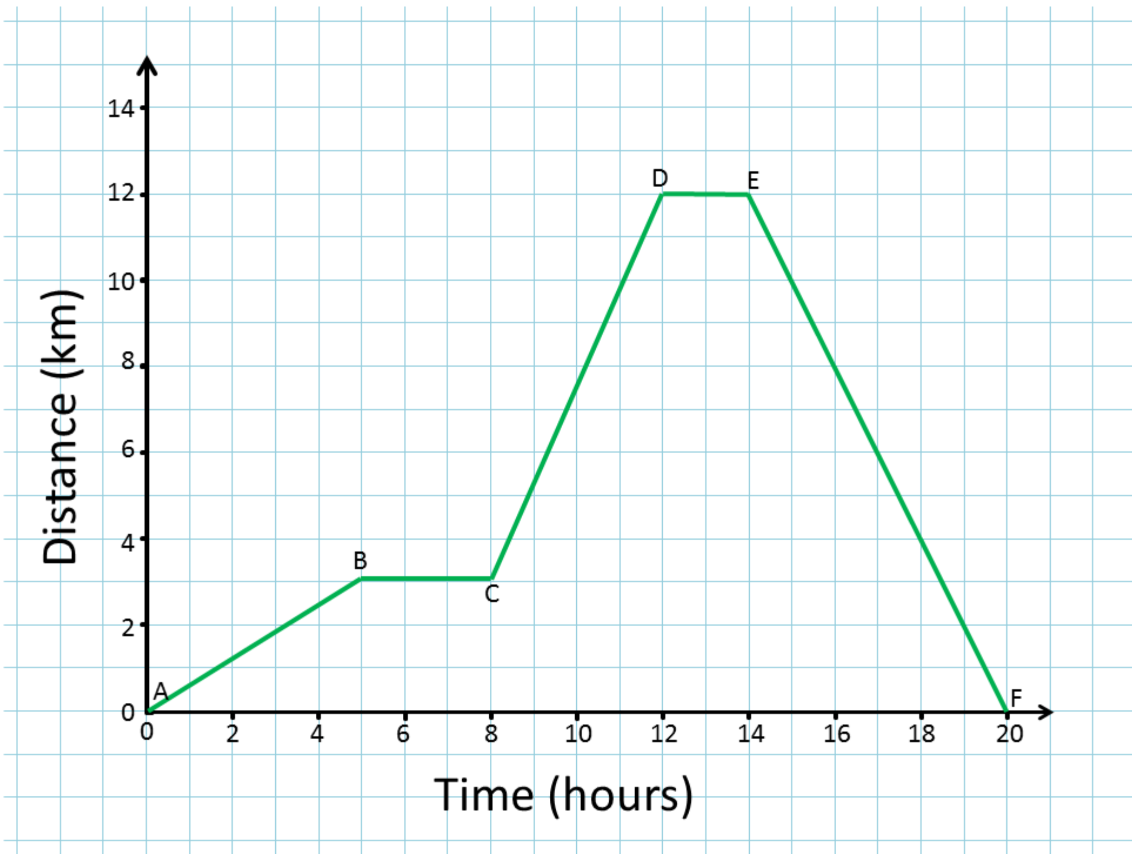
3. Describe the difference between speed and velocity.

4. A car moves round a circular track at 120 mph.
   Give the average velocity of the car. Explain your answer.

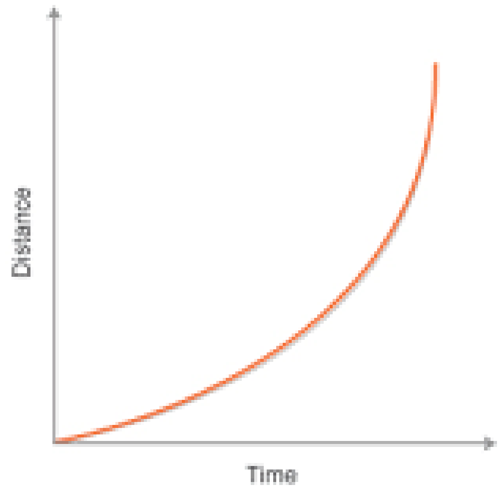
5. A motorcycle travels a distance of 420 miles in 8.5 hours.
   Give the average speed of the motorcycle.

6. Describe the difference between instantaneous speed and average speed.

7. Describe fully the motion shown in the distance-time graph shown below.



8. Describe how you would find the instantaneous speed of an object from a distance-time graph where the line is a curve.



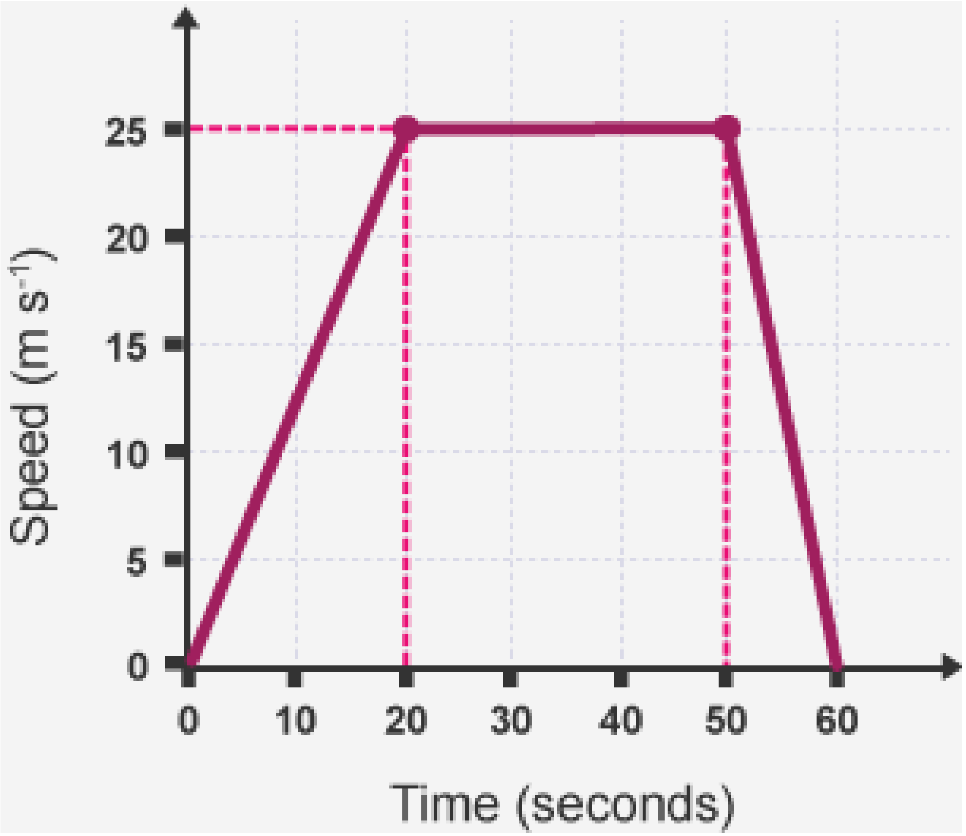
9. State the equation that links acceleration, change in velocity and time taken.

10. Describe what is meant by a negative acceleration.

10. Give the units of acceleration.

12. Describe how the distance travelled by an object can be found from a velocity-time graph.

13. Describe fully the motion shown in the velocity-time graph shown below.



14. A stone is dropped off a cliff.
    The stone hits the floor at 30 m/s.
    Calculate the height of the cliff.
    Take $g = 9.8\ m/s^2$

15. Explain how the motion of a skydiver changes from the moment they jump out of the plane until they land.

AnswerIT!

Forces and Motion

- Distance and Displacement
- Speed
- Velocity
- The Distance-Time Relationship
- Acceleration

1. State the typical speed of a person

   a) Walking
   1.5 m/s

   b) Cycling
   6 m/s

2. State the equation that links speed, distance and time.

$$\text{speed} = \frac{distance}{time}$$

3. Describe the difference between speed and velocity.
   Speed is a scalar quantity – it has magnitude but no direction.
   Velocity is a vector – it has magnitude and direction.

4. A car moves round a circular track at 120 mph.
Give the average velocity of the car. Explain your answer.

Average velocity is 0 m/s
As on completion of every lap the car has a displacement of 0 m and velocity is found using displacement / time the average velocity must be 0 m/s

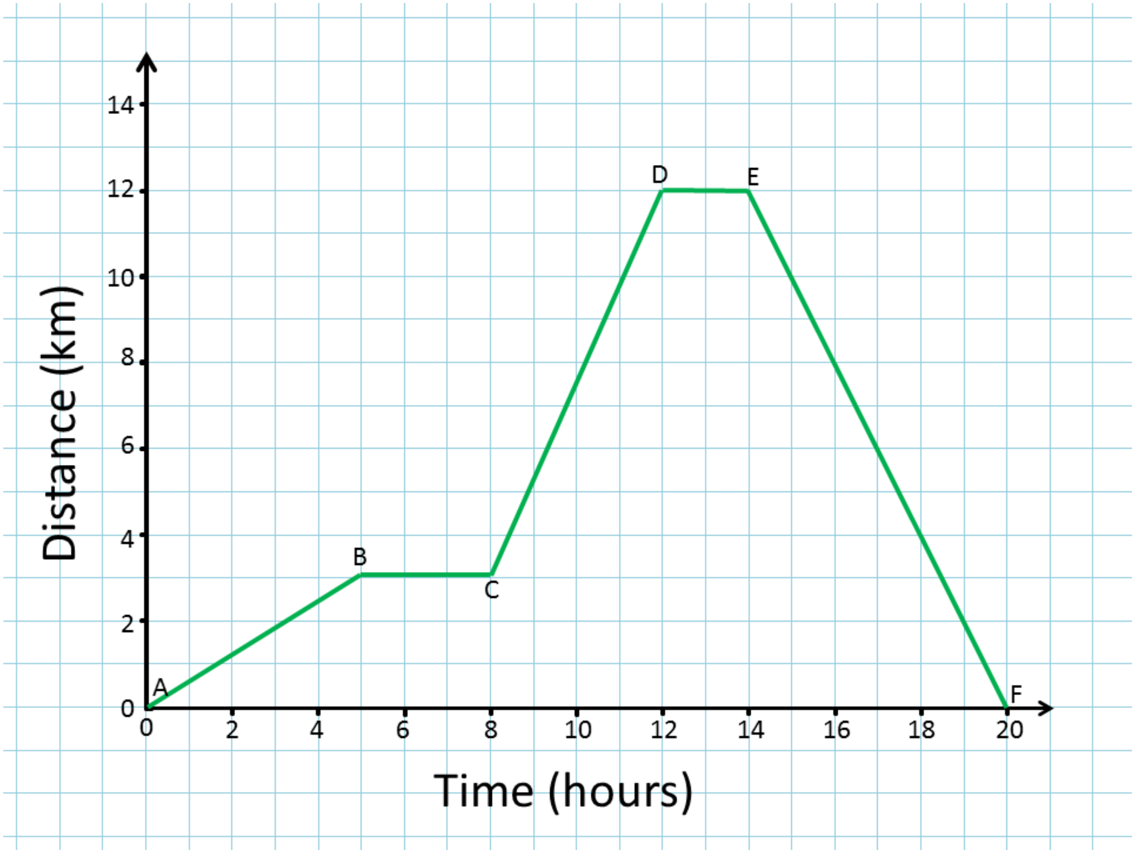
5. A motorcycle travels a distance of 420 miles in 8.5 hours.
Give the average speed of the motorcycle.

speed = distance / time
speed = 420 / 8
speed = 52.5 mph

6. Describe the difference between instantaneous speed and average speed.

Instantaneous speed is the speed at a given moment in time.
Average speed is the speed over the whole journey including periods of acceleration and deceleration.

7. Describe fully the motion shown in the distance-time graph shown below.



A to B: Constant speed of 0.6 km/s

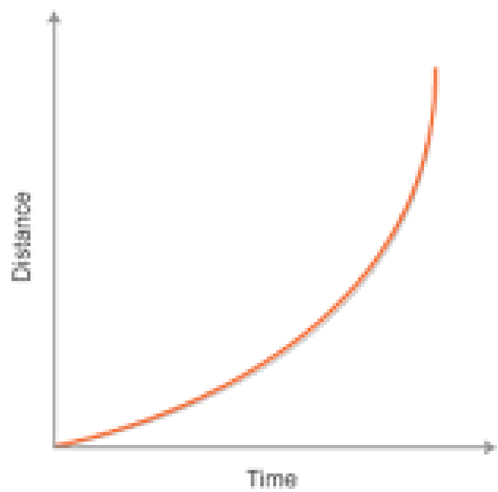
B to C: Stationary (for 4 s)

C to D: Constant speed of 2.25 km/s

D to E: Stationary (for 2 s)

E to F: Constant speed of 2 m/s going back to the origin

8. **Describe how you would find the instantaneous speed of an object from a distance-time graph where the line is a curve. (Higher Tier Only).**



Draw the tangent to the curve.

Find the gradient of the line you have drawn.

The gradient of the line is the instantaneous speed.

9. **State the equation that links acceleration, change in velocity and time taken.**

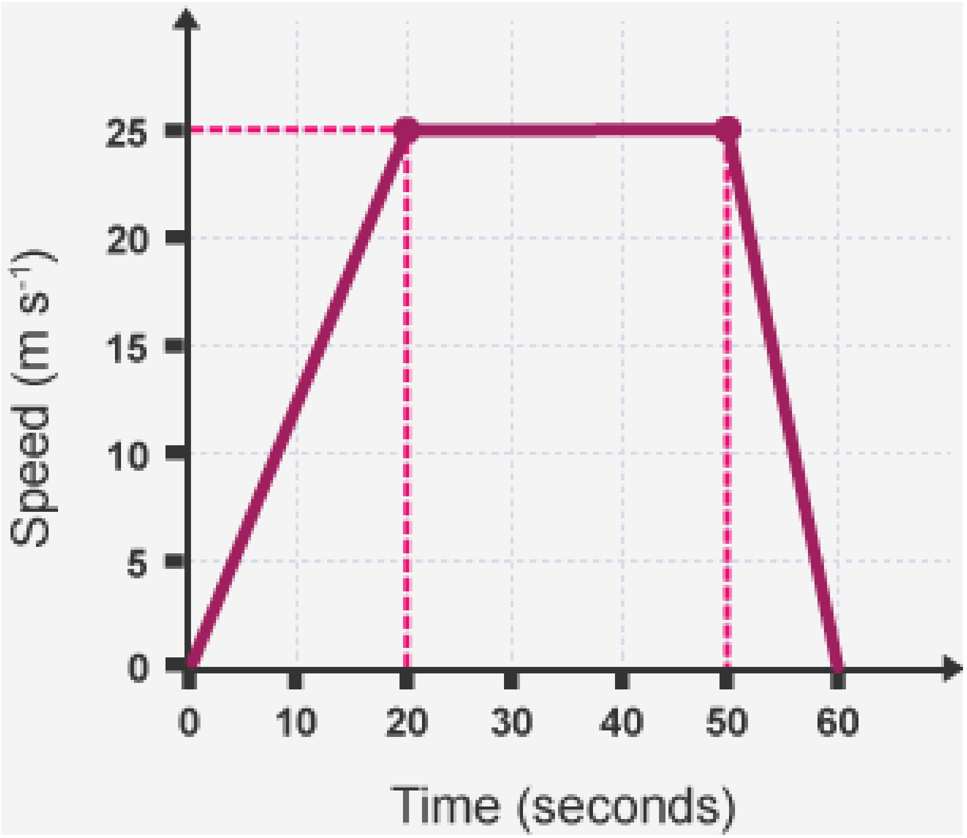
acceleration = change in velocity / time taken

10. Describe what is meant by a negative acceleration.
A negative acceleration means that the object is slowing down or speeding up in the opposite direction (to that which has been assumed to be positive).

11. Give the units of acceleration.
m/s^2 or $m/s/s$ or ms^{-2}

12. Describe how the distance travelled by an object can be found from a velocity-time graph.
The area under the line on a velocity-time graph represents the distance travelled by that object.

13. Describe fully the motion shown in the velocity-time graph shown below.



From 0 to 20 s: Constant rate of acceleration of 1.25 m/s^2

From 20 to 50 s: Constant speed of 25 m/s

From 50 to 60 s: Constant rate of deceleration of 2.5 m/s^2

Total distance travelled over the 60 seconds is:
250 m + 750 m + 125 m = 1125 m

14. A stone is dropped off a cliff.
The stone hits the floor at 30 m/s.
Calculate the height of the cliff.
Take $g = 9.8 \text{ m/s}^2$

Since the stone is dropped $u = 0$ m/s

Using	$v^2 - u^2 = 2as$
Substituting gives	$30^2 - 0^2 = 2 \times 9.8 \times s$
Simplifying gives	$900 = 19.6 \times s$
Rearranging gives	$900 / 19.6 = s$
Therefore	$s = 45.9$ m

15. **Explain how the motion of a skydiver changes from the moment they jump out of the plane until they land.**

- Skydiver accelerates due to gravity (at a rate of 10 m/s^2)
- As the skydiver picks up speed the drag they experience increases
- But the gravitational attraction stays the same
- so the acceleration of the skydiver decreases in size.
- When drag and weight are equal in size but opposite in direction the skydiver will fall with terminal speed
- as there is no resultant force so no acceleration
- When the parachute is opened there is an increase in drag
- Decelerating the skydiver
- Until weight and drag are equal in size but opposite in direction
- Then the skydiver falls at a new (lower) terminal speed
- Which is lower as the the large surface area of the parachute increases the amount of drag at a given speed.
- Skydiver decelerates to 0 m/s when they hit the ground.

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LearnIT!
KnowIT!

Forces, Accelerations and Newton’s Laws of Motion

- Newton’s First Law
- Newton’s Second Law
- Newton’s Third Law

Newton’s First Law of Motion

If the resultant force acting on an object is zero and:

- **the object is stationary, the object remains stationary**
- **the object is moving, the object continues to move at the same speed and in the same direction. So the object continues to move at the same velocity.**

The velocity of a vehicle will only change if there is a resultant force acting upon it. If the driving and resistive forces are balanced (there is no resultant force) then the vehicle will continue with a steady velocity (speed and direction).

Inertia – Higher Tier Only

Inertia is a property of matter. It is the resistance of the object to change its motion (speed and/or direction).

Mass is a measure of the amount of inertia an object has. The more inertia (or mass) an object has the harder it is to get that object to change its motion.

To find out which of two objects has the most inertia:

- **Apply an equal force to both of them when they are at rest.**
- **The one that has the greatest acceleration has the lowest inertia – it was easier to get it to change its motion.**

Newton's Second Law of motion

The acceleration of an object is proportional to the resultant force acting on the object, and inversely proportional to the mass of the object.

In equation form, Newton's Second Law is written as:

Force (N) = Mass (kg) x Acceleration (m/s^2)

$$F = m\,a$$

Inertial mass is the ratio of force divided by acceleration.

Using F = m a

Example 1:

A motorcycle has a mass of 240 kg and accelerates at a rate of 4 m/s^2. Work out the driving force of the motorcycle.

Solution:

Using

$$F = m\,a$$
$$F = 240 \times 4$$
$$F = 960\ \text{N}$$

Using F = m a

Example 2:

**A car brakes sharply from a velocity of 30 m/s to rest in 4.2 s.
The braking force applied by the brakes was 4800 N.
Work out the mass of the car.**

Solution:

Finding the acceleration of the car:

$$\text{acceleration} = \frac{\text{change in velocity}}{\text{time taken}}$$

$$\text{acceleration} = 7.1\ \text{m/s}^2$$

Substituting gives

$$F = m\,a$$

$$4800 = m \times 7.1$$

m = 672 kg allow 676 kg if acceleration was rounded down

Newton's Third Law of motion

Whenever two objects interact, the forces they exert on each other are equal in size and opposite in direction.

Examples:

When a car crashes into a crash barrier, the force acting on the car and the force acting on the barrier are equal and opposite.

A pen falling will be pulled down by the Earth, and the Earth will be pulled up by the pen.

QuestionIT!

Forces, Accelerations and Newton's Laws of Motion

- Newton's First Law
- Newton's Second Law
- Newton's Third Law

1. Describe why a cannon ball, when fired from a cannon does not continue to move with constant velocity.

2. What is the inertia of an object a measure of?

3. State the equation commonly used for Newton's second law.

4. A car has a driving force of 1200 N and a mass of 700 kg. Calculate the acceleration of the car.

5. A skydiver has a weight of 686 N and a mass of 70 kg. Calculate the acceleration of the skydiver the moment he jumps out of the plane.

6. A motorcycle has a driving force of 1400 N and an acceleration of 6 m/s^2. Calculate the mass of the motorcycle.

7. A father and his daughter were ice skating. The father has a mass of 75 kg and his daughter has a mass of 30 kg. The father pushed his daughter and she feels a force of 50 N.
   Calculate the force on the father.

8. A car crashed into a crash barrier. The force exerted by the barrier on the car was 4500 N. Describe the force exerted by the car onto the barrier.

AnswerIT!

Forces, Accelerations and Newton's Laws of Motion

- Newton's First Law
- Newton's Second Law
- Newton's Third Law

1. **Describe why a cannon ball, when fired from a cannon does not continue to move with constant velocity.**

- Gravity acts pulling the cannon ball downwards
- So, there is a resultant force
- Objects will only continue with uniform motion when no resultant force acts.

2. **What is inertia of an object a measure of?**

   How easy, or difficult, it is to get the object to change its motion.
   The more inertia an object has the harder it is to get it to change its motion.

3. **State the equation commonly used for Newton's second law.**

   force = mass x acceleration

4. A car has an acceleration of 1.7 m/s^2 and a mass of 700 kg. Calculate the driving force of the car.

Using F = m a

force = 700 x 1.7

force = 1190 N

5. A skydiver has a weight of 686 N and a mass of 70 kg. Calculate the acceleration of the skydiver the moment he jumps out of the plane.

acceleration = force / mass

acceleration = 686 / 70

acceleration = 9.8 m/s^2

6. A motorcycle has a driving force of 1400 N and an acceleration of 6 m/s^2. Calculate the mass of the motorcycle.

mass = force / acceleration

mass = 1400 / 6

mass = 233 kg

7. A father and his daughter were ice skating.
The father has a mass of 75 kg and his daughter has a mass of 30 kg.
The father pushed his daughter and she feels a force of 50 N.
Calculate the force on the father.
50 N
From Newton's third law: whenever two objects interact, the forces they exert on each other are equal in size and opposite in direction.

8. A car crashed into a crash barrier. The force exerted by the barrier on the car was 4500 N. Describe the force exerted by the car onto the barrier.
The force exerted by the car onto the barrier is 4500 N.
From Newton's third law: whenever two objects interact, the forces they exert on each other are equal in size and opposite in direction.

LearnIT!
KnowIT!

Forces and Braking

- Stopping Distance
- Reaction Time
- Factors Affecting Braking Distance 1
- Factors Affecting Braking Distance 2

Definitions

Stopping Distance

Thinking Distance: **Thinking distance is the distance that you travel while reacting to a stimulus until you get your foot onto the brake pedal. Thinking distance depends on reaction time, but these are not the same thing.**

Braking Distance: **Braking distance is the distance you travel from pressing the brake pedal until you come to a stop.**

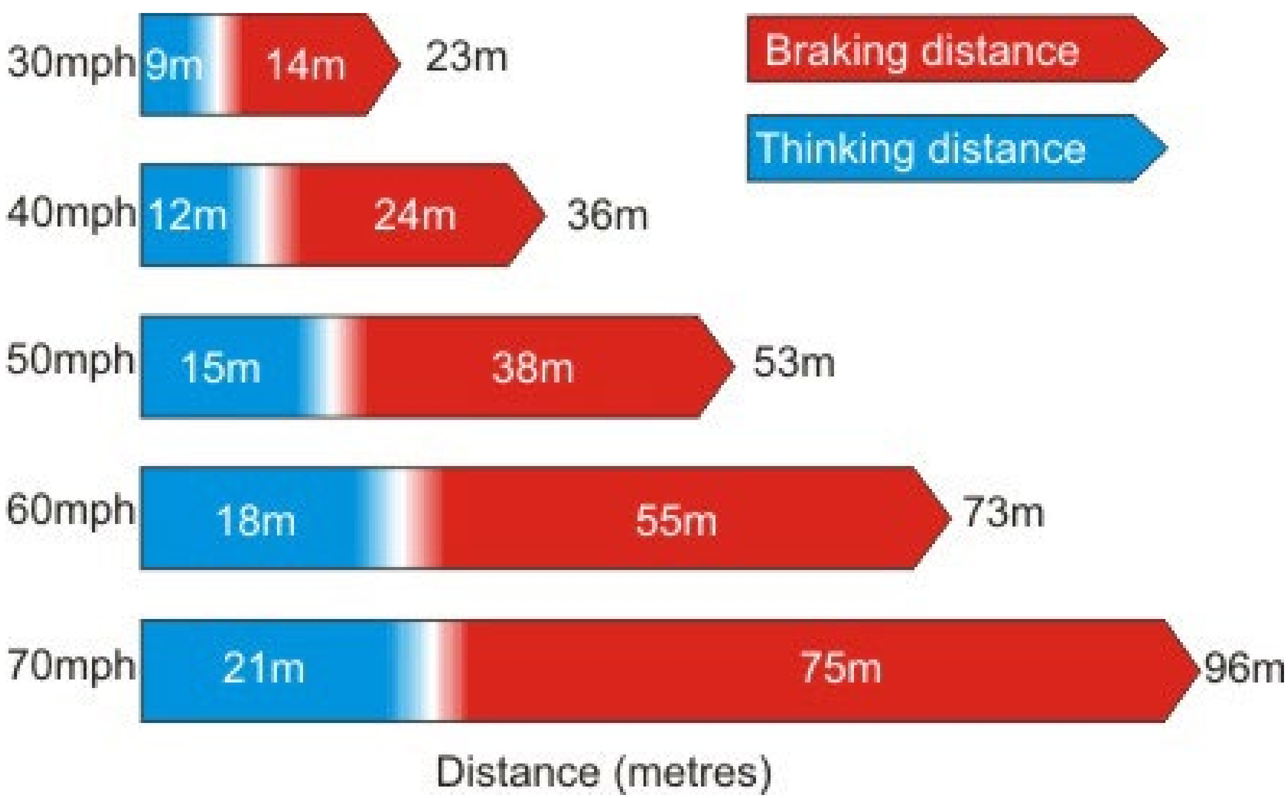
Stopping Distance: **Stopping distance is the sum of thinking distance and braking distance, usually shown as:**

Stopping distance = Thinking distance + Braking distance

How Speed Affects Stopping Distance

Increasing the speed of a vehicle will increase its stopping distance.

The highway code shows the stopping distances for cars at various speeds…



As you can see, when speed increases so does the overall stopping distance.

Also, it is both parts of the overall stopping distance – thinking and braking distance – that increases.

Speed and Thinking Distance

From the highway code it is possible to see patterns in the data.

When you double your speed your thinking distance will also double. This is shown by the thinking distance being 9 m at 30 mph and 18 m at 60 mph. The reason this happens is because your reaction time does not change but you will now travel further while you react:

If you take 0.5 seconds to react then at a speed of 10 m/s you would travel 5 m while reacting to a stimulus. If the speed doubled to 20 m/s then you would now travel 10 m while reacting to the stimulus – the thinking distance has doubled when the speed has doubled.

Speed and Braking Distance

Doubling your speed will more than double your braking distance. In fact doubling the speed of a vehicle will cause the braking distance to quadruple.

At 30 mph the braking distance is 14 m and at 60 mph the braking distance is 55 m (according to the highway code) which is approximately four times greater: The difference of 1 m is accounted for by rounding.

When the speed of a vehicle doubles the kinetic energy of the vehicle is four times greater. This happens because kinetic energy is found using the equation:

$$\text{kinetic energy} = \tfrac{1}{2} \times \text{mass} \times (\text{velocity})^2$$

As there is four times the kinetic energy it takes four times longer to stop at a given braking force.

Reaction Time

A typical person's reaction time varies from 0.2 to 0.9 seconds.

There are a number of factors that will affect your reaction time, and in turn thinking distance.

These factors include:

Factor	Affect on Reaction Time
Alcohol	Increases
Caffeine	Decreases
Tiredness	Increases
Distractions	Increases

Drugs can either increase or decrease reaction times as some drugs are stimulants and some are depressants.

Measuring Reaction Time

A person's reaction time is very short. Trying to measure this reaction time is going to be difficult but there are ways of measuring it.

1. **There are online tests that display a stimulus and measures the time taken to respond to the stimulus – often by clicking a mouse button.**

2. **Ruler drop. This is where a ruler is dropped through your hand. As soon as you see the ruler move you close your hand. The distance that the ruler moves through your hand corresponds to a given reaction time - these can be found online at:**

http://www.topendsports.com/testing/tests/reaction-stick.htm

Factors Affecting Braking Distance

There are a number of factors that affect the braking distance of a vehicle. Some of these are shown in the table below:

Factor Affecting Braking Distance	How this factor affects braking distance
Speed	Increasing speed increases braking distance
Weight of Vehicle	Increasing weight of vehicle increases braking distance
Icy Roads	Braking distance increases due to reduced friction between tyre and road
Wet Roads	Braking distance increases due to reduced friction between tyre and road
Poor Brake Condition	Braking distance increases
Bald Tyres	Braking distance increases when wet.

Braking Force

When a force is applied to the brakes of a vehicle, work done by the frictional forces between the brake pads and the brake disc reduces the kinetic energy of the vehicle and the temperature of the brakes increases.

The greater the speed of a vehicle the greater the braking force needed to stop the vehicle in a certain distance.

The greater the braking force the greater the deceleration of the vehicle. Large decelerations may lead to brakes overheating and/or loss of control.

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QuestionIT!

Forces and Braking

- Stopping Distance
- Reaction Time
- Factors Affecting Braking Distance 1
- Factors Affecting Braking Distance 2

1. Define thinking distance.

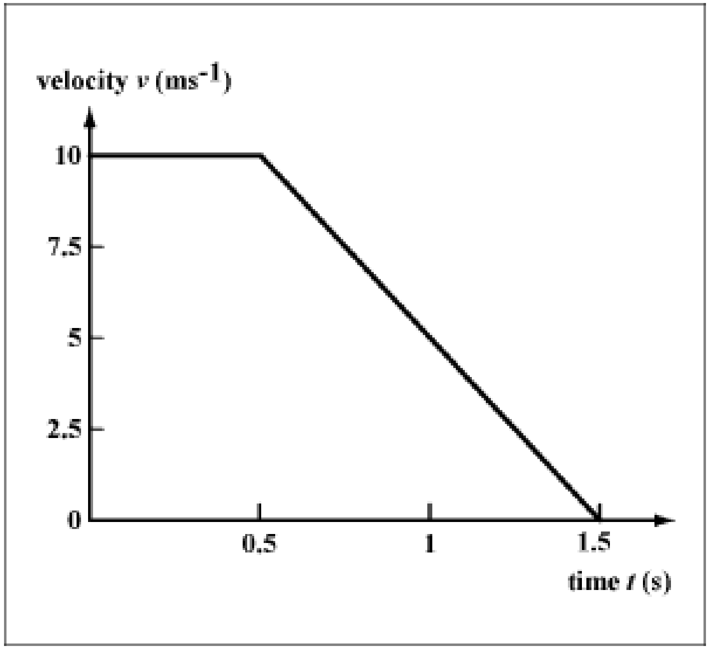
2. Complete the equation:

Stopping distance = ……………………………… + ………………………………..

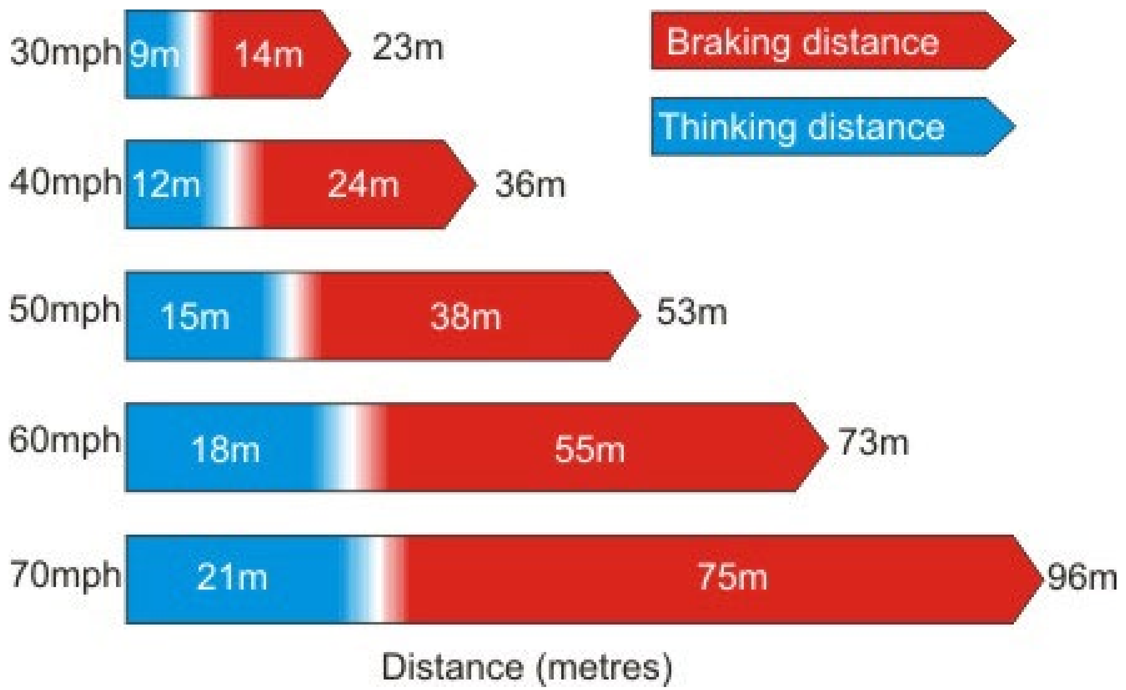
3. Describe how the speed of a vehicle affects the thinking distance.

4. A driver sees a car braking sharply in front of him. The driver takes 0.5 s to react to the stimulus and then brakes. Figure 1 shows the velocity-time graph for the motion of the vehicle from seeing the stimulus to stopping. Calculate the stopping distance of the vehicle.

Figure 1



5. The highway code shows the stopping distances for vehicles up to 70 mph. In 2011 the government proposed a new 80 mph speed limit for UK motorways.
Use the information in the diagram, and your own knowledge, to determine the overall stopping distance of a vehicle at 80 mph.



6. Describe how you could measure the reaction time of a person.

7. Explain the dangers caused by large decelerations of a vehicle.

8. Put the following factors under the correct headings to show whether the factor affects thinking distance, braking distance or both thinking and braking distance.

Speed Mass Icy roads Tiredness

Poor brakes Mobile Phone use Alcohol Bald tyres

Thinking Distance	Braking Distance	Both

AnswerIT!

Forces and Braking

- Stopping Distance
- Reaction Time
- Factors Affecting Braking Distance 1
- Factors Affecting Braking Distance 2

1. **Define thinking distance.**
   The distance travelled while the driver reacts to a stimulus until the driver gets their foot onto the brake pedal (but before the brake pedal is pressed).

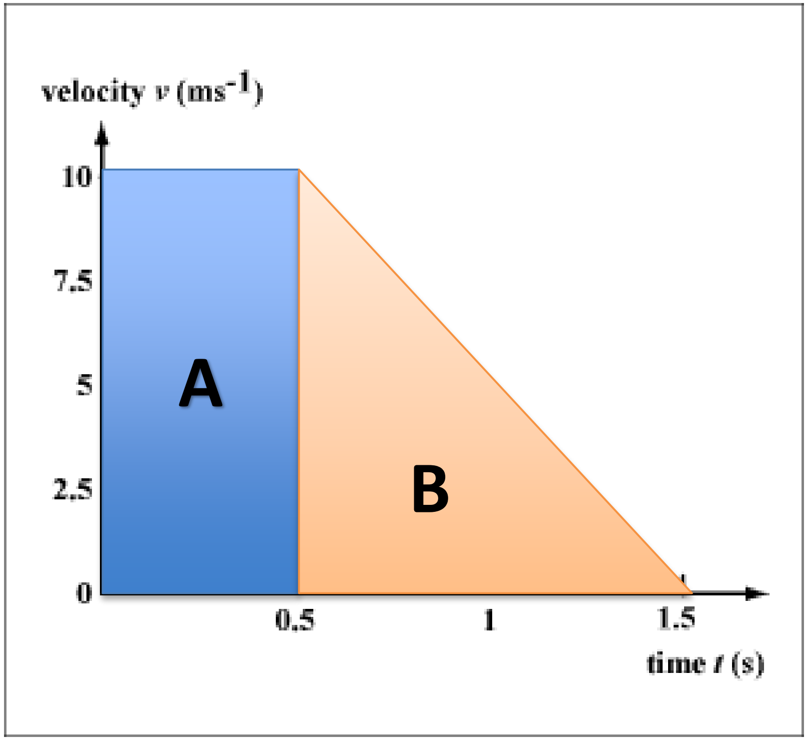
2. **Complete the equation:**

   stopping distance = thinking distance + braking distance

3. **Describe how the speed of a vehicle affects the thinking distance.**
   Increasing speed increases thinking distance
   Doubling your speed doubles the thinking distance.

4. A driver sees a car braking sharply in front of him. The driver takes 0.5 s to react to the stimulus and then brakes. Figure 1 shows the velocity-time graph for the motion of the vehicle from seeing the stimulus to stopping. Calculate the stopping distance of the vehicle.

Figure 1



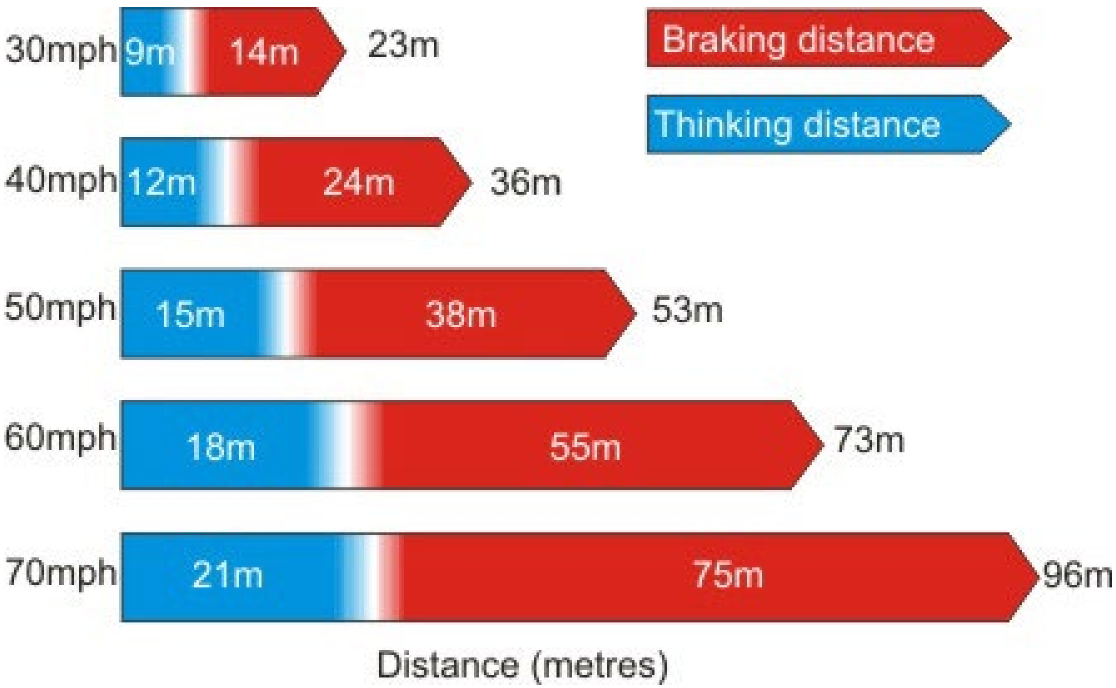
stopping distance = area under line

stopping distance = Area A + Area B

stopping distance = 5 + 5

stopping distance = 10 m

5. **The highway code shows the stopping distances for vehicles up to 70 mph. In 2011 the government proposed a new 80 mph speed limit for UK motorways. Use the information in the diagram, and your own knowledge, to determine the overall stopping distance of a vehicle at 80 mph.**



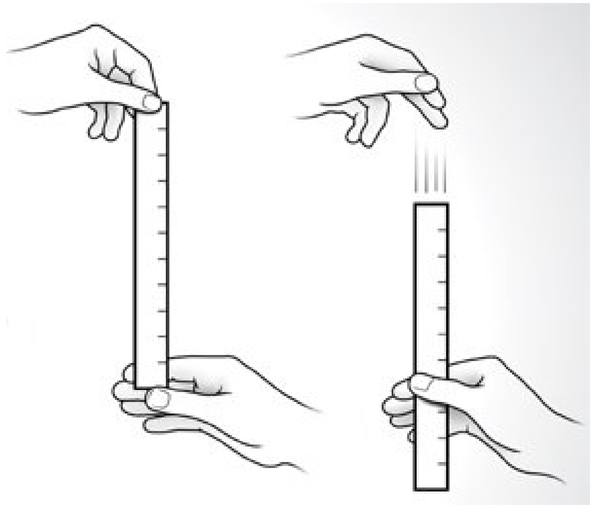
When speed doubles thinking distance doubles and braking distance quadruples. So,

At 80 mph:

Thinking distance = 24 m
Braking distance = 96 m
Stopping distance = 120 m

6. Describe how you could measure the reaction time of a person.

- Get the person to stand with their hand open
- Place a ruler at the top a the person's hand
- Drop the ruler through their hand
- When the person sees the ruler move they need to close their hand
- The distance the ruler travels corresponds to the thinking distance



6. Explain the dangers caused by large decelerations of a vehicle.

- Large decelerations can cause the brakes to overheat and become less effective
- Large decelerations can also cause a loss of control
- Large decelerations can also exert large forces of people within a vehicle.

8. Put the following factors under the correct headings to show whether the factor affects think distance, braking distance or both thinking and braking distance.

Speed Mass Icy roads Tiredness

Poor brakes Mobile Phone use Alcohol Bald tyres

Thinking Distance	Braking Distance	Both
Tiredness	Mass	Speed
Mobile Phone use	Icy roads	
Alcohol	Poor brakes	
	Bald tyres	

LearnIT!
KnowIT!

Momentum (HT Only)

- Momentum is a Property of Moving Objects
- Conservation of Momentum
- Changes in Momentum (Physics Only)

Momentum

Momentum is a vector quantity.

The momentum of an object only depends on it's mass and it's velocity.

The equation linking momentum, mass and velocity is:

Momentum (kg m/s) = Mass (kg) x Velocity (m/s)

$$p = m\,v$$

From this equation we can see that if an object is not moving (it has a velocity of 0 m/s) then it has no momentum.

Conservation of Momentum: Crashes

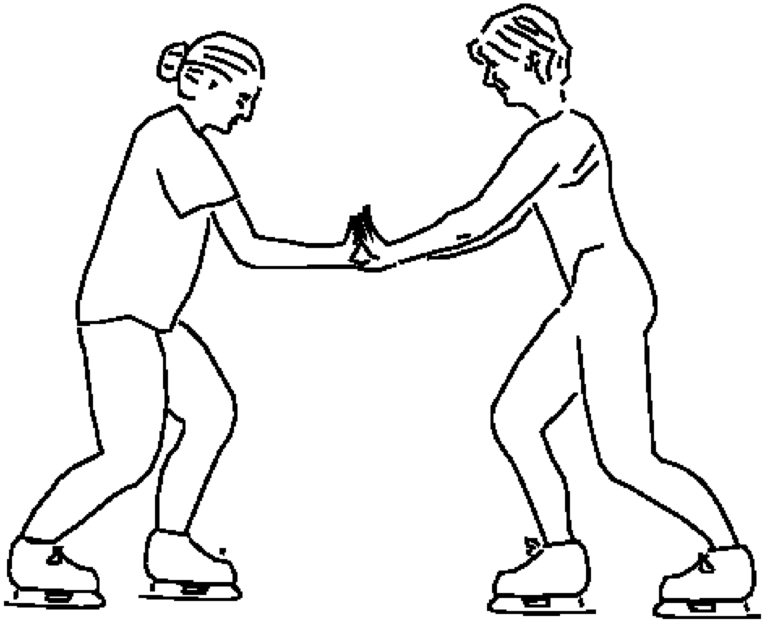
Momentum is a conserved quantity. The momentum of a system remains the same before and after an event.

e.g. In a car crash the momentum of the vehicles before the crash equals the momentum of the vehicles after the crash.

Conservation of Momentum: Explosive Events

In an explosion the momentum of the system is also conserved. This may seem strange as everything is stationary to begin with, but after the explosion parts are moving to the left and right and these cancel – since velocity is a vector and depends on direction.

An example of an explosive event is two ice skaters pushing themselves apart, where the momentum of each ice skater is equal in size and opposite in direction to the other. This then adds to be 0 kgm/s, which is what it was at the start.



Changes in Momentum

The force acting on an object is usually found using the equation F = m a.

However, as the acceleration of an object is found using the equation:

$$\text{Acceleration } (m/s^2) = \frac{\text{Change in speed (m/s)}}{\text{Time taken (s)}}$$

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

Combining the two equations gives:

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

The quantity $m\Delta v$ is the change in momentum of an object.
So, force is the rate of change of momentum.

Changes in Momentum: Safety Features

Cars have air bags to reduce the injuries caused in a crash.

Air bags work by increasing the time of impact – it takes a person's head longer to come to a stop (compared to hitting the steering wheel).

As the time of impact increases the force acting on the person's head decreases since:

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

Changes in Momentum: Safety Features continued…

Seatbelts also increase the time it takes a person to stop.

By increasing the time it takes to stop the force acting is reduced as,

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

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QuestionIT!

Momentum (HT Only)

- Momentum is a Property of Moving Objects
- Conservation of Momentum
- Changes in Momentum (Physics Only)

Momentum - QuestionIT

1. State the units of momentum.

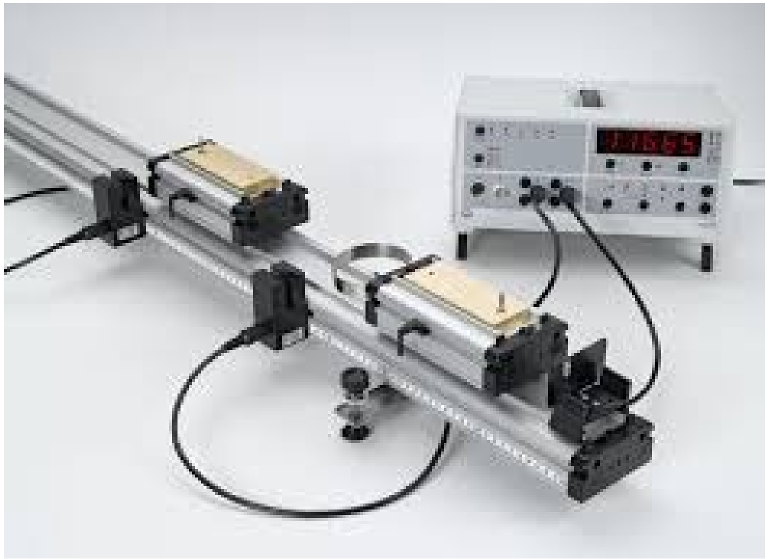
2. State the equation that links mass, momentum and velocity.

3. Momentum is a conserved quantity.
   Explain what is meant by a conserved quantity.

4. A football has a mass of 0.75 kg and is kicked with a speed of 12 m/s.
   Calculate the momentum of the kicked football.

5. Two ice skaters push themselves apart on the ice.
   Explain how the conservation of momentum applies in this case.

6. A trolley has a mass of 1.2 kg and a speed of 4.5 m/s. The trolley crashes into a stationary trolley of mass 0.8 kg. On impact the two trolley's stick together and move off with speed, v.



a. Calculate the momentum of the trolleys before impact.

b. Calculate the speed of the trolleys after impact.

7. A gymnast falls onto a crash mat. The crash mat reduces the risk of injury to the gymnast.
   Explain how the crash mat reduces injury.

8. A car of mass 850 kg hits a crash barrier at a speed of 30 m/s.
   The car stops in 0.1 s. Calculate the force on the car.

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AnswerIT!

Momentum (HT Only)

- Momentum is a Property of Moving Objects
- Conservation of Momentum
- Changes in Momentum (Physics Only)

1. State the units of momentum.
   kgm/s

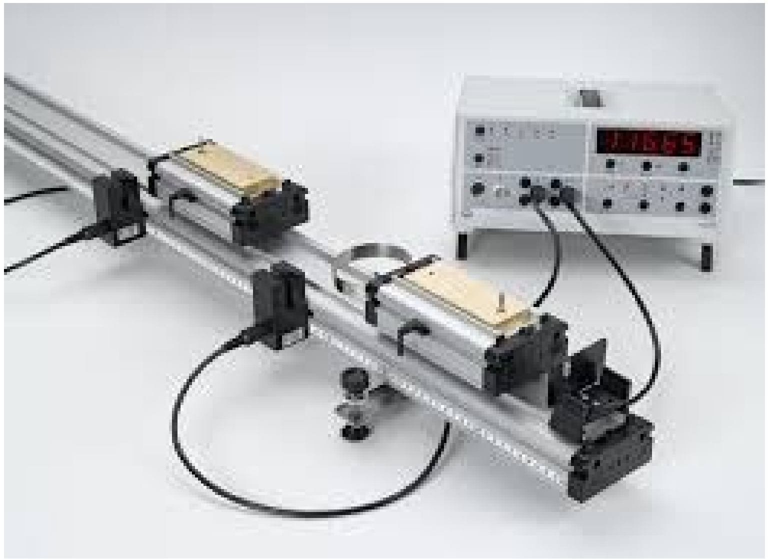
2. State the equation that links mass, momentum and velocity.
   Momentum = mass x velocity

3. Momentum is a conserved quantity.
   Explain what is meant by a conserved quantity.
   The momentum before and after an event is equal in a closed system

4. **A football has a mass of 0.75 kg and is kicked with a speed of 12 m/s. Calculate the momentum of the kicked football.**
   Using momentum = mass x velocity
   Momentum = 0.75 x 12
   Momentum = 9 kgm/s

5. **Two ice skaters push themselves apart on the ice. Explain how the conservation of momentum applies in this case.**
   The momentum before pushing is 0 kgm/s as they are not moving
   On pushing apart the momentum of each ice skater is the same size but in the opposite direction
   When adding (vector addition) of the momentum of the two ice skaters sum is also 0 kgm/s
   So momentum is conserved.

6. A trolley has a mass of 1.2 kg and a speed of 4.5 m/s. The trolley crashes into a stationary trolley of mass 0.8 kg. On impact the two trolley's stick together and move off with speed, v.



a. Calculate the momentum of the trolleys before impact.

Using momentum = mass x velocity
momentum = 1.2 x 4.5
momentum = 5.4 kgm/s

b. Calculate the speed of the trolleys after impact.

Using conservation of momentum; Momentum before = Momentum after
5.4 = mass$_{after}$ x velocity$_{after}$
velocity$_{after}$ = 5.4 / 2 = 2.7 m/s

7. A gymnast falls onto a crash mat. The crash mat reduces the risk of injury to the gymnast.

   Explain how the crash mat reduces injury.

   The crash mat increases the time taken to come to a stop

   This decreases the acceleration

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

   This reduces the force acting on the gymnast

8. A car of mass 850 kg hits a crash barrier at a speed of 30 m/s. The car stops in 0.4 s. Calculate the force on the car.

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

   $F = 850 \times \frac{30}{0.4}$

   $F = 63\ 750$ N