Dynamics and Space
National 5 Physics

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Velocity and Displacement

Vectors and Scalars

A **scalar** quantity is a quantity which is specified by magnitude or size alone.
A **vector** quantity is a quantity which is specified by magnitude or size but will also have a direction.

For example, speed is a scalar quantity which has magnitude only e.g a car can be travelling at 5 m s^{-1}. Velocity is a vector quantity which has both magnitude and direction e.g. a car can be travelling at 5 m s^{-1} due north.

The table below shows a list of common vector and scalar quantities.

Scalar quantities	***Vector Quantities***
Speed	Velocity
Distance	Displacement
Temperature	Acceleration
Mass	Force
Energy	Weight
Time	

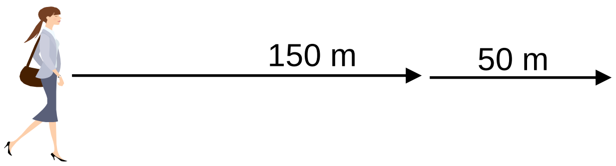
Some scalar quantities have equivalent vector quantities. Velocity is the vector equivalent of speed i.e. a velocity has magnitude in a particular direction while speed has no associated direction.

Displacement is the vector equivalent of distance i.e. a displacement has direction whilst distance has not.

Adding Vectors

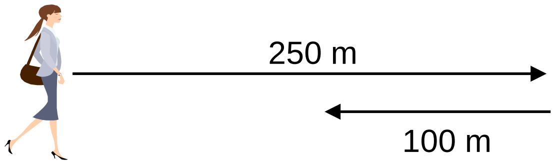
If vectors are in the same direction then they are simply added together.

For example, a woman walks 150 m to the right followed by another 50 m to the right. Her total displacement is 200 m to the right.



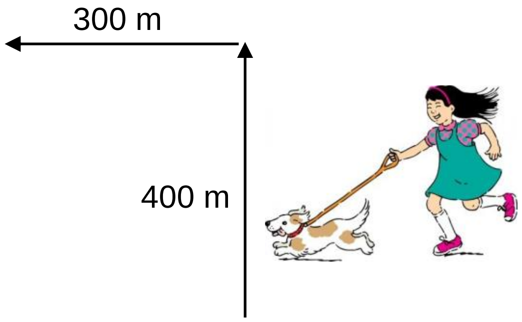
If vectors are in the opposite direction then they are subtracted, one from the other.

For example, a woman walks 250 m to the right followed by 100 m to the left. Her total displacement is 150 m to the right.



Sometimes vectors will be at right angles to one another. In this case they have to be added using either trigonometry or by scale drawing. It does not matter which method you use, both are acceptable so use whichever method you find easiest.

A vector is represented by an arrow with the arrowhead pointing in the direction of the vector. Here is an example. A girl takes her dog for a walk by walking 400 m north followed by 300 m west. The sum of these two displacements is called the resultant displacement

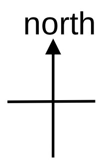


Finding the resultant of two forces using a scale drawing

Using the example above find the resultant displacement by scale drawing. Here are the steps in finding the answer.

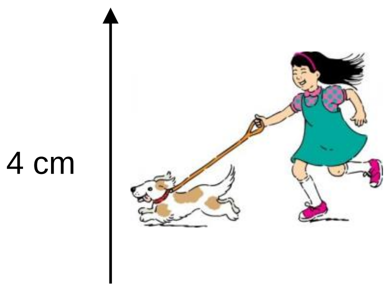
1. Decide on a suitable scale and write this down at the start of the answer. If appropriate write down the direction you take as forwards, north etc.

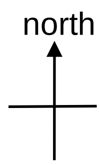
   Let 1 cm = 100 m



2. Draw an arrow to represent the first vector ensuring that it is the correct size and in the correct direction.

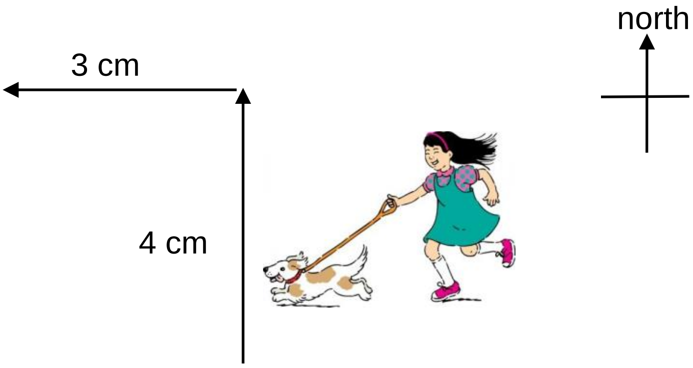
   Let 1 cm = 100 m





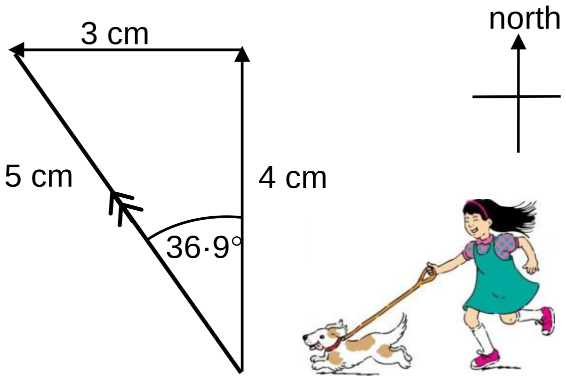
3. Draw a second arrow to represent the second vector starting at the head of the first vector. **Vectors must always be added head to tail.** Continue until all the vectors have been drawn.

Let 1 cm = 100 m



4. The resultant vector is now found by drawing it from the tail of the first vector to the head of the last vector. The resultant vector can be distinguished from other vectors by drawing a double arrow on it. The magnitude and direction of this vector is the required answer. These are found by measuring the line using a ruler and finding the angle with a protractor. In this example the girl's resultant displacement is 500 m at an angle of 36·9° west of north.

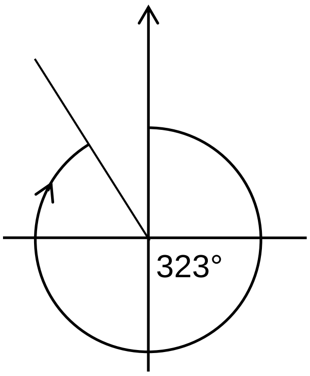
Let 1 cm = 100 m



5. The resultant is 5 cm long which means the displacement is 500 m. When quoting the final answer always ensure you clearly state the magnitude and direction of the resultant.

Resultant displacement of the girl is 500 m at an angle of 36·9° to the west of north.

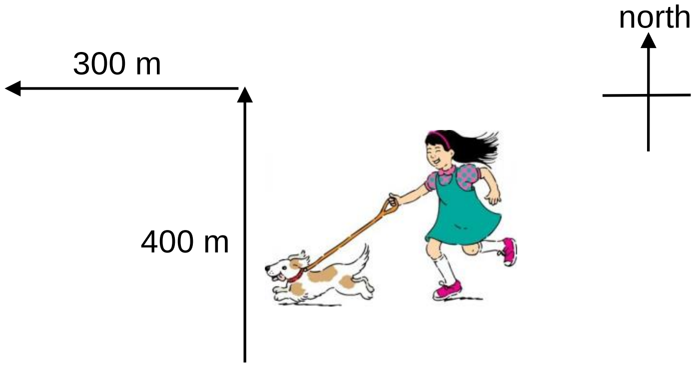
It is also possible to quote the direction as a bearing. If North is regarded as 000° and the bearing of the resultant displacement is 323°.



Finding the Resultant using Trigonometry

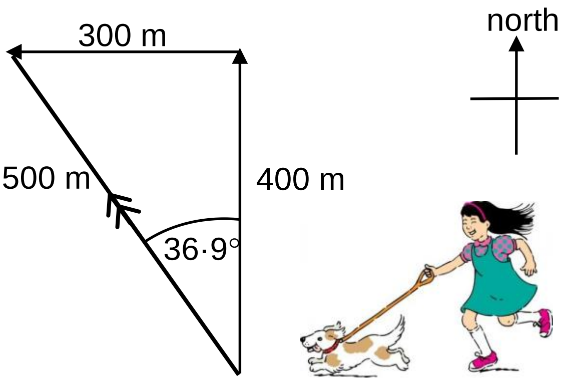
When you are dealing with two vectors at right angles, the resultant can be found using Pythagoras' theorem and one of the three trigonometric ratios (sine, cosine and tangent).

Consider the problem involving the girl and her dog described previously. Always sketch the situation first so that you know what the approximate answer will be.



The magnitude of the resultant of the two vectors is found by using Pythagoras' theorem.

$$\text{resultant velocity} = \sqrt{300^2 + 400^2}$$
$$= \sqrt{250\,000}$$
$$= 500\,\text{m}$$



The direction is found using a trigonometric function i.e.

$$\sin\theta = \frac{\text{opposite}}{\text{hypotenuse}} \qquad \cos\theta = \frac{\text{adjacent}}{\text{hypotenuse}} \qquad \tan\theta = \frac{\text{opposite}}{\text{adjacent}}$$

$$\sin\theta = \frac{300}{500} \quad \text{or} \quad \cos\theta = \frac{400}{500} \quad \text{or} \quad \tan\theta = \frac{300}{400}$$

$$\theta = \sin^{-1} 0{\cdot}6 \qquad \theta = \cos^{-1} 0{\cdot}8 \qquad \theta = \tan^{-1} 0{\cdot}75$$

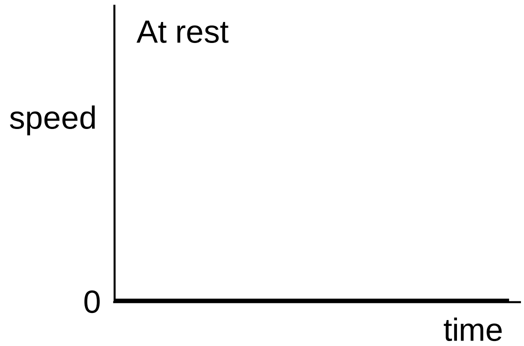
$$\theta = 36{\cdot}9° \qquad \theta = 36{\cdot}9° \qquad \theta = 36{\cdot}9°$$

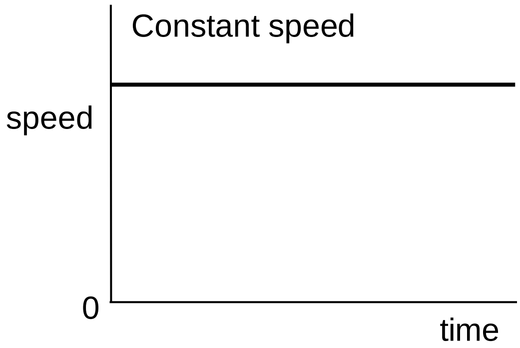
Displacement of the girl and dog is 500 m at an angle of 36·9° west of north.

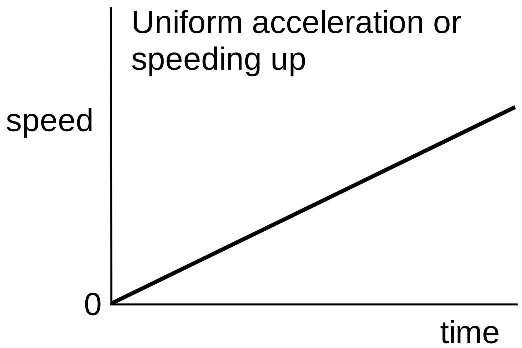
The above methods can be applied to any two vectors you want to add, whether they are displacements, velocity or some other vector.

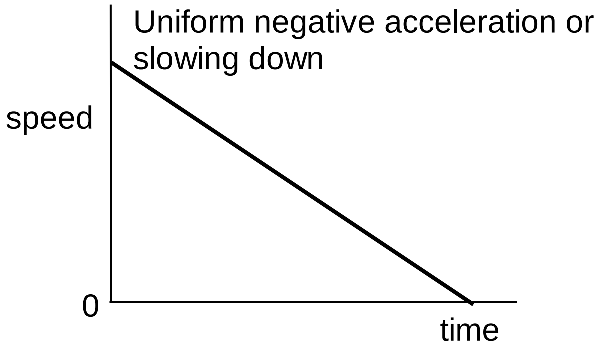
Speed-Time Graphs

Speed-time graphs can provide information about the motion of an object. The graphs below demonstrate the shape obtained for different types of motion.

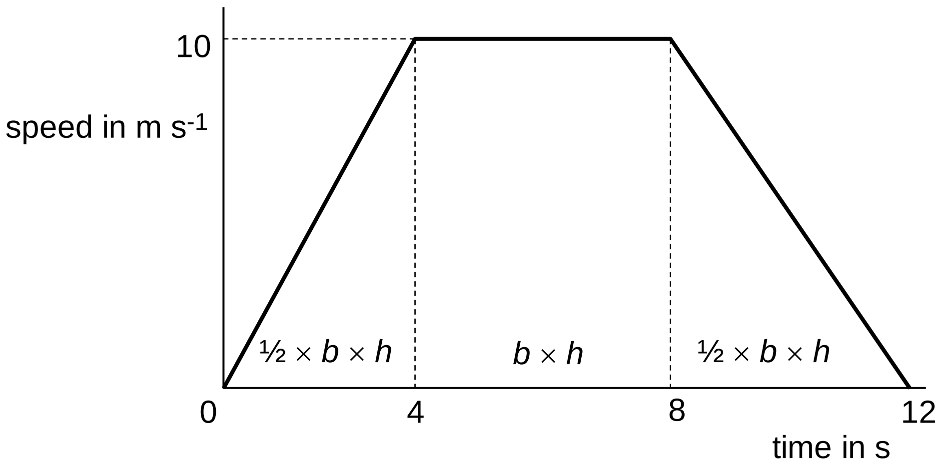








A speed time graph can tell us how far an object has travelled. The distance travelled is equal to the area under the graph. The graph can be split into sections and the area of each calculated. The sum of these is equal to the distance travelled.



Total area = (½ × 4 × 10) + (4 × 10) + (½ × 4 × 10) = 80 m

Average and Instantaneous speeds

Speed is calculated by dividing the distance travelled by the time taken. Measured over a long distance or long time, the speed calculated is an average speed.

The average speed can be found using the formula:

$$\text{average speed} = \frac{\text{distance travelled}}{\text{time taken}} \qquad v = \frac{d}{t}$$

where v = final speed measured in metres per second (m s^{-1})
d = distance measured in metres (m)
t = time measured in seconds (s)

Worked example

A car travels from Aberdeen to Stonehaven, a distance of 24 km. Calculate the average speed of the car in m s^{-1} if it takes 15 minutes to complete the journey.

$$v = \frac{d}{t}$$

$$v = \frac{24000}{15 \times 60}$$

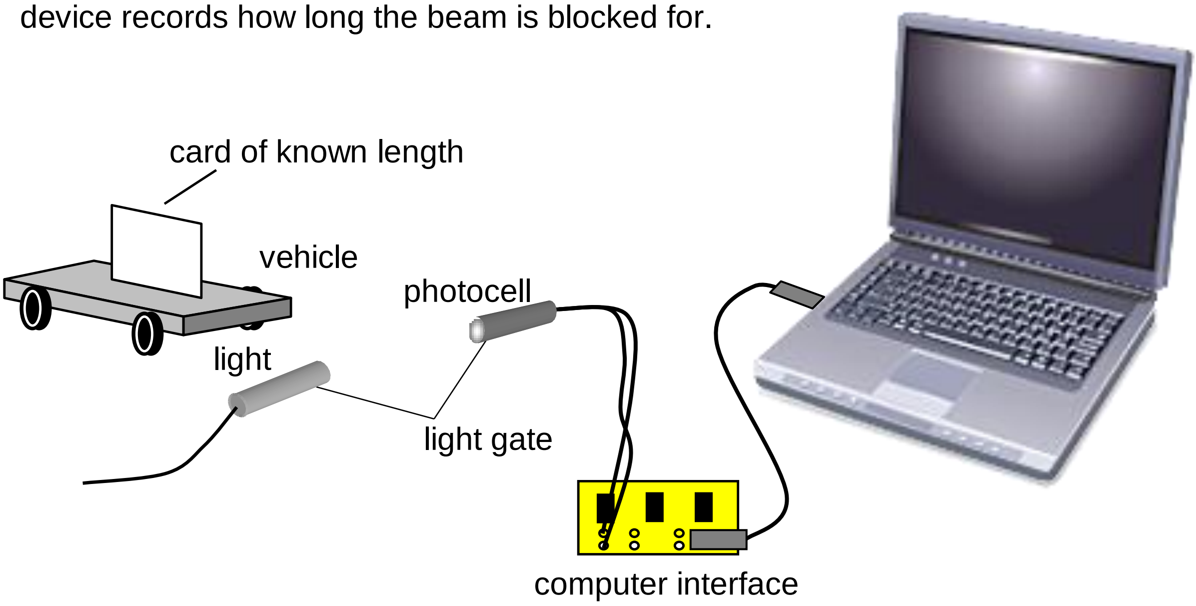
$$v = 26 \cdot 7 \text{ m s}^{-1}$$

The instantaneous speed of a vehicle is measured over very short distances or time intervals. In a car, the speedometer indicates the instantaneous speed.

Electronic methods of measuring instantaneous speed can be used in the laboratory. This is done with an electronic timer or computer connected to light gates.

Using Light Gates to Measure Speed

A light gate consists of a light source and a photocell. The photocell is connected to an electronic timing device or a computer. The timing device is triggered by the light beam falling on the photocell being blocked by a card or similar. The timing device records how long the beam is blocked for.



The instantaneous speed can then be found using the formula:

$$\text{instantaneous speed} = \frac{\text{length of card}}{\text{time beam is blocked}}$$

Acceleration

Acceleration is a measure of the rate at which something increases or decreases its speed. (something slowing down is said to have negative acceleration).
Definition:- acceleration is the change in velocity per unit time.
Acceleration can be calculated using the formula below.

$$\text{acceleration} = \frac{\text{final velocity - initial velocity}}{\text{time taken for change}} \quad \text{or} \quad a = \frac{v - u}{t}$$

where a = acceleration measured in metres per second per second (m s^{-2})
v = final velocity measured in metres per second (m s^{-1})
u = initial velocity measured in metres per second (m s^{-1})
t = time measured in seconds (s)

Worked example

A cheetah can accelerate from rest to 24 m s⁻¹ in 3 s. Calculate its acceleration.

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

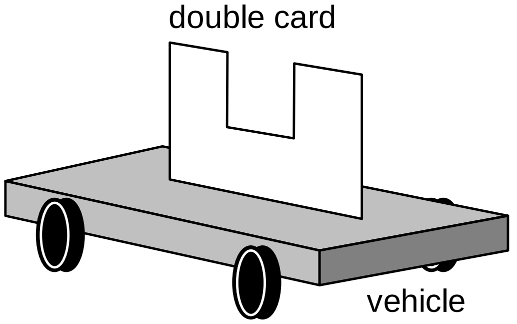
$$a = \frac{24 - 0}{3}$$

$$a = 8\,\text{m s}^{-2}$$

Using Light Gates to Measure Acceleration

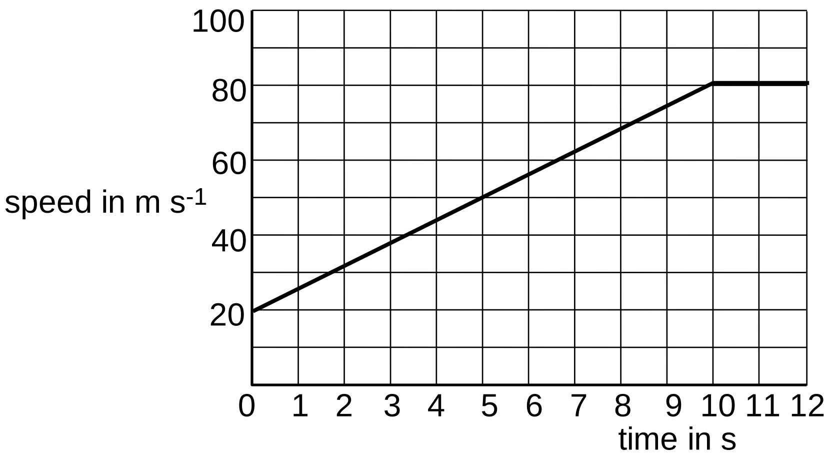
Just as light gates can be used to measure speed, light gates can be used to measure acceleration also.

To calculate acceleration you need to know an initial velocity and a final velocity. This is achieved by using a double card. The same effect can also be achieved by using a single card and two light gates.



Measuring Acceleration from Speed-Time Graphs
Information can be obtained from a speed-time graph which allows acceleration to be calculated.

Worked example
A car accelerates from 20 m s^{-1} to 80 m s^{-1} in a time of 10 s as shown in the graph below. Calculate its acceleration between 0 s and 10 s.



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

$$a = \frac{80 - 20}{10}$$

$$a = 6\,\text{m s}^{-2}$$

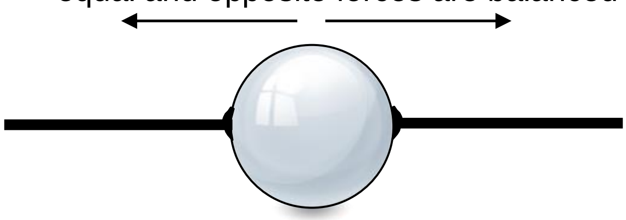
Newton's Laws

Force is measured in newtons. When a force is applied to an object it can change its shape, its speed or its direction of travel.

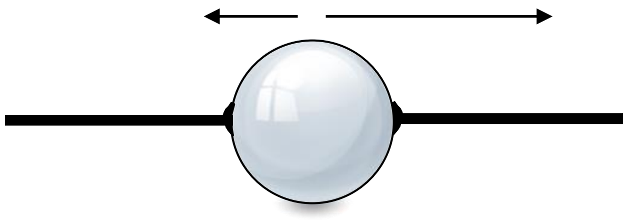
When forces are applied to an object they can either be balanced or unbalanced.

In a situation where the forces are balanced there are either no forces acting on the object or the forces that are acting, cancel each other out. Remember that force is a vector quantity with both direction and magnitude.

equal and opposite forces are balanced



In a situation where the forces are unbalanced there will be a net or resultant force acting on the object.



Sir Isaac Newton summarised the effect of forces in his three Laws of Motion.

Newton's First Law of Motion states:

"An object at rest will remain at rest unless acted on by an unbalanced force. An object in motion continues in motion with the same speed and in the same direction unless acted upon by an unbalanced force."

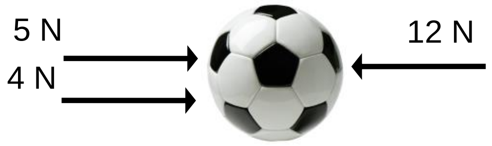
In simple terms, this means that:

if the forces acting on a stationary object are all balanced the object remains at rest;

if the forces acting on a moving object are all balanced the object will continue to move at a steady speed in a straight line;

if the forces acting on an object are unbalanced the object will accelerate in the direction of the unbalanced force.

Worked example
Calculate the resultant force acting on the football and describe its motion as a result.



Total force to the right = 9 N. Total force to the left = 12 N.
Resultant force = 3 N to the left.

Newton's Second Law of Motion states:

"The acceleration of an object is dependent upon two variables – the net force acting upon the object and the mass of the object. The acceleration of an object depends directly upon the net force and inversely upon the mass of the object. The relationship between an object's mass m, its acceleration a, and the applied force F is:

$$F = m \times a.$$

If there are more than two forces acting on an object, it is important that it is the net unbalanced force that is used in the calculation. Using the equation below can help you to remember this.

$$F_{un} = m \times a.$$

where F_{un} = unbalanced force measured in newtons (N)
m = mass measured in kilograms (kg)
a = acceleration measured in metres per second per second (m s^{-2})

In simple terms this means that if an object is acted on by an unbalanced force it will accelerate. The amount of acceleration increases as the force increases. However if you apply the same force to a larger mass the acceleration will be less.

Worked example
A cyclist pedals to produce a forward force of 200 N. The forces of friction acting on the cyclist are 60 N.

(a) *Find the resultant force acting on the cyclist.*

(b) *Calculate the acceleration of the cyclist if he has a mass of 70 kg.*

(*a*) Resultant force = 200 – 60 = 140 N.

(*b*)

$$F = m \times a$$
$$140 = 70 \times a$$
$$a = \frac{140}{70}$$
$$a = 2\,\text{m s}^{-2}$$

Work Done, Force and Distance
Work takes place when an object is moved by a force, the force transferring energy to the object.

If an archer pulls back the string on a bow and arrow, the work done on stretching the string and bow will be transferred to the arrow when it is fired.

The work done by a weightlifter in applying an unbalanced upward force to the weights is transferred into the potential energy they gain.

When work is done against friction the energy will be transferred into heat.

Work can be calculated using the formula below.

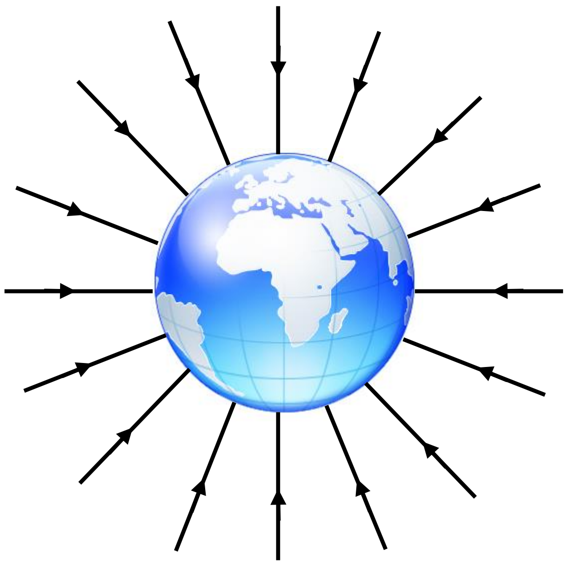
work = force $\times$ distance in direction of force $\quad E_w = F\,d$

where E_w = work measured in joules (J)
F = force measured in newtons (N)
d = distance measured in metres (m)

Worked example
A wheelbarrow is pushed a distance of 20 m by applying a force of 50 N. Calculate the work transferred.

Work = force $\times$ distance
$E_w = F\,d$
$E_w = 50 \times 20$
$= 1000$ J

Weight and Gravity
A gravitational field exists around the Earth as shown opposite. It acts on any mass to attract it towards the Earth.



The downwards force per kilogram is called the gravitational field strength and is 9·8 N kg^{-1} on Earth.

Note that mass is defined as the amount of matter in a body and is measured in kilograms.

Weight is the force with which the Earth's gravity pulls an object downwards and, as it is a force, is measured in newtons.

Weight = mass × gravitational field strength or $W = m\,g$

where W = weight and is measured in newtons (N)
m = mass measured in kilograms (kg)
g = gravitational field strength and is 9·8 N kg^{-1} on Earth

Worked example
A pupil has a mass of 50 kg. Calculate her weight.

weight = mass × gravitational field strength

$W = m\,g$

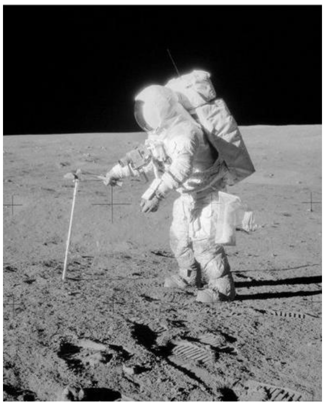
$W = 50 \times 9{\cdot}8$

$= 490$ N

The value of gravitational field strength (g) varies from planet to planet. Whilst the mass of objects will not vary, their weight will, depending upon where the object is.
Definition:- Gravitational field strength is the force per unit mass.
The table below shows values of g for the moon and different planets.

Planet	***Gravitational field strength (N kg^{-1})***
Moon	1·6
Mercury	3·7
Venus	8·9
Earth	9·8
Mars	3·7
Jupiter	26
Saturn	11·2
Uranus	9·0
Neptune	11·3

Worked example
A hammer has a mass of 1·2 kg. Calculate the weight of the hammer on the moon.



$W = m\,g$

$W = 1{\cdot}2 \times 1{\cdot}6$

$= 1{\cdot}92$ N

Newton's Laws and Space Flight

Sir Isaac Newton's Third Law of Motion states:
"For every action force there is an equal and opposite reaction force."

This statement means that forces always exist in pairs. There are many practical examples of this.

- If two ice skaters stand opposite each other and one pushes the other, they both move backwards.
- When a gun is fired there is a force pushing the bullet out of the muzzle but an equal and opposite force pushing the gun backwards (called the recoil).
- When the space shuttle rockets are fired the hot gases are forced out backwards. This causes an equal and opposite force propelling the shuttle forwards.

When a rocket is launched it will accelerate upwards due to the thrust from its engines. As it uses up fuel the rockets will continue to produce the same upwards thrust but the force is acting on a smaller and smaller mass. As a result, the acceleration of the rocket increases.

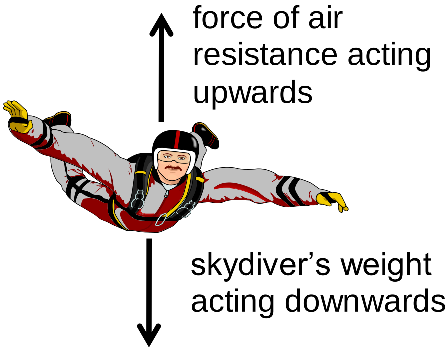
As it climbs upwards, the gravitational field strength decreases. This means that the weight of the shuttle which is a downwards force acting against its movement, gets less and less. At the same time the atmosphere, which produces air resistance acting against the shuttles movement, gets less and less. Both of these factors also contribute to a greater unbalanced upwards force and so greater acceleration.

Once the rocket has escaped from the pull of the Earth's gravity the rockets can be switched off and it will continue at the same speed as there are now no forces acting against its motion.

Free Fall and Terminal Velocity

When a skydiver jumps out of a plane they accelerate downwards due to the force of gravity. As their speed increases the force of friction due to air resistance gets greater and greater. Eventually the weight and friction reach a point where they are equal.

There are now no unbalanced forces acting on the skydiver so, by Newton's Second Law, they continue downwards at a steady speed. They are said to have reached their terminal velocity.



Projectiles

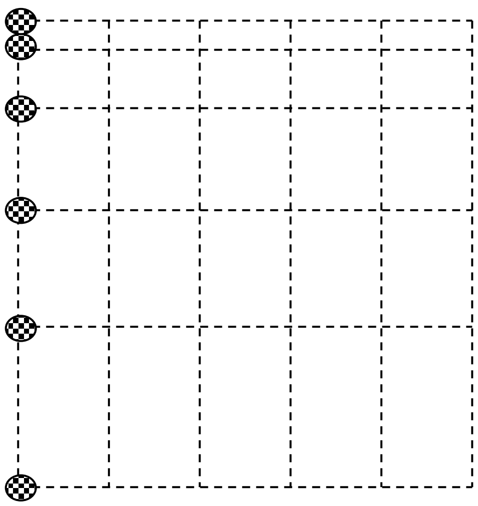
A projectile is an object which has a forwards speed at the same time as it is falling freely through the air.

Strobe photographs can be taken of projectiles where multiple images are made of a moving object a short time interval apart. The picture below shows a bouncing basketball. Notice that the horizontal distance the ball travels between each image remains constant whilst the vertical distance changes.

A popular experiment uses the apparatus shown opposite. It projects one ball bearing horizontally whilst dropping another vertically at the same time.

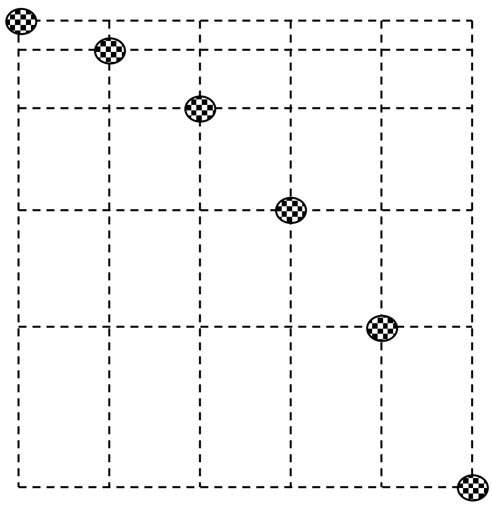
If air resistance is ignored, the ball bearing projected horizontally continues at a constant speed. Both ball bearings will be pulled downward with the same force of gravity so have the same downward acceleration. As a result they will reach the floor at the same instant. The diagrams below illustrate the trajectory or flight of each ball bearing. The images are taken equal time intervals apart.

Ball bearing dropped vertically



The ball bearing accelerates downwards which increases the distance it travels during each time interval.

Ball bearing projected horizontally



Like the ball bearing dropped vertically, the distance the ball bearing travels vertically during each time interval increases. However, in the horizontal direction it travels an equal distance each time interval.

When solving projectile problems, the horizontal motion has to be considered separately from the vertical motion. Use equations for constant speed for the horizontal motion and acceleration for the vertical motion.

Horizontal motion - $v = \frac{d}{t}$

Vertical motion - $a = \frac{v - u}{t}$ or $v = u + at$

Worked example

A ball rolls off the top of a horizontal laboratory bench at 2 m s⁻¹. It lands on the floor 1·2 s later.

(*a*) *State the final horizontal speed of the ball just as it hits the ground.*

(*b*) *State the initial vertical speed of the ball.*

(*c*) *Calculate the final vertical speed of the ball if acceleration due to gravity is 9·8 m s⁻².*

(*d*) *Calculate the horizontal distance the stone lands away from the table.*

(*a*) 2 m s^{-1}.

(*b*) 0 m s^{-1}.

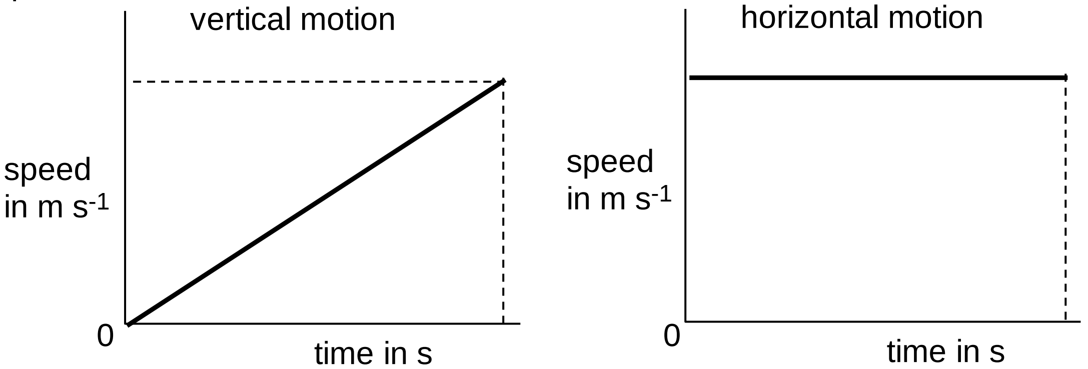
(*c*)

$$v = u + at$$
$$v = 0 + 9 \cdot 8 \times 1 \cdot 2$$
$$v = 11 \cdot 76 \text{ m s}^{-1}$$

(*d*)

$$d = v \times t$$
$$d = 2 \times 1 \cdot 2$$
$$d = 2 \cdot 4 \text{ m}$$

The horizontal and vertical motion of a projectile can also be represented on graphs as shown below.

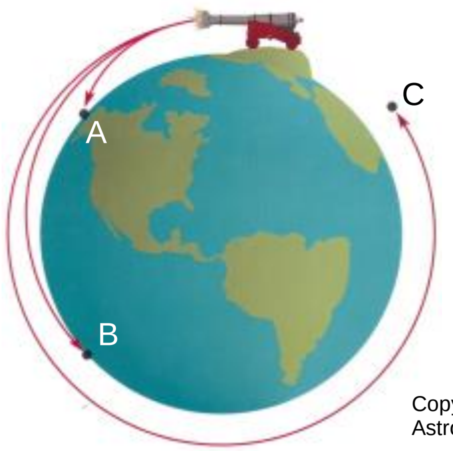


The horizontal distance and vertical distance travelled can be calculated from the area under the lines on the respective graphs.

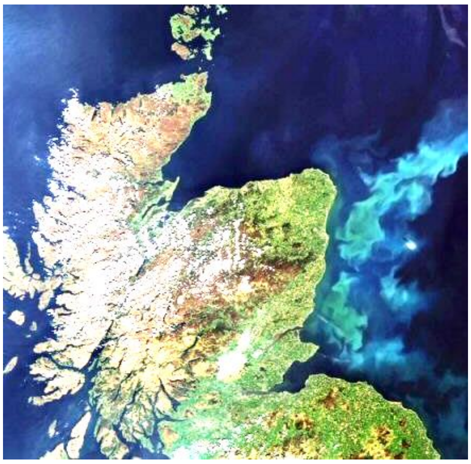
Satellite motion

A satellite is like a projectile which is falling towards the Earth's surface at the same rate as the Earth's surface is curving away from the satellite. This means that the satellite never gets any closer to the Earth and so is said to be in orbit.

Think of a cannonball fired from the top of a very high mountain. At a certain horizontal velocity, A, it will fall towards the Earth's surface. Increase the speed, as in B, and it will travel further. Increase the speed even more and it will never reach the Earth's surface as in C, and will be in orbit around the Earth.



Satellites can be either orbiting or geostationary. Orbiting satellites orbit at a lower height above the Earth's surface and can be used to map the ground, observe weather or be used for military purposes.



Geostationary satellites are in a higher orbit and orbit the Earth once every 24 hours. As a result, they always remain in the same position above the Earth's surface. They are mostly used for telecommunications and weather observation.

Space exploration
The exploration of space and the technology involved has brought a lot of benefits. There is also a negative side to the exploration of space. You must decide if it is worth the risk.

Benefits
Communication – modern communication uses satellites and could not function as it does without them.

Satellite navigation – this is not only used in cars but a whole range of industries including shipping, mining and aviation. The oil industry uses it to accurately position drilling rigs.

Jobs – there are thousands of people employed directly by the space industry but there are probably millions who are employed in spin off technology such as satellite communication including mobile phones and television.

Spin-off technologies. Many applications that are developed for the space industry have been adopted widely and are now part of everyday life such as bar codes, miniaturised electronics, scratch resistant glasses, industrial materials, cordless power tools, water purification systems – even non-stick coatings for frying pans!

Mapping – satellites are able to accurately map the surface of the earth which aids important industries such as mining and can improve land use.

Weather monitoring – accurately predicting weather patterns and anticipating dangerous hurricanes and tropical storms is now made more accurate and easier through using satellite imaging.

Satisfying our curiosity – finding out more about the universe and our place in it has become possible through the advances in space exploration. In the past 50 years we have sent men to the Moon and probes to distant planets.

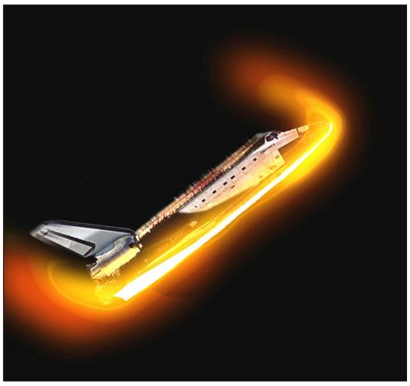
Risks and Costs
Pollution of space with debris from satellites and spacecraft. There is a risk that some debris may fall to Earth and reach the Earth's surface. The risk of being hit is infinitely small though

Danger to life – several astronauts have lost their lives in both the Apollo Moon missions and shuttle missions.

Cost – the budget for space exploration is high could that money be better spent elsewhere.

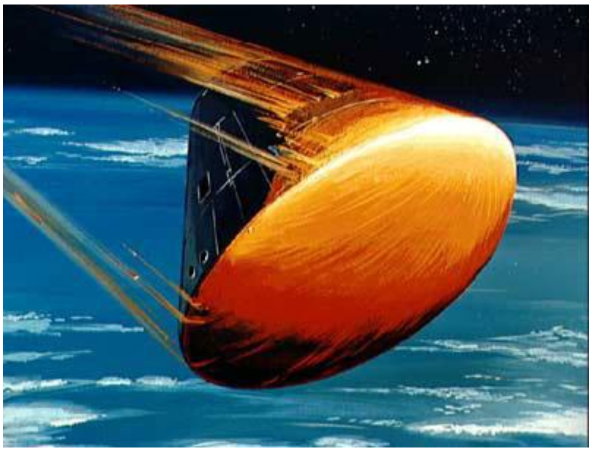
Re-entry and Heat

In space there is no atmosphere and hence no friction for spacecraft to contend with. However, when re-entering the Earth's atmosphere at high speed, the spacecraft faces problems.



If the spacecraft hits the atmosphere at the wrong angle it can bounce back into space like a stone skipping off water.

The atmosphere also creates a great deal of friction creating a lot of heat. As the spacecraft loses kinetic energy this is converted into heat energy. The space shuttle is covered with heat resistant tiles which prevent damage to the shuttle.

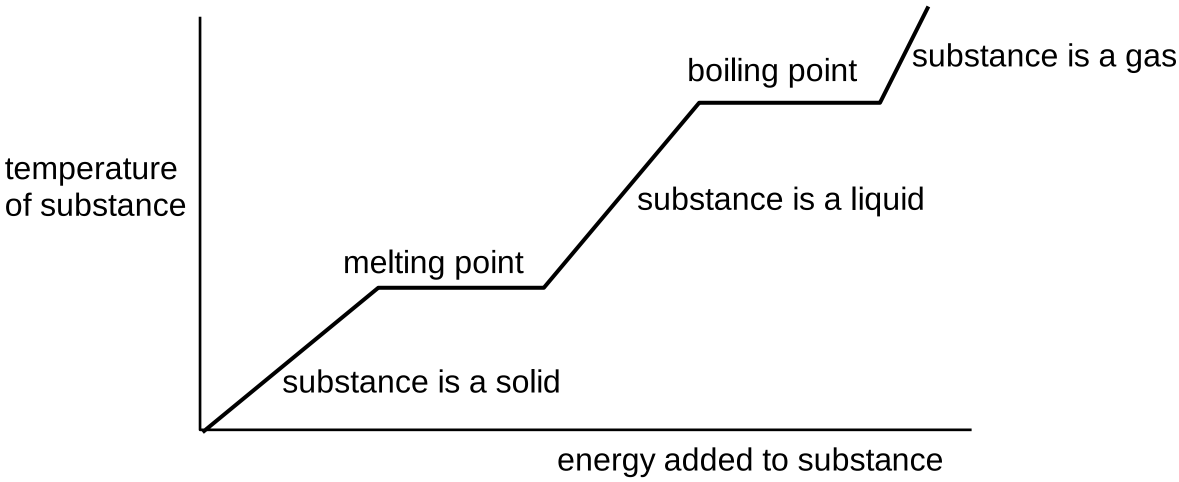


Older spacecraft such as the American Apollo missions and Russian Soyuz missions used a system called ablation to prevent damage to the re-entry modules like the one shown opposite.

The underside of the craft which experiences most friction is covered with a heat shield, a material which undergoes a process called ablation. This means that it removes excess heat by melting. The heat absorbed by the heat shield to melt it is called the latent heat of fusion.

Latent Heat

The graph below shows what happens to the temperature of a solid substance as heat energy is added to it.



As energy is added to a substance its temperature rises. However, when it reaches its melting or boiling point the energy being added to it causes a change of state rather than a rise in temperature.

The latent heat of fusion is the energy added or removed from a kilogram of substance to change it from solid to liquid or liquid to solid;

The latent heat of vaporisation is the energy added or removed from a kilogram of substance to change it from liquid to gas or gas to liquid.

Note that there is never a change in temperature when the change of state takes place e.g. boiling water changes from water to steam at 100°C—both the steam and the water are at the same temperature. The energy added to the water goes into changing the substance's state, not into raising its temperature.

The amount of energy required to change the state of a substance can be found using the equation below.

heat energy = mass changed × specific latent heat $\qquad E_h = m\,l$

Worked example
A material is being tested for use on the heat shield of a spacecraft. It has a mass of 0·5 kg. How much heat energy is required to change it from a solid to a liquid if its latent heat of vaporisation is $3{\cdot}10 \times 10^5$ J kg^{-1}

$E_h = m\,l$

$E_h = 0{\cdot}5 \times 3{\cdot}10 \times 10^5$ J kg^{-1}

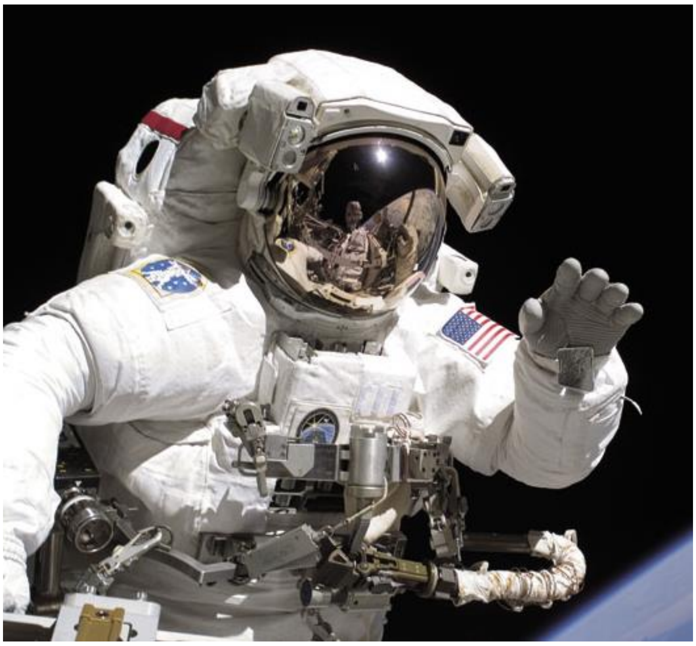
$E_h = 155\,000$ or 155 kJ

Remember that you may be asked to carry out calculations involving the interchange of energy e.g. calculating the kinetic energy of an object in space using $E_k = ½m\,v^2$ and heat energy using $E_h = c\,m\,\Delta T$ or $E_h = m\,l$

The Dangers of Space

Outer space is a very unpleasant place to be. It is hard to get up there in the first place but once you are there, you have to be protected from all the dangers that surround you. This is largely accomplished through wearing a specially designed space suit.

Space is a vacuum so there is no oxygen there. As a result you would lose consciousness very quickly.



Worse will happen however, due to this lack of an atmosphere. As there is no air pressure acting on your body, dissolved gases in your body would come out of solution and your body fluids would start to boil. (fluids boil at lower temperatures at lower pressure). The boiling process also removes energy from the body which cools down very rapidly indeed.

Tissues in your body and critical organs such as the heart will swell up and expand due to the boiling fluids. Death would be very quick but agonisingly painful.

There would be extremes of temperature. Parts of your body in direct sunlight would experience very high temperatures whilst those in the shade would be extremely cold.

Your body would be bombarded by radiation and charged particles from the Sun. The Earth's atmosphere filters most of the harmful radiation out before it reaches the Earth's surface but there would be no protection in space.

If all of the above have not already killed you, there is a risk that you would be hit by tiny particles of dust or rock that are moving at very high speeds. You might even be hit by debris or 'space junk' from the many satellites and spacecraft that have been abandoned in space.

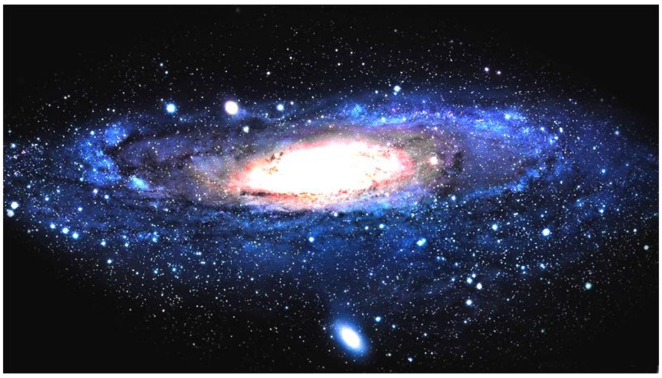
Cosmology

The Universe

On Earth, distances are measured in kilometres. In space, the distances involved are so large that they are measured in light years i.e. the distance that light will travel in 1 year.

Since light travels at 3×10^8 m s^{-1} and there are $3{\cdot}15 \times 10^7$ ($60 \times 60 \times 24 \times 365$) seconds in a year it means that in 1 year light travels 9·5 million million kilometres or $9{\cdot}5 \times 10^{15}$ m.

Some important distances in light years are:
The Sun to the Earth - 8·5 minutes
The Sun to the nearest star - 4·3 light years
The diameter of the Milky Way - 120 000 light years



You should know a number of definitions and terms relating to space and the universe.

Planet - a body revolving around a star.

Moon - a body revolving around a planet.

Star - a ball of burning gas at the centre of a solar system.

Sun - the star at the centre of our solar system.

Solar system - a star and its associated planets.

Galaxy - a grouping of solar systems.

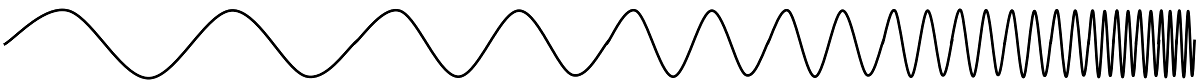
Universe - all the matter that we know of.

The Earth is part of our solar system which orbits the star in the middle—the Sun. The Sun is just one of many stars which are found in the galaxy of which we are part. The galaxy is called the Milky Way and contains 100 000 million other stars. The Milky Way consists of a spiral of stars and is about 1 $\times 10^{21}$ m wide.

The Milky Way is not the only galaxy there is. It is estimated there are hundreds of billions of galaxies. That means there are a.vast number of stars, some of which will have orbiting planets and some of these may also contain life. The universe itself is probably about 93 billion light years wide but that's only what we can observe. Scientists have been able to calculate that the universe is about 13 billion years old and it is constantly expanding. No one knows what lies beyond the edge of the universe.

Telescopes and waves

Electromagnetic waves arrive at the Earth from space. These waves belong to the electromagnetic spectrum and all travel at the speed of light (3×10^8 m s^{-1}) Radio waves have the lowest frequency with gamma radiation having the highest frequency.



radio waves	TV waves	microwaves	infra red	visible light	ultraviolet radiation	X-rays	gamma radiation

Different detectors are used for different waves. These are listed below.

Radio waves - aerial and radio receiver.

Television -aerial and television receiver

Microwaves – aerial and microwave receiver.

Infrared – Photodiode, thermocouple or themistor.

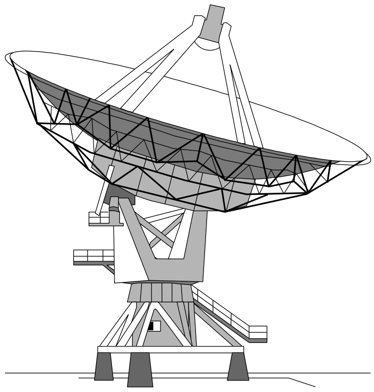
Visible light - the eye or photographic film.

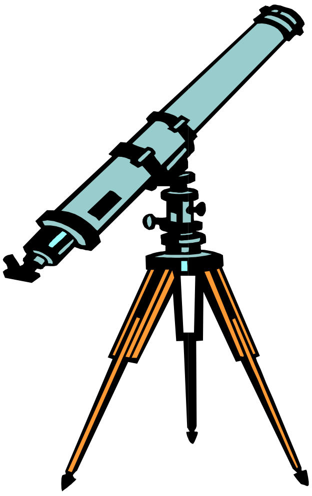
Ultraviolet - fluorescent material.

X-rays - photographic film.

Gamma radiation - Geiger counter, photographic film.

Different types of telescopes can be used to detect different waves. Radio telescopes like the one shown opposite are used to detect radio waves emitted by stars.





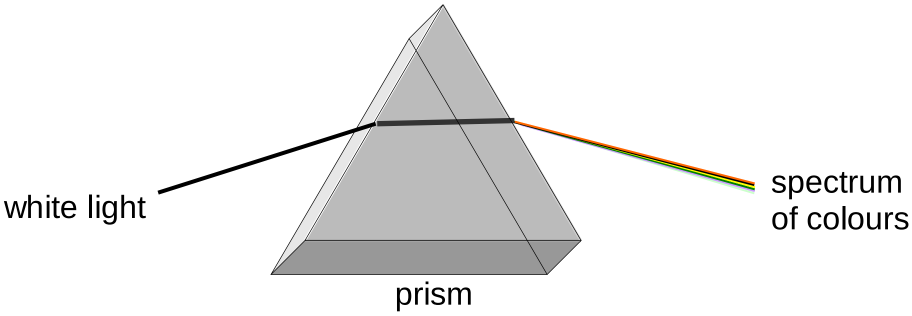
Optical telescopes are used to observe visible light from stars. An objective lens at the end of the telescope gathers light from an object in space to form a very small image. This is magnified using the eyepiece lens The larger the diameter of the objective lens, the more light can be captured and hence the brighter the image.

The Earth's atmosphere and light from other sources limit the quality of image that can be seen using a telescope on Earth. The answer is to place it in space which was done with the Hubble telescope opposite

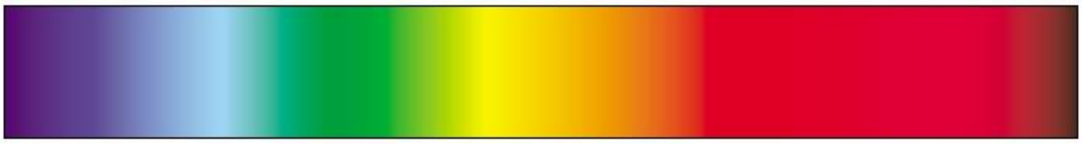
illustration by NASA/ESA

Using the Spectra

A prism will split white light into its component wavelengths or colours. This can also be achieved using a device called a diffraction grating.



If white light is shone through a grating it produces a continuous spectrum.



By shining light from a star through a grating a spectrum made up of a series of lines is observed called a line spectrum.

The line spectra depends upon the elements present in the star with every element having its own unique set of lines. Astronomers can identify the elements making up a star by analysing the light coming from it.

Velocity and Displacement

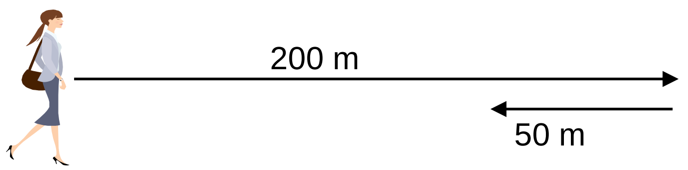
Vectors and Scalars

1. State the difference between a vector quantity and a scalar quantity.

2. State whether the following measurements are vector or scalar quantities. The first has been done for you.

	Quantity	***Vector or Scalar***
(*a*)	force	vector
(*b*)	speed	
(*c*)	velocity	
(*d*)	distance	
(*e*)	displacement	
(*f*)	acceleration	
(*g*)	mass	
(*h*)	weight	
(*i*)	time	
(*j*)	energy	

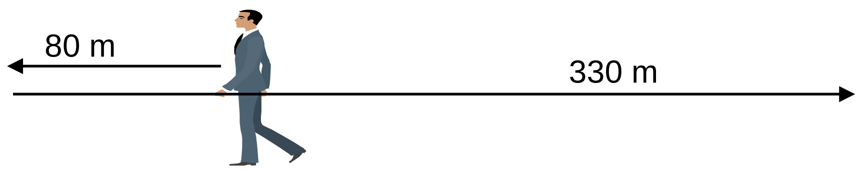
3. A woman walks 200 m to the right then 50 m to the left.



(*a*) Calculate the total distance she has walked.

(*b*) Calculate the total displacement of the woman.

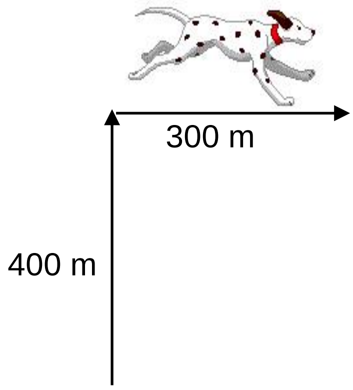
4. A man walks 80 m to the left then 330 m to the right.



(*a*) Calculate the total distance he has walked.

(*b*) Calculate the total displacement of the man.

5. A dog runs 400 m north then turns at right angles and runs 300 m east.



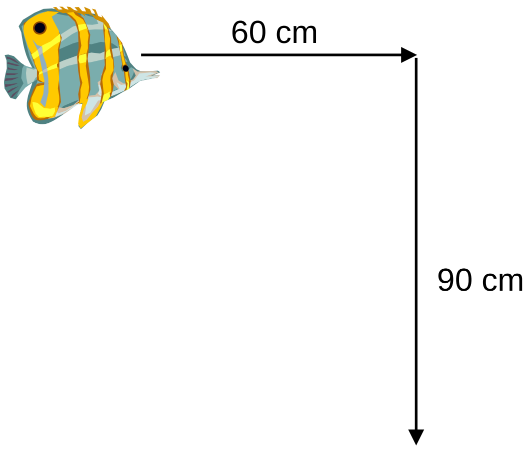
(*a*) Calculate the total distance the dog ran.

(*b*) Calculate the total displacement of the dog.

6. A fish swims 60 cm east then swims 90 cm south.

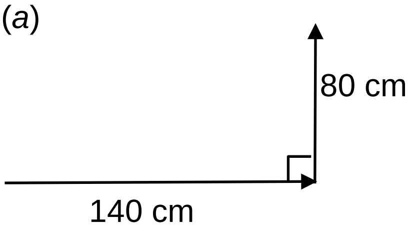
(*a*) Calculate the total distance the swam.

(*b*) Calculate the total displacement of the fish.

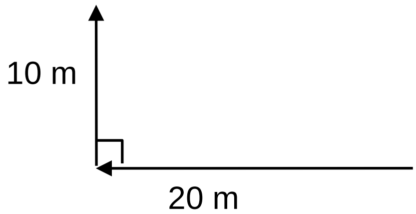


7. Find the resultant displacement in the following examples by drawing a scale diagram or by calculation.

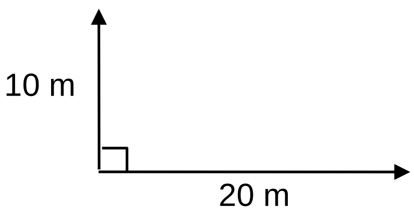
(*a*)



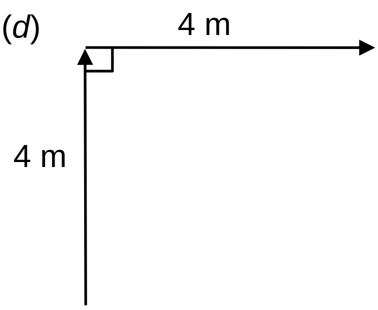
(*b*)



(*c*)



(*d*)



8. A package on a conveyor belt in a factory moves forwards a distance of 5 m and then travels to the right 3 m. Find the displacement of the package.

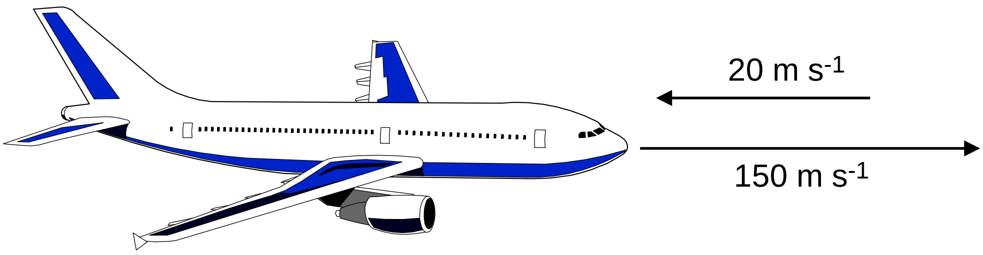
9. A sailing boat travels 20 km north followed by 16 km west.
Find the displacement of the boat.

10. The driver following the satellite navigation system of his car travels 1500 m east and then 800 m south.

(*a*) Calculate the distance travelled by the car.

(*b*) Calculate the displacement of the car from its starting point.

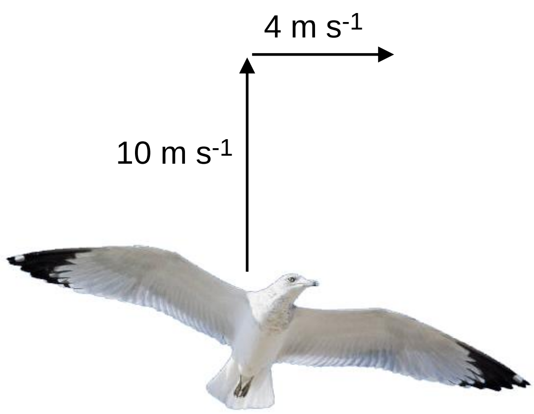
11. An aeroplane is flying horizontally forwards at 150 ms^{-1}. A headwind is blowing it backwards at 20 ms^{-1}.



Calculate the resultant velocity of the plane relative to the ground.

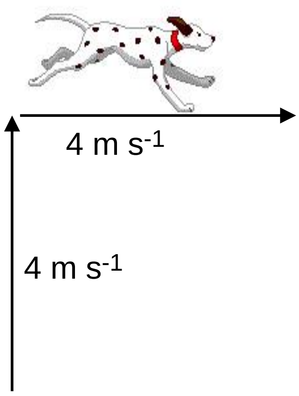
12. A bird is flying at 10 m s^{-1} forwards. At the same time a side wind blows it at 4 m s^{-1} to the right.

Calculate the resultant velocity of the bird.



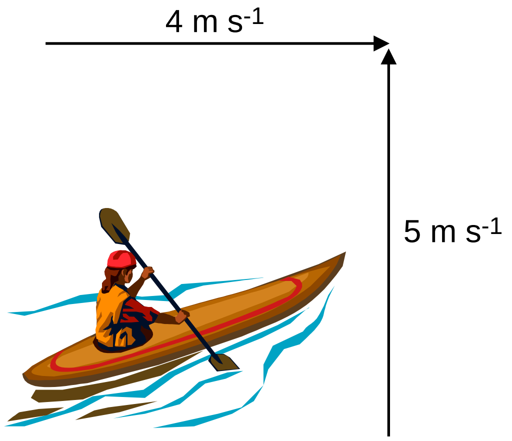
13. A dog runs at 4 m s^{-1} north then turns at right angles and runs at 4 m s^{-1} east.

Calculate the resultant velocity of the dog.



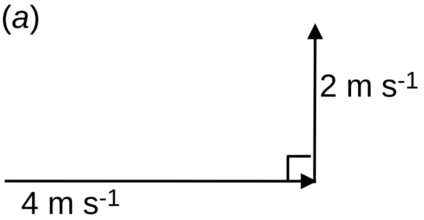
14. A canoeist paddles, left to right, from one river bank to the other, at 4 m s^{-1}.
A strong current carries her down stream at 5 m s^{-1}.

Calculate the resultant velocity of the canoeist.

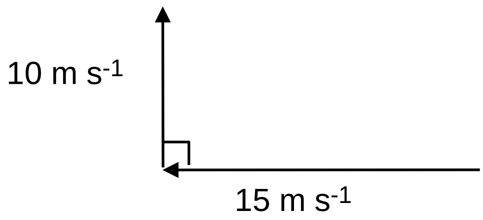


15. Find the resultant velocity in the following examples by drawing a scale diagram or by calculation.

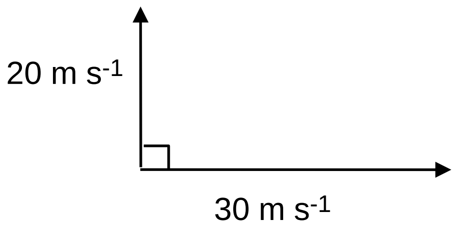
(*a*)



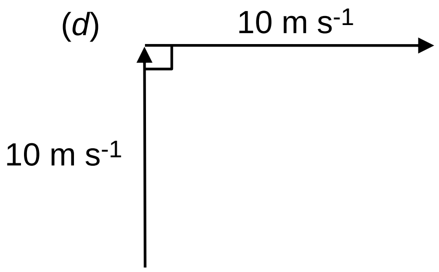
(*b*)



(*c*)



(*d*)



16. A train is moving forwards at 2·5 m s^{-1}. A passenger on the train walks from left to right in his carriage at 0·75 m s^{-1}. Find the resultant velocity of the passenger.

17. A hang glider is flying north with a velocity of 18 m s^{-1}. A sudden strong gust of wind blows the glider from west to east at 7 m s^{-1}.
Find the resultant velocity of the hang glider relative to the ground.

18. During an orienteering exercise, a competitor runs at 2·0 m s^{-1} south followed by 3·5 m s^{-1} east. Calculate their resultant velocity.

Average and Instantaneous Speed

19. Which of the following are instantaneous speeds and which are average speeds?

A A car's speed between Aberdeen and Dundee.

B The speed of a tennis ball as it leaves the racquet.

C The reading on a car speedometer.

D The speed of a roller-coaster at the bottom of a loop.

E The speed of an athlete over a 100 m race.

20. A pupil is given a 50 m measuring tape, a stop watch and the help of some friends. Describe how she could find the speed of one of her friends as she runs a race.

21. State an equation that links speed, distance and time.

22. Calculate the missing values in the table below.

Speed	***Distance***	***Time***
(*a*)	10 m	4 s
(*b*)	500 m	10 s
2 m s^{-1}	30 m	(*c*)
0·5 m s^{-1}	60 m	(*d*)
8 m s^{-1}	(*e*)	120 s
0·2 m s^{-1}	(*f*)	3 minutes

23. An ice hockey player strikes the puck and it moves off at 10 m s^{-1}. Calculate the time it will take to travel 8 m.

24.

(*a*) A speed skater completes a 500 m course in 35 s. Calculate the average speed the skater travelled at.

(*b*) Speed skaters also compete in races which are 10 000 m long. Calculate the time it would take the skater to complete the course if they travelled at an average speed of 12·5 m s^{-1}.

25. A car travels a distance of 2000 m along a motorway in 60 s. Calculate the average speed of the car.

26. Someone standing on the Earth's equator will travel 28·8 km in 1 minute due to the spin of the Earth. Calculate the speed they are travelling at in metres per second.

27. A cyclist pedals for 50 minutes at a speed of 12 m s^{-1}. Calculate the distance she will have travelled.

28. Calculate the time it will take a train travelling at an average speed of 80 km per hour to complete a journey 60 kilometres long.

Extension Questions

In the following questions remember that there is a difference between speed and velocity.

$$\text{average speed} = \frac{\text{total distance}}{\text{time}} \qquad \text{average velocity} = \frac{\text{total displacement}}{\text{time}}$$

29. A sprinter is warming up before a race. He runs a distance of 120 m along a track in a time of 15 s. He then turns around and jogs back 40 m towards the starting line. This takes a further 20 s.

(*a*) (i) What is the total distance travelled by the sprinter?

(ii) Calculate the sprinter's average speed.

(*b*) (i) What is the total displacement of the runner?

(ii) Calculate the sprinter's average velocity.

(*c*) (i) What would be the runner's displacement if he was to return to the starting point of his sprint?

(ii) Calculate the average velocity of the sprinter if he did this.

30. A spider scurries 40 cm up a wall. It then moves horizontally 30 cm to the right. It takes the spider 7 s to complete this manoeuvre.

(*a*) (i) What is the total distance travelled by the spider?

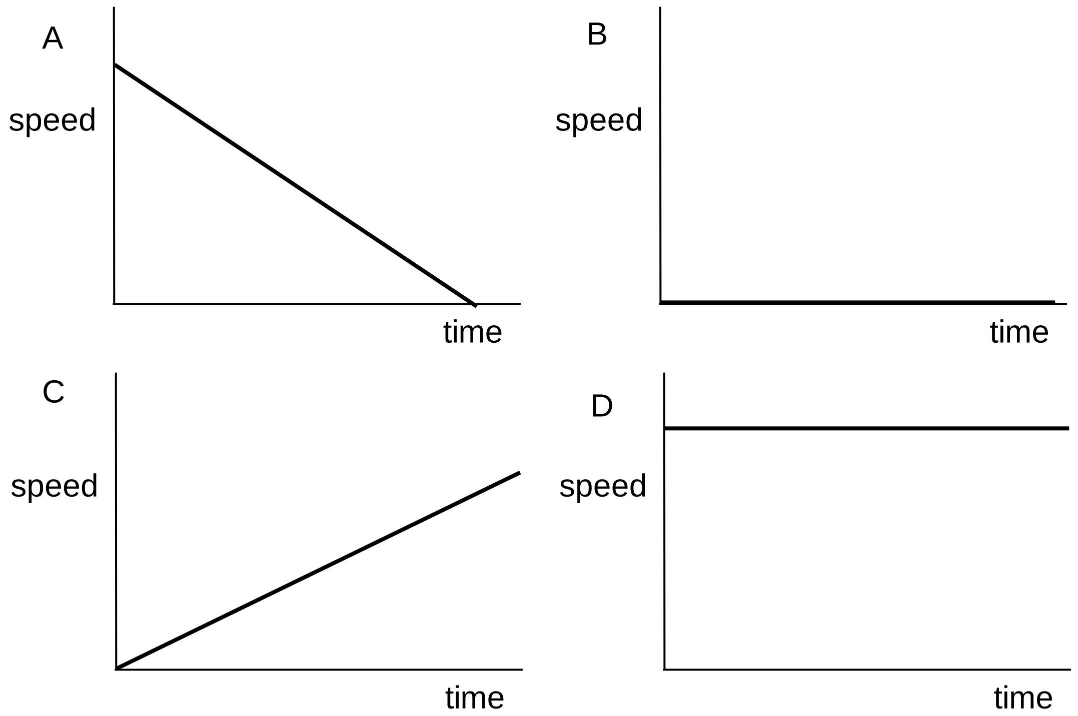
(ii) Calculate the spider's average speed.

(*b*) (i) What is the total displacement of the spider?

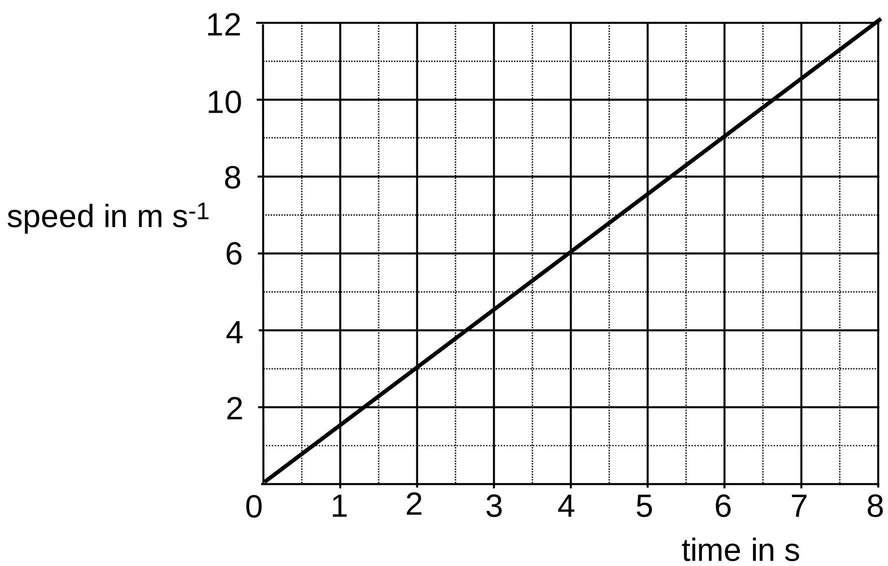
(ii) Calculate the spider's average velocity.

Speed-Time Graphs

31. Look at the speed time graphs below. State which shows an object at rest, travelling at a constant speed, slowing down and speeding up.



32. The speed time graph below shows the motion of a car over 8 seconds.



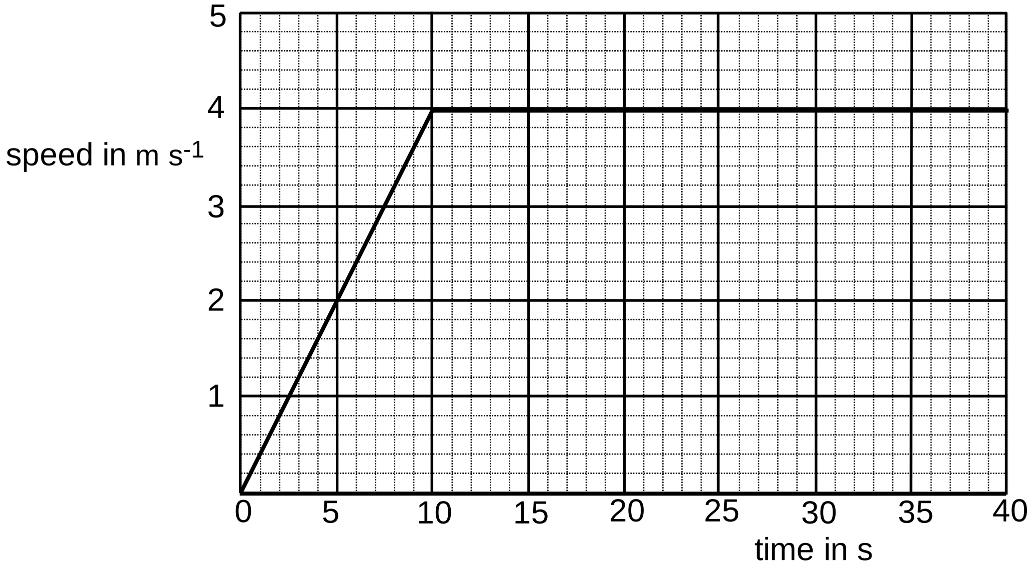
(*a*) State the speed of the car after:

(i) 2 s;

(ii) 6 s.

(*b*) Calculate the distance travelled by the car over the 8 s of its motion.

33. A speed time graph is shown below for the motion of a cyclist.

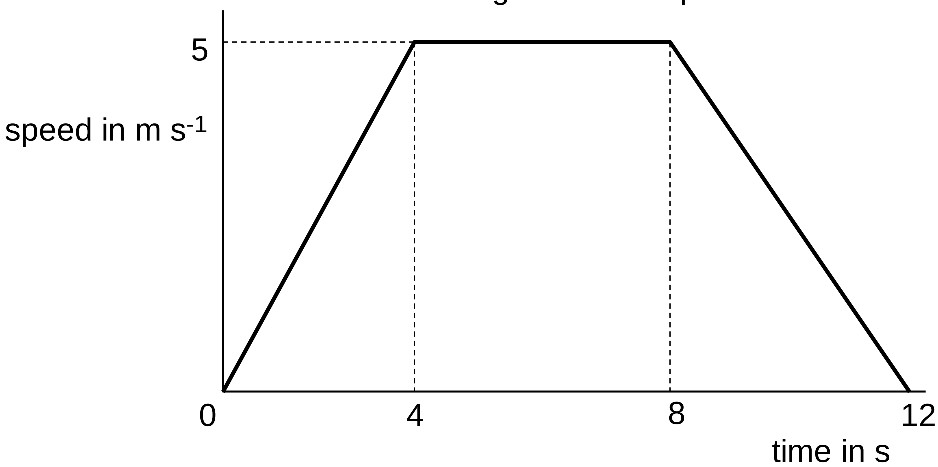


(*a*) Describe the motion of the cyclist over the 40 s.

(*b*) Calculate the total distance travelled by the cyclist.

(*c*) Calculate the average speed of the cyclist over the 40 s.

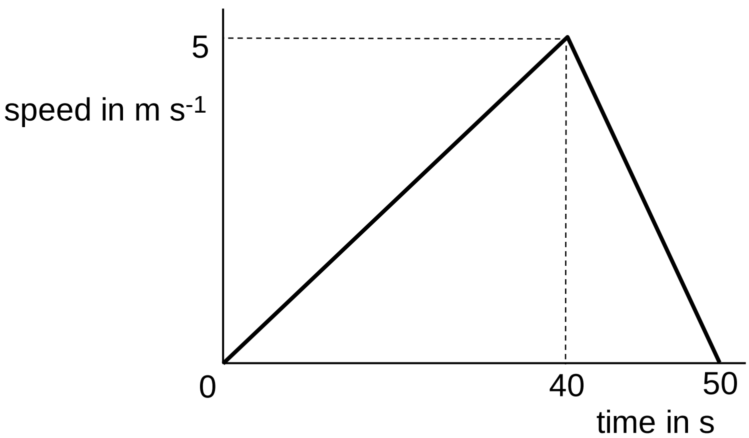
34. A sprinter warming up for a race produces the following speed-time graph. Calculate the distance travelled during the warm-up.



35. The graph opposite shows how the speed of a cyclist changes with time.

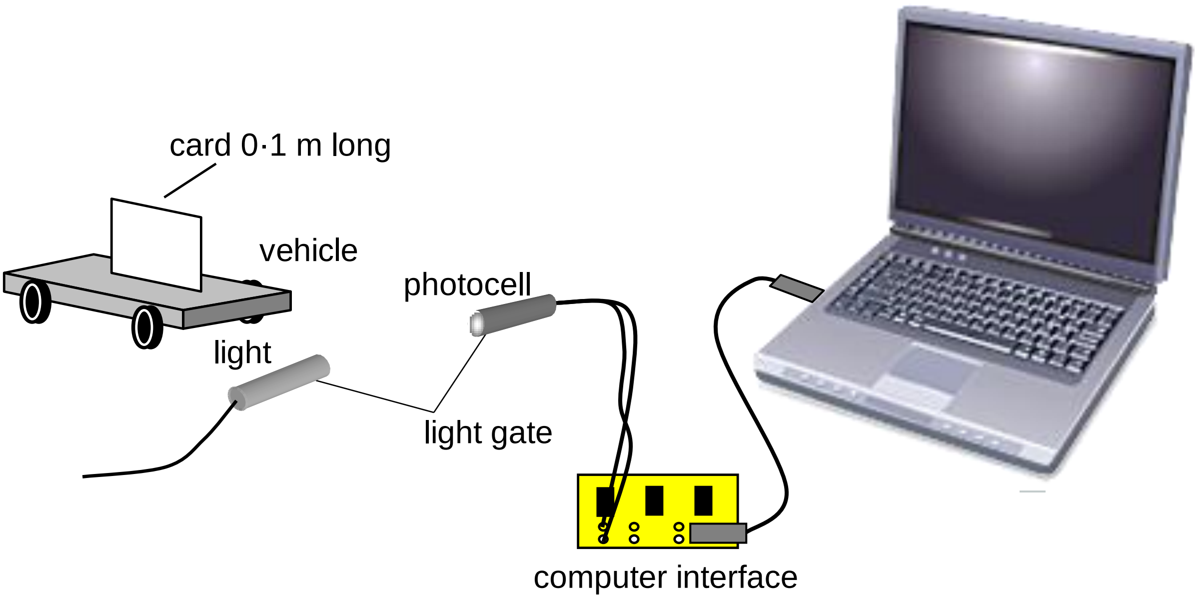
(*a*) Describe the motion of the cyclist over the 50 s.

(*b*) Calculate the distance travelled by the cyclist.



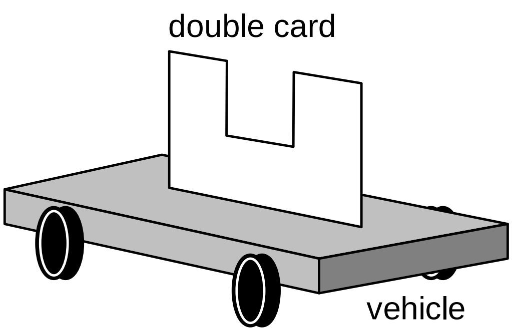
Using Light Gates to Measure Speed and Acceleration

36. A pupil uses light gates and a computer to measure the speed of a trolley. The trolley has a card 0·1 m long attached to it.



Describe how the light gate and computer are used to calculate the speed of the trolley.

37. The apparatus used in question 26 can be modified to measure acceleration. One way of achieving this is by replacing the single card with a double card as shown below.



(*a*) State the equation used to measure acceleration.

(*b*) Explain how the double card makes it possible to measure acceleration using a single light gate.

(*c*) Acceleration can also be found experimentally using a single card but using two light gates. Explain how this arrangement works.

38. Acceleration can be measured using the formula below.

$$\text{acceleration} = \frac{\text{final speed - initial speed}}{\text{time taken for change}} \quad \text{or} \quad a = \frac{v - u}{t}$$

Rearrange the formula so that it is in the form v = ... ie, to calculate final speed.

39. Calculate the missing values in the table below.

Acceleration	***Initial speed***	***Final speed***	***Time taken for change***
(*a*)	0 m s^{-1}	20 m s^{-1}	5 s
(*b*)	0 m s^{-1}	100 m s^{-1}	20 s
5 m s^{-2}	0 m s^{-1}	(*c*)	20 s
0·5 m s^{-2}	10 m s^{-1}	(*d*)	50 s
2 m s^{-2}	(*e*)	50 m s^{-1}	10 s
2·5 m s^{-2}	(*f*)	40 m s^{-1}	8 s
5 m s^{-2}	5 m s^{-1}	60 m s^{-1}	(*g*)
4 m s^{-2}	0 m s^{-1}	20 m s^{-1}	(*h*)
(*i*)	10 m s^{-1}	0 m s^{-1}	5 s
–2 m s^{-2}	40 m s^{-1}	(*j*)	10 s

40. A space shuttle, starting from rest on the launch pad, reaches a speed of 1000 m s^{-1} after 45 s. Calculate the acceleration of the shuttle.

41. A high speed lift in a high rise tower accelerates from rest at 3·5 m s^{-2}. Calculate the final speed of the lift after 4 s.

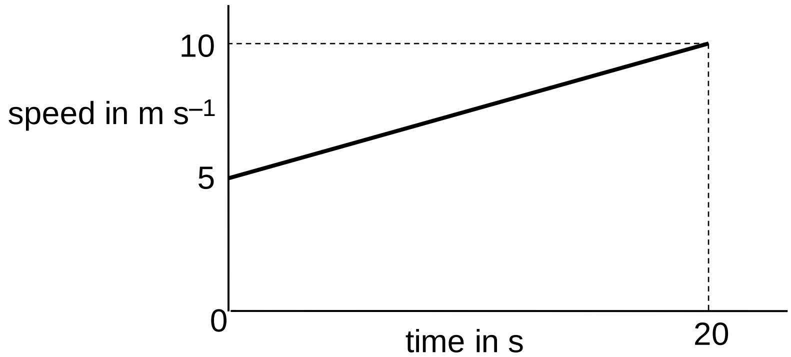
42. A cruise ship manoeuvres out of harbour at a speed of 1 m s^{-1}. It then accelerates to a speed of 9 m s^{-1}. Calculate the time this will take if the ship accelerates at 0·04 m s^{-2}.

43. (*a*) A high speed bullet train leaves a station and accelerates from rest to 60 m s^{-1} in a time of 120 s. Calculate the acceleration of the train.

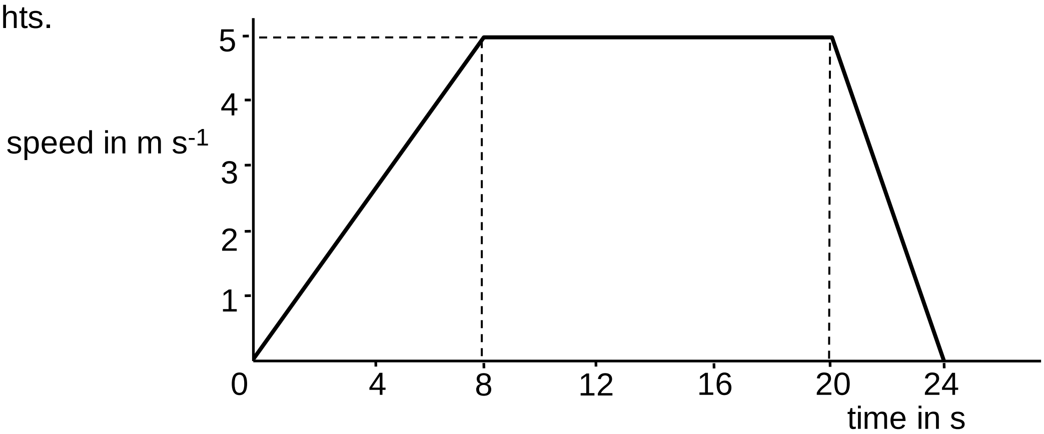
(*b*) The train is travelling at its top speed of 80 m s^{-1} and brakes to slow down with a negative acceleration of –0·8 m s^{-2}. Calculate the time it will take for the train to stop.

Acceleration Graphs

44. A vehicle accelerates as shown in the graph opposite. Calculate the value of its acceleration.



45. The graph shown below is produced by a car as it moves between traffic lights.



(*a*) Calculate the acceleration of the car as it left the first set of traffic lights.

(*b*) Calculate the acceleration of the car as it slowed down for the second set of traffic lights.

46. A racing car is undergoing tests before a race. The driver accelerates and then brakes to a halt.

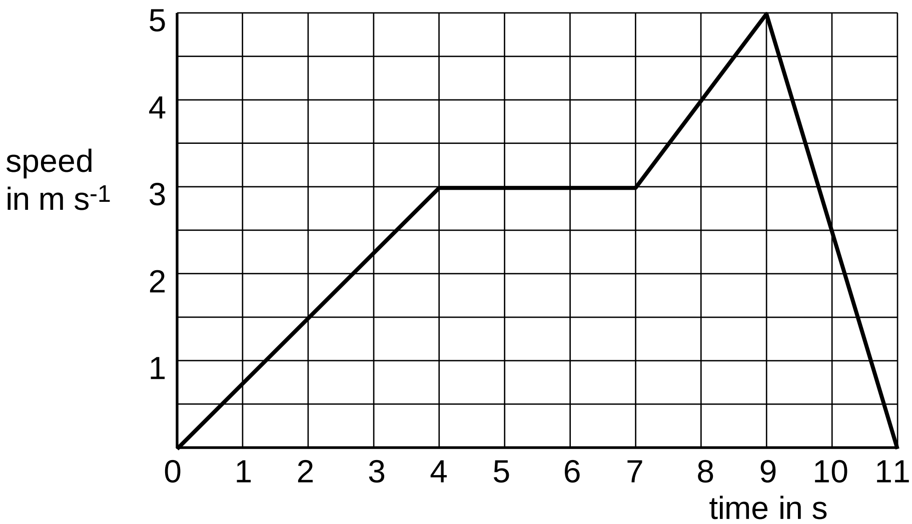
(*a*) Calculate the car's acceleration between 0 and 2 seconds.

(*b*) Calculate the car's acceleration between 2 and 8 seconds.

(*c*) Calculate the car's acceleration between 8 and 10 seconds.

Extension Questions

47. The graph below represents the motion of a football player during part of a game of football.



(*a*) Calculate the acceleration of the footballer during

(i) the first 4 seconds

(ii) between the 4th and 7th second

(iii) between the 7th and 9th second

(iv) over the last 2 seconds.

(*b*) Calculate the total distance run by the player during the 11 seconds.

48. The table below shows the speed of a car as it travels along a straight stretch of road.

Time in seconds	0	10	20	30	40	50	60	70	80
Speed in m s^{-1}	0	5	10	15	20	20	20	10	0

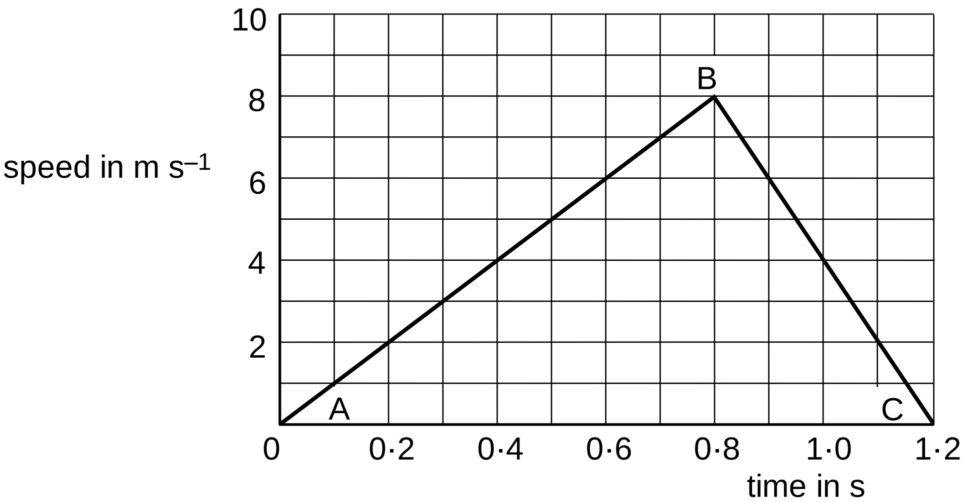
(*a*) Using graph paper, plot a speed-time graph for the car's journey.

(*b*) Calculate the acceleration during each part of the car's journey.

(*c*) What was the total distance travelled by the car?

(*d*) Calculate the average speed of the car during this journey.

49. A high diver dives from the edge of a diving platform into the pool below. The graph below shows her downwards speed from the time she leaves the board till she comes to a halt as she enters the water.



(*a*) Describe the motion of the diver between A and B and B and C.

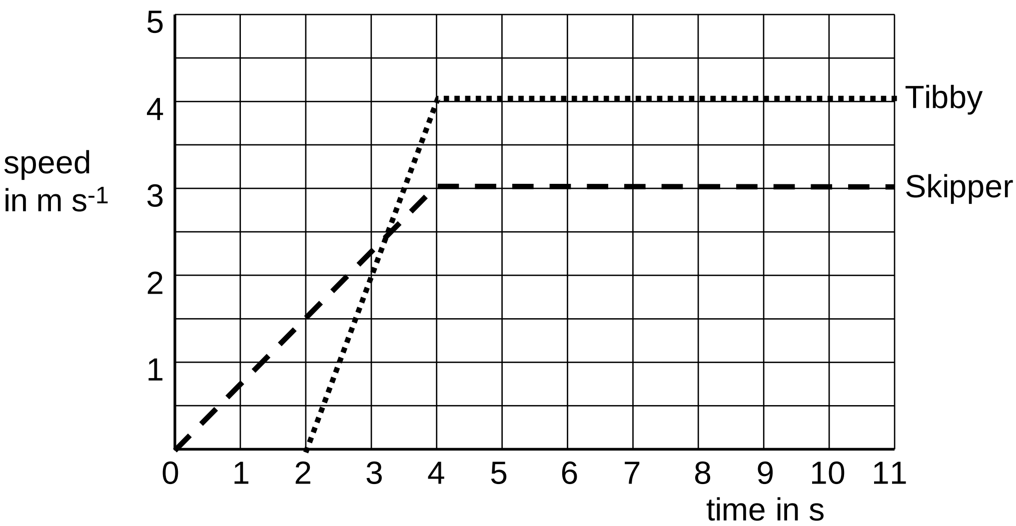
(*b*) At point did the diver enter the water?

(*c*) Calculate the distance travelled by the diver from the diving platform till she came to a halt.

(*d*) Calculate the average speed of the diver during the dive.

(*e*) Calculate the acceleration of the diver between A and B and between B and C.

50. Skipper and Tibby are two Tibetan Terriers who love to chase one another. Skipper begins to run and Tibby starts to chase him 2 s later. The speed time graph of the dogs is shown below.



(*a*) State the final speed reached by:

(i) Skipper;

(ii) Tibby.

(*b*) Which dog accelerated for the longest time?

(*c*) Calculate the acceleration of:

(i) Skipper;

(ii) Tibby.

(*d*) Show, by calculation, which dog was furthest ahead after the 11 seconds of the chase.

Newton's Laws

Newton's Laws of Motion – Balanced and unbalanced forces

51. Sir Isaac Newton's First Law of Motion states:

"An object at rest will remain at rest unless acted on by an unbalanced force. An object in motion continues in motion with the same speed and in the same direction unless acted upon by an unbalanced force."

(*a*) Explain how this law applies to a snooker ball before it is hit by a snooker cue.

(*b*) Explain how this law applies to a snooker ball after it has been hit by a snooker cue.

52. A force is applied to a soft rubber ball. State three ways in which the ball may be affected.

53. State the effect of a force in the following situations.

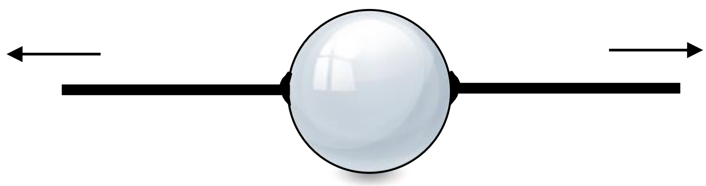
(*a*) A cyclist applies the brakes on his bicycle.

(*b*) A footballer kicks a football.

(*c*) You sit on a cushion on a chair.

(*d*) A goalkeeper catches a penalty shot during a football match.

54. Two pieces of elastic are attached to a ball and stretched so that they apply a force to the ball.



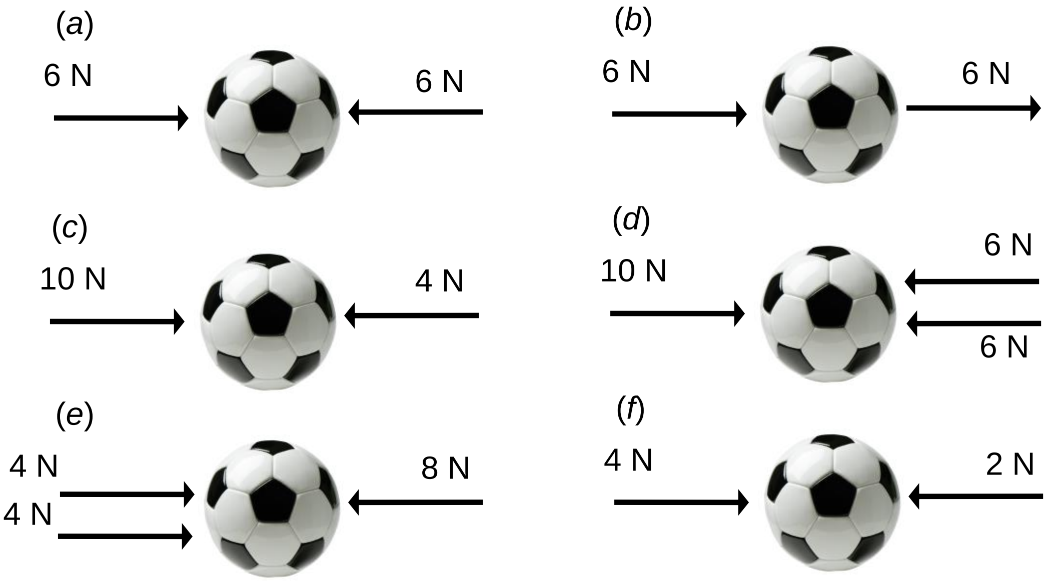
(*a*) State what happens when one piece of elastic is pulled and the other is left slack.

(*b*) What will happen to the ball if both pieces of elastic are pulled with the same force?

(*c*) (i) What name is given to the forces in this situation?

(ii) What overall force would the ball experience in this situation.

55. State whether the footballs shown below remain stationary or will move. If they move, in which direction will they move?



56. A car is stationary at traffic lights.

(*a*) What can be said about the forces acting on it?

(*b*) When the traffic lights change to green, the car moves away from the lights. What has changed about the forces acting on it?

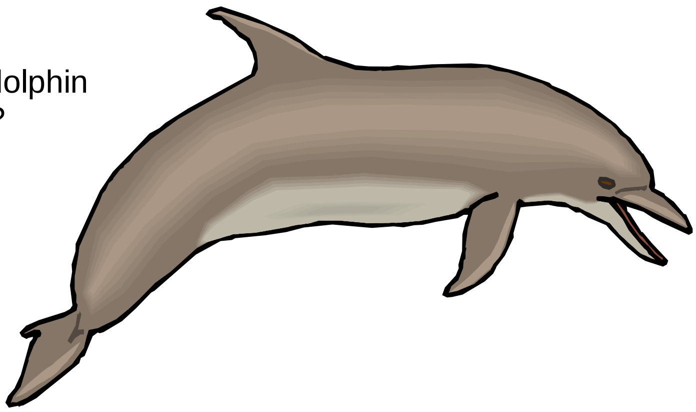
(*c*) (i) After a short time the car is travelling at a constant speed. What can be said about the forces acting on it now?

(ii) There are forces of friction acting against the car. Describe the source of two of these.

57. A dolphin is swimming through the water. It is propelled forwards by the force from its tail.

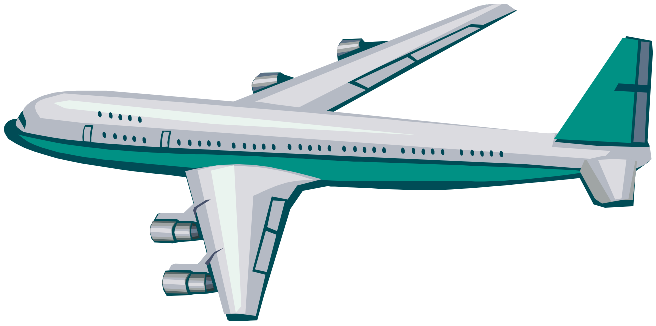
(*a*) What other forces act on the dolphin as it swims through the water?

(*b*) As the dolphin swims faster, the backward forces acting on it increase. What will happen when the forward and backward forces are equal?



58. An aeroplane is flying horizontally at a constant speed. Redraw the plane and mark on the following forces on your diagram. Use an arrow to indicate the direction of the force.

engine thrust **weight** **lift** **friction**



59. Sir Isaac Newton's Second Law of Motion states:

"The acceleration of an object is dependent upon two variables – the net force acting upon the object and the mass of the object. The acceleration of an object depends directly upon the net force and inversely upon the mass of the object. The relationship between an object's mass m, its acceleration a, and the applied force F is:

$$F = m \times a.$$

(*a*) Explain how this law predicts the acceleration of a bus and a small car if the same force was applied to each.

(*b*) Explain how this law predicts the acceleration of a car when the engine provides a small force and a large force.

60. (*a*) A car is being driven with no passengers. What effect will adding three passengers and a full boot of luggage have on the acceleration of the car?

(*b*) The same model of car comes with a more powerful engine which can provide a greater engine force. How will the acceleration of this car compare with the acceleration of the car in part (*a*) assuming the mass of both cars is identical?

61. Calculate the missing values in the table below.

Force	***Mass***	***Acceleration***
(*a*)	10 kg	2 m s^{-2}
(*b*)	0·5 kg	200 m s^{-2}
50 N	5 kg	(*c*)
10 N	1 kg	(*d*)
20 N	(*e*)	4 m s^{-2}
30 N	(*f*)	0·6 m s^{-2}

62. A jogger with a mass of 50 kg accelerates at 0·5 m s^{-2}. Calculate the unbalanced force required to produce this acceleration.

63. A car has a total mass of 1200 kg. Calculate the force required to accelerate the car at 2 m s^{-2}.

64. Calculate the acceleration of a car that has a mass of 800 kg and is acted on by an unbalanced force of 2400 N.

65. A force of 180 N is applied by a cyclist to his bicycle to produce an acceleration of 3 m s^{-2}. Calculate the combined mass of the cyclist and bicycle.

66. (*a*) A car travelling along a flat straight road slows down with an acceleration of –2 m s^{-2}. What braking force must be applied if the car has a mass of 1000 kg?

(*b*) A road surface is often covered with special grit near dangerous road junctions.

(i) What effect will this have on the friction between the car tyres and the road surface?

(ii) How will the negative acceleration of the car be affected by the road surface assuming the same braking force is applied?

67. A car with a mass of 800 kg is travelling at a constant speed on a flat, level road. The forwards engine force is 1000 N.

(*a*) What will be the size and direction of the frictional forces acting on the car?

(*b*) The engine force is increased to 1400 N. Calculate the acceleration of the car assuming frictional forces remain the same.

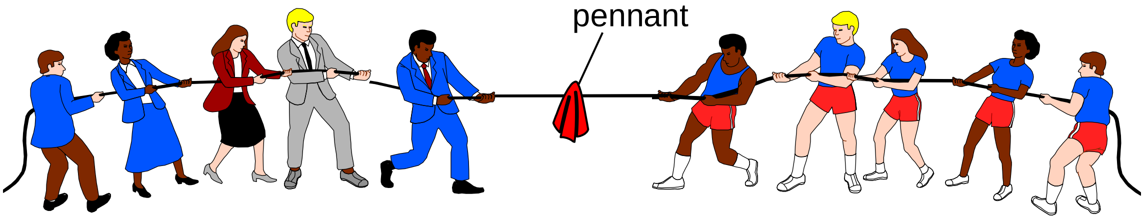
68. An aircraft has a mass of 20 000 kg. Its engines produce a force of 160 000 N but frictional forces of 20 000 N act on the aircraft. Calculate its acceleration.

69. An oil tanker of mass 10 000 000 kg is travelling at a steady speed. When its engines are switched off it accelerates at $-0{\cdot}01$ m s^{-2}.

(*a*) Calculate the size of the force due to water resistance.

(*b*) What was the size of the force exerted by the tanker's engines before they were switched off?

70. A tug of war competition takes place between teachers and pupils. Each teacher pulls with a force of 100 N. Each pupil pulls with a force of 95 N.



(*a*) (i) Calculate the total force exerted by the teachers.

(ii) Calculate the total force exerted by the pupils.

(*b*) State the direction in which the pennant moves.

Work Done, Force and Distance

71. Give an equation which links work done, unbalanced force and distance

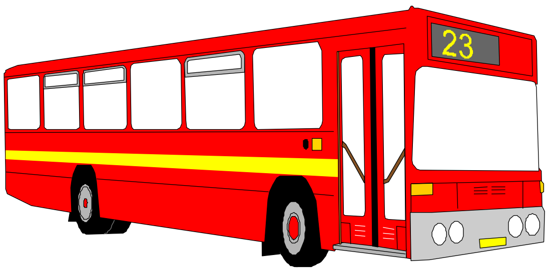
72. Calculate the missing values in the table below.

Work Done	***Force***	***Distance***
(*a*)	10 N	0·5 m
(*b*)	100 N	20 m
200 J	5 N	(*c*)
10 J	20 N	(*d*)
20 J	(*e*)	2 m
2 kN	(*f*)	20 m

73. A gardener can push a wheel barrow with a force of 190 N. If she uses 1200 J of energy, how far has she pushed the barrow?

74. Calculate the energy transferred (work done) by a locomotive exerting a pull of 10 000 N on a train of wagons to pull it a distance of 300 m.

75. A bus driving at constant speed has 225 000 J of kinetic energy. The bus driver applies the brakes which produce a constant stopping force of 4500 N.



(*a*) (i) Calculate the distance in which the bus will come to a halt.

(ii) What has happened to the kinetic energy lost by applying the brakes?

(*b*) Calculate the acceleration of the bus if it has a mass of 9000 kg.

Weight and Gravity

76. Three pupils are discussing their Physics lesson that day.

Pupil A says "*Weight is measured in kilograms and is the downwards pull on a body due to gravity*."

Pupil B says "*Weight is measured in newtons and is the downwards pull on a body due to gravity*."

Pupil C says "*Mass is measured in kilograms and is the downwards pull on a body due to gravity*."

State which pupil made the correct statement and explain what mistakes the others made.

77. State the value of gravitational field strength on Earth?

78. State an equation that can be used to convert the mass of a body into its weight.

79. Complete the table below to convert between mass and weight for an object on Earth.

Mass	***Weight***
1 kg	(*a*)
0·5 kg	(*b*)
4 kg	(*c*)
(*d*)	9·8 N
(*e*)	49 N
(*f*)	30 N

80. A pupil says that her weight is 50 kg.

(*a*) What is wrong with her statement?

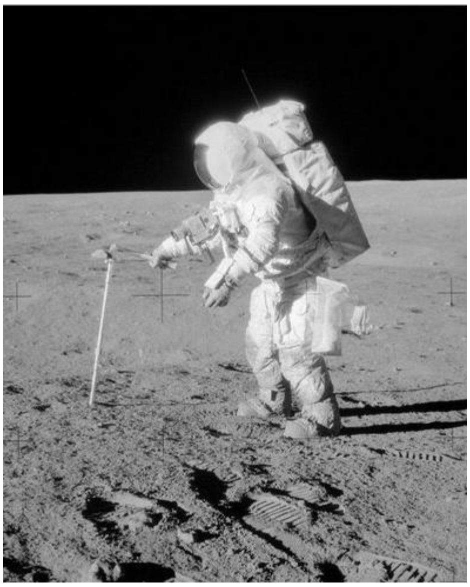
(*b*) Calculate the value of her weight on Earth.

81. A lift is designed to carry a maximum load of 10 people, each with a mass of 80 kg. The lift has a mass of 500 kg. Calculate the total weight of the lift when full.

82. An astronaut has a hammer with a mass of 0·8 kg on the Moon

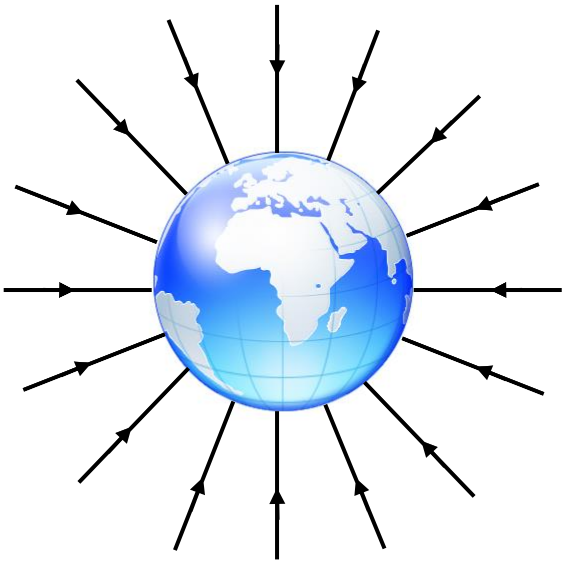
(*a*) Calculate the hammer's weight on Earth where the value of g is 9·8 N kg^{-1}.

(*b*) Calculate the hammer's weight on the Moon where the value of g is 1·6 N kg^{-1}.



83. A satellite orbits the earth at a height of 2000 kilometres where the value of gravitational field strength is 5·7 N kg^{-1}. Calculate the weight of the satellite if it has a mass of 900 kilograms.

84. The diagram opposite represents the gravitational field strength around the earth. The closer the field lines are together, the stronger the gravitational field.



(*a*) What happens to the strength of the gravitational field acting on a body as it moves away from the earth?

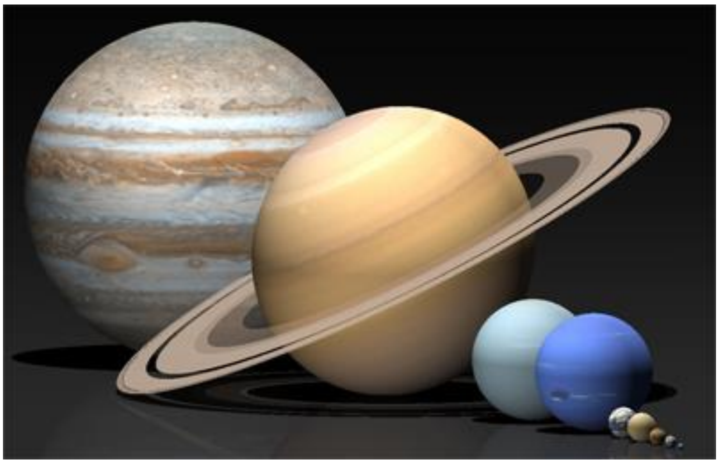
(*b*) An asteroid with a mass of 2·5 kg is moving towards the Earth. What will be its weight when the gravitational field from the Earth is 4·5 N kg^{-1}?

85. (*a*) The Apollo Moon missions travelled from the Earth to the Moon. Describe what happened to the gravitational field strengths from the Earth and the Moon as the Apollo spaceship made that journey.

(*b*) A pupil says that at some point between the Earth and the Moon the gravitational fields will cancel each other out. Comment on this statement.

Extension questions

86. The table below shows the gravitational field strength on a number of planets in our solar system. Use these values to answer the questions which follow.



Planet	***Gravitational field strength ($N\ kg^{-1}$)***
Mercury	3·7
Venus	8·9
Earth	9·8
Mars	3·7
Jupiter	26
Saturn	11·2
Uranus	9·0
Neptune	11·3

(*a*) A vehicle exploring Mars has a mass of 174 kg. Calculate its weight on the Martian surface.

(*b*) What would be the weight of:

(i) a 60 kg person on Earth;

(ii) a 60 kg person on Jupiter?

(*c*) An object has a weight of 63 N on the surface of Uranus. Calculate its mass.

(*d*) Calculate the weight of a 5 kg object on the surface of Neptune.

Newton's Laws and Space Flight

87. When the space shuttle took off it piggy backed on a large fuel tank. This supplied fuel for the three rocket motors. The shuttle also used two solid fuel rockets to boost its acceleration.

Information is given below about the rockets and the shuttle.

Thrust from each engine = 1800 kN

Thrust from each solid fuel booster rocket = 12 000 kN

Mass of fuel tank at lift off = 750 000 kg

Mass of solid booster rockets at lift off = 600 000 kg

Mass of shuttle at lift off = 110 000 kg

(*a*) Calculate the total mass of the shuttle at lift off including the two solid fuel booster rockets and the fuel tank.

(*b*) (i) Calculate the total thrust provided by the solid fuel booster rockets and the three main engines.

(ii) Calculate the weight of the shuttle at lift off.

(iii) Calculate the unbalanced force acting on the shuttle at lift off and hence its initial acceleration.

(*c*) The solid fuel booster rockets and large fuel tank are jettisoned when their fuel is used up. Explain why this is done.

(*d*) (i) Name two forces which act against the motion of the shuttle when it initially lifts off.

(ii) Explain why these two forces decrease as the shuttle gains altitude.

(iii) What effect has the decrease of these forces have on the acceleration of the shuttle?

88. Sir Isaac Newton's Third Law of Motion states:

"For every action force there is an equal and opposite reaction force."

(*a*) When a cannon ball is fired from a cannon like the one opposite, the cannon moves backwards. Explain why this happens.

(*b*) If you blow up a balloon and release it, it will demonstrate Newton's 3rd law. Explain how it does this.

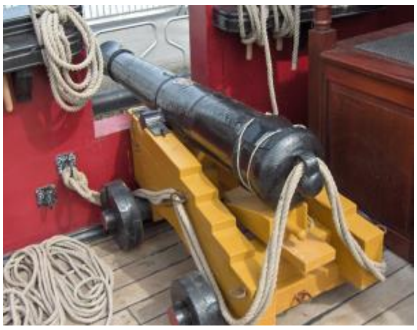


photo by Georges Jansoone

89. A rocket can be made using a 'Rokit' kit and an empty plastic bottle. The bottle is half filled with water and then air pumped in through a tube connected to the bottom of the rocket. When the pressure inside is great enough the tube is forced out from the base of the rocket and the water ejected. Explain why the rocket is propelled upwards when this happens.

90. An astronaut is making a space walk outside a spaceship. He pushes against the side of the spaceship. Which of the following will happen?

The astronaut moves backwards.

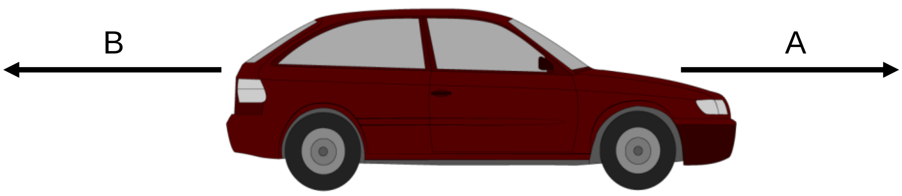
The spaceship moves backwards.

Both the astronaut and spaceship move backwards.

Give reasons for your answer.

Free Fall and Terminal Velocity

91. Look at the diagram of the car below.

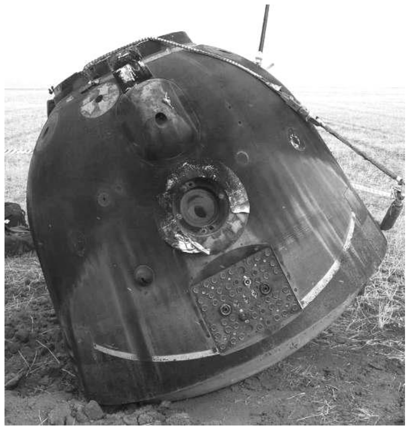


(*a*) Name the two forces represented by the arrows A and B.

(*b*) The car accelerates along a straight road. Eventually the driver finds that the car will go no faster. What can be said about the size of forces A and B at this point?

(*c*) It is said that at this point the car has reached its __________ velocity. What is the missing word?

92. The picture opposite shows a Russian Soyuz space capsule after it has returned to Earth.



(*a*) The capsule's outer shell is badly scorched. Explain why this happens.

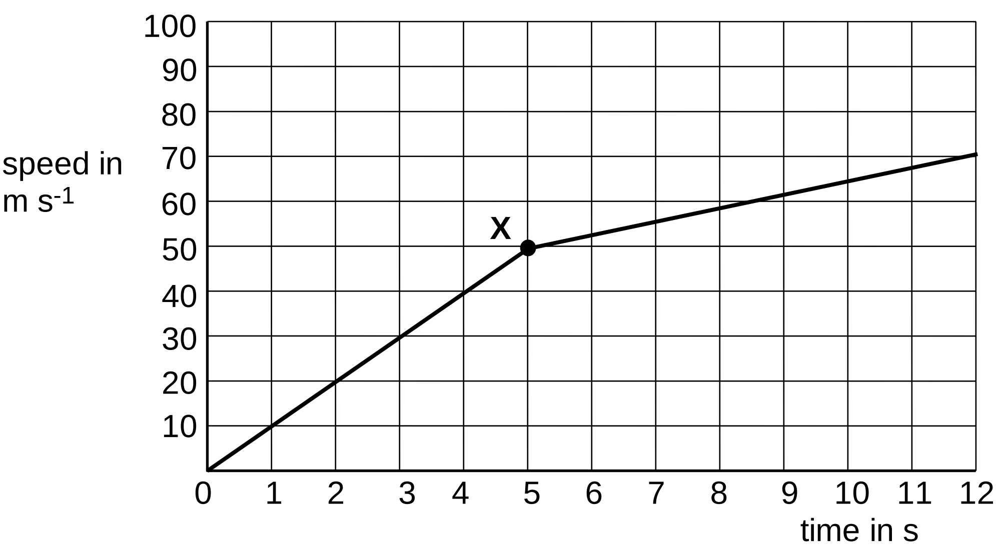
(*b*) The capsule has a very high terminal velocity on entry to the Earth's atmosphere. Explain what is meant by 'terminal velocity'.

(*c*) How is the terminal velocity reduced to a value where the capsule can safely land on solid ground?

Extension Questions

93. An RAF free-fall parachute display team control their rate of descent by altering their body position. In this way they can join up together as part of a display

The speed-time graph for a skydiver is shown below from the time he jumps out of the plane until he links up with other skydivers after 12 s.



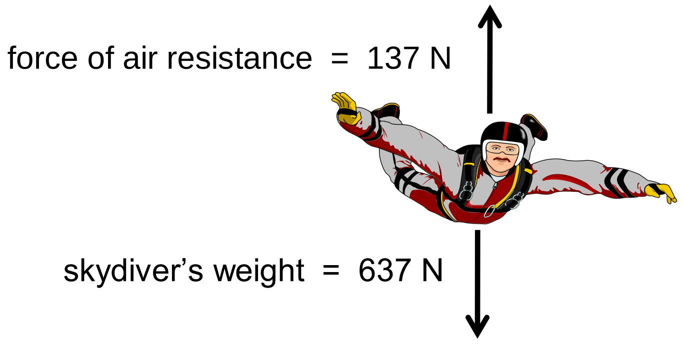
(*a*) Calculate the acceleration of the skydiver between 0 s and 5 s.

(*b*) Calculate the height the skydiver fell during the first 12 s after jumping out of the plane.

(*c*) At point X the skydiver stretches out his arms and legs. Explain the effect this has on his motion.

93. (continued)

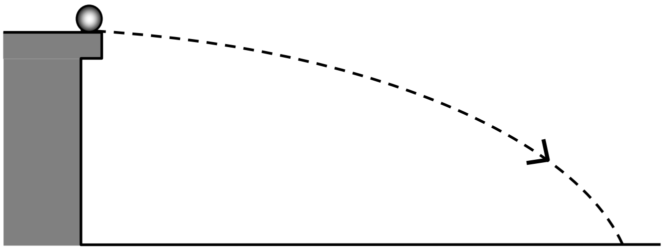
(*d*) The skydiver has a mass of 65 kg. The diagram below shows the forces acting on him as he falls.



Calculate the acceleration of the skydiver.

Projectiles

94. A ball is rolled along the top of a laboratory bench. As it leaves the edge of the bench it is observed to follow a curved path.



(*a*) What name is given to the curved path a falling object can take?

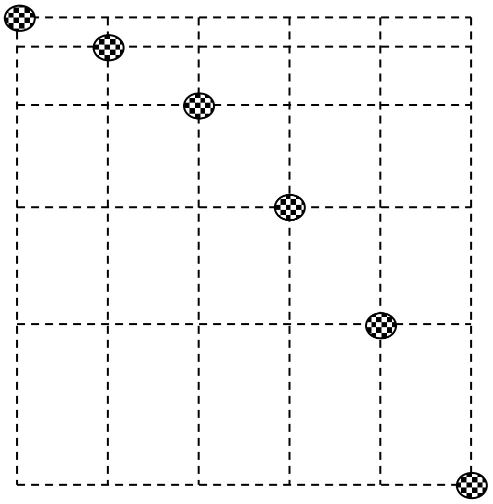
(*b*) Ignoring any effect of air resistance, what forces are acting on the ball

(i) horizontally;

(ii) vertically.

(*c*) Use your answers to (*b*) above to explain why the ball follows a curved path.

95. The picture opposite shows a strobe photograph of a projectile. The dotted lines show the ball's horizontal and vertical positions at equal time intervals.



(*a*) Describe the spacing of the ball

(i) horizontally;

(ii) vertically.

(*b*) Explain the spacing described in (*a*) (i) and (ii).

96. A stone is thrown horizontally from the top of a cliff with a horizontal speed of 5 m s^{-1}.

(*a*) State the initial vertical speed of the stone.

(*b*) After the stone leaves the cliff top, describe its motion in

(i) the horizontal direction;

(ii) the vertical direction.

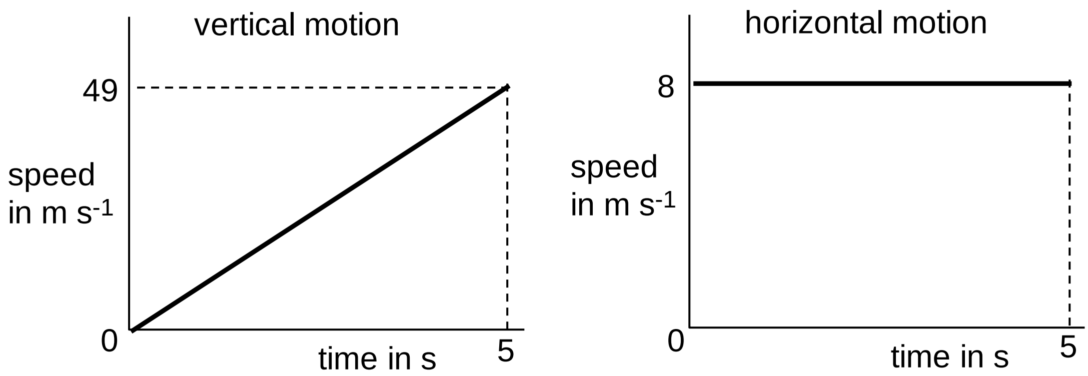
(*c*) The stone lands 25 m from the base of the cliff. Ignoring any effects due to air resistance, calculate the length of time it takes the stone to travel this horizontal distance.

(*d*) State the length of time the stone travels vertically before hitting the ground.

(*e*) (i) State the rate of acceleration of the stone vertically.

(ii) Calculate the final vertical speed of the stone just before it hits the ground.

97. A tennis ball is projected horizontally from a tall building. The graphs below show its horizontal motion and its vertical motion.



(*a*) (i) State the initial vertical velocity of the ball.

(ii) State the final vertical velocity of the ball just before it hits the ground.

(*b*) (i) State the initial horizontal velocity of the ball.

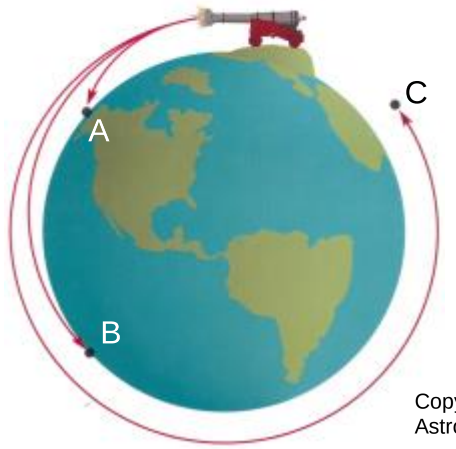
(ii) State the final horizontal velocity of the ball just before it hits the ground.

(*c*) (i) Calculate the vertical distance the ball fell.

(ii) Calculate the horizontal distance the ball travelled.

Satellite motion

98. Newton's 'thought experiment' considers a cannonball fired from the top of a very high mountain.



(*a*) What name is given to the motion of the cannonball as shown in A?

(*b*) The cannonball is fired with a higher horizontal speed.

(i) What change has the higher horizontal speed have on the vertical motion of the cannonball?

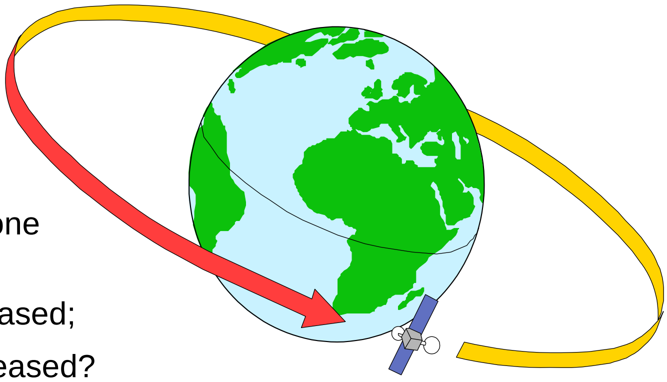
(ii) How does the curve of the Earth affect the time the cannonball is in the air?

(*c*) The horizontal speed of the cannonball is increased further still as shown in C.

(i) What name is given to this motion?

(ii) Explain why the cannonball now has this motion.

99. A satellite is in orbit around the Earth.



(*a*) The satellite orbits the Earth once every 24 hours. What name is given to the time for one complete orbit?

(*b*) What will happen to the time for one complete orbit of the satellite if:

(i) the height of the orbit is increased;

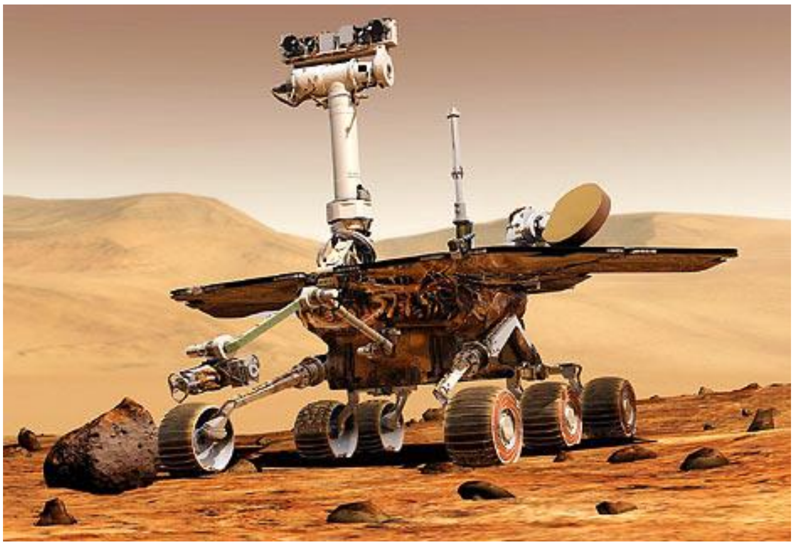
(ii) the height of the orbit is decreased?

(*c*) (i) What name is given to a satellite which always remains above the same point on the Earth's surface?

(ii) State one use for a satellite of this type.

Space exploration

100. The Mars Rover was sent to Mars to explore its surface.



(*a*) Why was the Mars Rover sent on its mission?

(*b*) Describe any of the discoveries made by the Mars Rover which could only have been made by sending a vehicle to Mars.

(*c*) What is the next stage in the exploration of Mars?

101. Read the passage which follows and then answer the questions on the risks and benefits of space exploration.

For thousands of years, men and women have studied the stars and looked at what we call 'space'. Only recently, in the last 60 years, have we had the means to actually go into space, send probes to distant planets and use ever more powerful telescopes. The exploration of space has brought great benefit along with costs and risks.

Benefits

Communication – modern communication uses satellites. Would you be without your mobile phone or Sky television?

Satellite navigation – this is not only used in cars but a whole range of industries including shipping, mining and aviation. The oil industry uses it to accurately position drilling rigs.

101. continued

Jobs – there are thousands of people employed directly by the space industry but there are probably millions who are employed in spin off technology such as satellite communication including mobile phones and television.

Spin off technologies – Many applications that are developed for the space industry have been adopted widely and are now part of everyday life such as bar codes, miniaturised electronics, scratch resistant glasses, industrial materials, cordless power tools, water purification systems – even non-stick coatings for frying pans!

Mapping – satellites are able to accurately map the surface of the earth which aids important industries such as mining and can improve land use.

Weather monitoring –predicting weather patterns and anticipating dangerous hurricanes and tropical storms is now made more accurate and easier through using satellite imaging.

Satisfying our curiosity – finding out more about the universe and our place in it has become possible through the advances in space exploration. In the past 50 years we have sent men to the Moon and probes to distant planets.

Risks and Costs

Pollution of space with debris from satellites and spacecraft. There is a risk that some debris may fall to Earth and reach the Earth's surface. The risk of being hit is infinitely small though

Danger to life – several astronauts have lost their lives in both the Apollo Moon missions and shuttle missions.

Cost – the budget for space exploration is high. Could that money be better spent elsewhere?

Answer these questions on the passage above.

(*a*) How long ago did space exploration begin?

(*b*) How are modern communication systems dependent on space?

(*c*) Are more people employed in the space industry directly or in jobs which depend upon space 'spin-offs'?

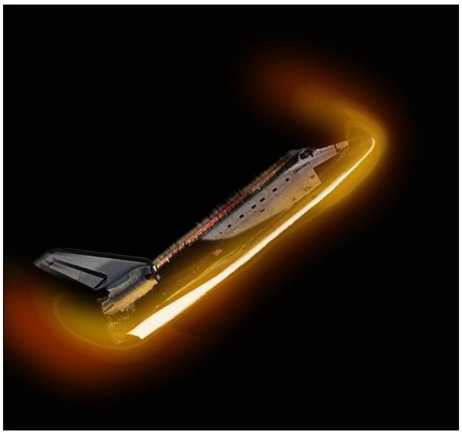
(*d*) How do modern maps of the earth depend upon the exploration of space?

(*e*) The furthest man has travelled so far into space is to the Moon.

(i) Find out some facts about the Apollo 11 mission—the first mission to the Moon.

(ii) It is hoped to send a manned mission to the planet Mars. Investigate some of the difficulties of such a mission.

Re-entry and Heat



102. When the shuttle enters the atmosphere it does so at an angle. This helps to slow it down but generates a lot of heat.

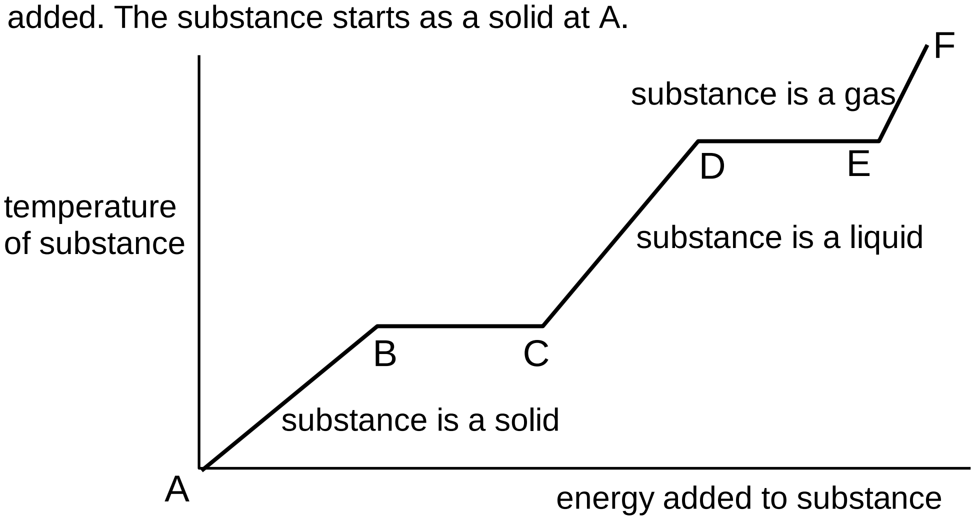
(*a*) Why is so much heat generated when the shuttle enters the Earth's atmosphere?

(*b*) How is the shuttle protected from the intense heat?

103.

The space shuttle Columbia was destroyed when it broke up re-entering the Earth's atmosphere on the return from its mission. A piece of foam is believed to have hit the tiles on the edge of one of the shuttle's wings. Explain why this may have led to the disaster.

104. A block of a solid substance is heated till it turns to liquid then to a vapour. The graph below shows its temperature against the energy added. The substance starts as a solid at A.



(*a*) What is happening to the substance between:

(i) B and C

(ii) D and E?

(*b*) What is happening to the energy being added to the substance between B and C and D and E?

(*c*) What name is given to the heat absorbed when there is a change of state?

105. State a formula linking heat energy, latent heat and mass.

106. (*a*) What name is given to the latent heat when a solid turns into a liquid or vice versa?

(*b*) What name is given to the latent heat when a liquid turns into a gas or vice versa?

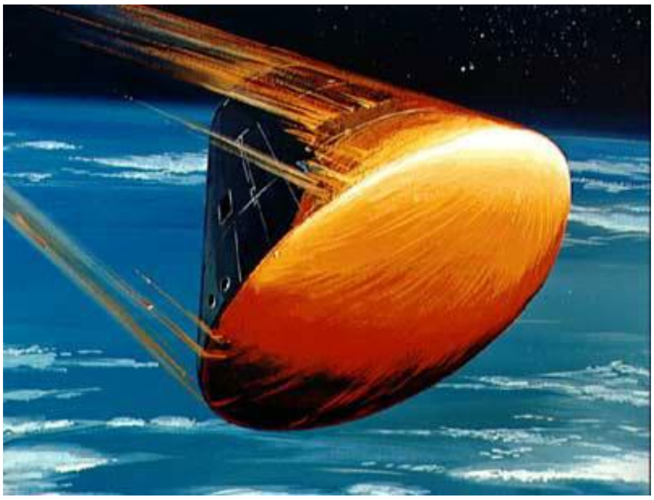
107. Calculate the missing values in the table below.

Heat Energy	***Mass***	***Latent Heat***
(*a*)	2 kg	$11{\cdot}2 \times 10^5$ J kg^{-1}
(*b*)	0·5 kg	$3{\cdot}34 \times 10^5$ J kg^{-1}
36 000 J	0·01	(*c*)
$3{\cdot}0 \times 10^7$ J	30 kg	(*d*)
$3{\cdot}6 \times 10^6$ J	(*e*)	$1{\cdot}8 \times 10^5$ J kg^{-1}
113 000 J	(*f*)	$22{\cdot}6 \times 10^5$ J kg^{-1}

108. (*a*) Calculate the energy required to convert 3 kg of ice at 0 °C into water at 0 °C. (latent heat of fusion of water = $3{\cdot}34 \times 10^5$ J kg^{-1})

(*b*) Calculate the energy required to convert 3 kg of water at 100 °C into steam at 100 °C. (latent heat of vaporisation of water = $22{\cdot}6 \times 10^5$ J kg^{-1})

109. The Apollo missions to the Moon during the 1970s required the astronauts to return to earth in a capsule like the one shown opposite. The heat shield points towards the Earth and heats up to very high temperatures where it undergoes a process called ablation (the heat shield melts and erodes away).



(*a*) What is required to change the state of an object from solid to liquid?

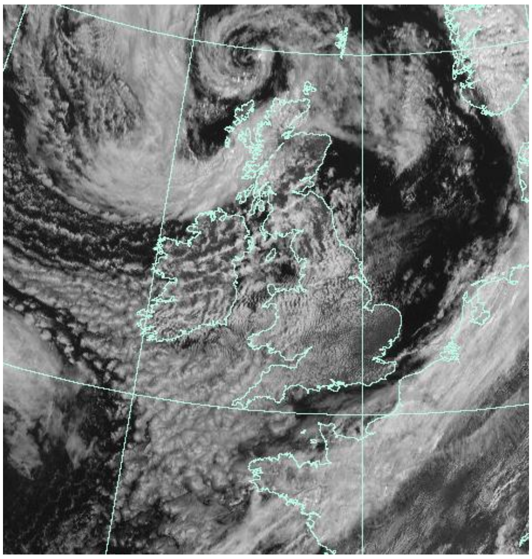
(*b*) Why does the capsule heat up so much during re-entry?

(*c*) Explain how the capsule is prevented from being destroyed during re-entry.

110. When an astronaut is walking on the Moon or in space, he or she has to wear a special protective suit. Explain why this is necessary.

Extension Questions

111. Weather satellites are in orbit around the Earth. Pictures of the weather systems around the globe can be sent back to allow more accurate weather predictions to be made.



(*a*) Explain what is meant by the weather satellite being in orbit around the Earth.

(*b*) A satellite transmits an image of the same part of the Earth all the time. State whether this is a geostationary or orbiting satellite.

(*c*) A satellite is relocated to a higher orbit. How does this affect:

(i) The pull of gravity on the satellite?

(ii) The time for the satellite to make one orbit of the Earth?

112. A flare is fired horizontally from the top of a cliff with a horizontal speed of 40 m s^{-1}. It hits the ground below after 6 s.

(*a*) Ignoring air resistance, state what forces are acting on the flare in:

(i) the horizontal direction;

(ii) the vertical direction.

(*b*) Sketch a graph of the flare's horizontal motion including numerical values on the graph.

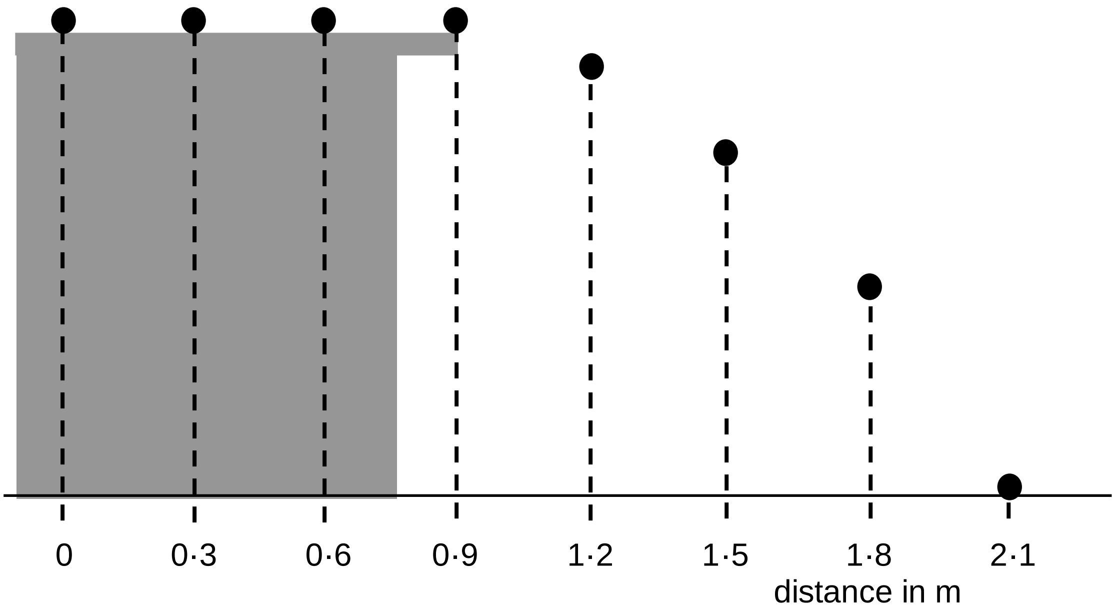
(*c*) (i) State the vertical acceleration of the flare.

(ii) Calculate the final speed of the flare just before it hits the ground.

(iii) Sketch a graph of the flare's vertical motion including numerical values on the graph.

(*d*) Calculate from the graphs you have drawn, the horizontal and vertical distances travelled by the flare.

113. A marble rolls along the top of a bench and then falls to the floor. A series of photographs were taken of the balls motion—each image is 0·1 s apart.



(*a*) By analysing the photograph, find the time it takes from the marble leaving the edge of the bench till it reaches the floor.

(*b*) Calculate the horizontal speed of the marble

(*c*) Calculate the final vertical speed of the marble when it reaches the floor.

114. Read the passage which follows and then answer the questions on the dangers of outer space.

Outer space is a very unpleasant place to be. It is hard to get up there in the first place but once you are there, you have to be protected from all the dangers that are surround you. This is largely accomplished through wearing a specially designed space suit.

What would happen if you left a spacecraft and forgot to put your spacesuit on?

Space is a vacuum so there is no oxygen there. As a result you would lose consciousness very quickly. Worse will happen however, due to this lack of an atmosphere. As there is no air pressure acting on your body, dissolved gases in your body would come out of solution and your body fluids would start to boil. (fluids boil at lower temperatures at lower pressure). The boiling process also removes energy from the body which cools down very rapidly indeed.

Tissues in your body and critical organs such as the heart will swell up and expand due to the boiling fluids. Death would be very quick but agonisingly painful.

There would be extremes of temperature. Parts of your body in direct sunlight would experience very high temperatures whilst those in the shade would be extremely cold.

Your body would be bombarded by radiation and charged particles from the Sun. The Earth's atmosphere filters most of the harmful radiation out before it reaches the Earth's surface but there would be no protection in space.

If all of the above have not already killed you, there is a strong risk that you would be hit by tiny particles of dust or rock that are moving at very high speeds. You might even be hit by debris or 'space junk' from the many satellites and spacecraft that have been abandoned in space.

(*a*) Why would the fluids in your body 'boil' in outer space?

(*b*) (i) Calculate the kinetic energy of a speeding bullet which has a mass of 0·004 kg (4 g) travels at 600 m s^{-1}.

(ii) Calculate the kinetic energy of a tiny particle space debris which has a mass of 1×10^{-5} kg (0·01 g) and is travelling at 10×10^{3} m s^{-1}. (10 km per s)

(iii) Explain why being hit by the space debris is more dangerous than being hit by the bullet.

(*c*) Spacesuits have circulating water to keep the body temperature constant. Why is this required.

Cosmology

The Universe

115. Astronomers us the term a ‘light year’. Explain what is meant by the term a ‘light year’.

116. Light travels at 3×10^8 m s^{-1}. Calculate the distance that light will travel in one year.

117. Calculate the distance the Sun is from the Earth if it takes light 8·5 minutes to travel to the Earth.

118. The nearest star to our solar system is Alpha Centauri. Calculate how many light years away it is if it is 4×10^{16} m away.

119. Our solar system lies within the galaxy called the Milky Way. The distance from Earth to the centre of the Milky Way is $2{\cdot}84 \times 10^{20}$ m. How many light years is Earth from the centre of our galaxy?

120. Copy the following terms down then match them against their correct definitions.

Term	***Definition***
(*a*) Solar system -	a body revolving around a planet.
(*b*) Moon -	a body revolving around a star.
(*c*) Planet -	the star at the centre of our solar system.
(*d*) Sun -	a grouping of solar systems.
(*e*) Galaxy -	a ball of burning gas at the centre of a solar system.
(*f*) Universe -	a star and its associated planets.
(*g*) Star -	all the matter that we know of.

121. The most popular theory about the origins of the universe is the ‘Big Bang Theory’.

Describe what is meant by the Big Bang Theory and what evidence there is for it.

Telescopes and waves

122. The electromagnetic spectrum is made up of a number of different types of wave. Match each of the waves below with the appropriate type of detector.

Wave	***Detector***
(*a*) Visible light -	Geiger counter, photographic film.
(*b*) X-rays -	aerial and radio receiver.
(*c*) Radio -	aerial and microwave receiver.
(*d*) Television -	photographic film.
(*e*) Gamma radiation -	IR camera or film.
(*f*) Infrared -	fluorescent material.
(*g*) Ultraviolet -	the eye or photographic film.
(*h*) Microwaves -	aerial and television receiver

123. (*a*) The electromagnetic spectrum is shown below. Copy and complete the diagram to show the missing waves at A, B, C and D.

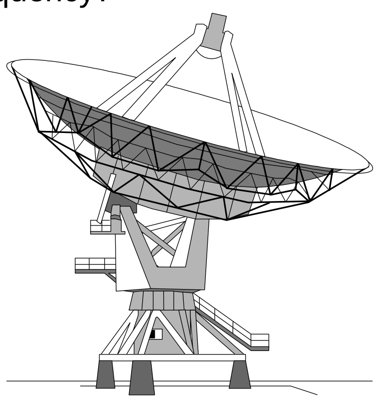
A	TV waves	B	C	visible light	ultraviolet radiation	D	gamma radiation

(*b*) What is the speed of travel of waves from the electromagnetic spectrum when in a vacuum?

(*c*) (i) Which of the waves has the longest wavelength?

(ii) Which of the waves has the highest frequency?

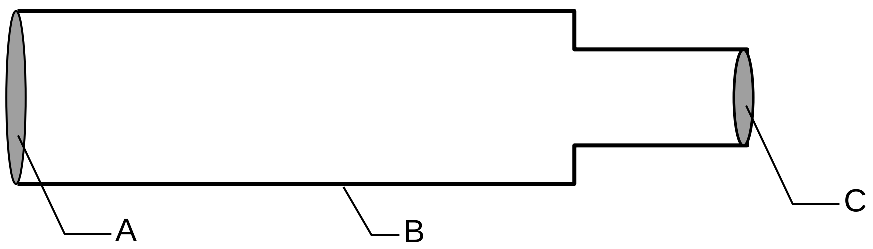
124. (*a*) The illustration opposite shows a special type of telescope. Which part of the electromagnetic spectrum is it designed to detect?



(*b*) The telescope is designed to detect very weak signals. Describe one way in which its design helps to accomplish this.

(*c*) The Hubble telescope is in orbit around the Earth. Why does this allow it to obtain much better images than telescopes situated on the Earth's surface?

125. (*a*) A diagram of a basic refracting telescope is shown below.

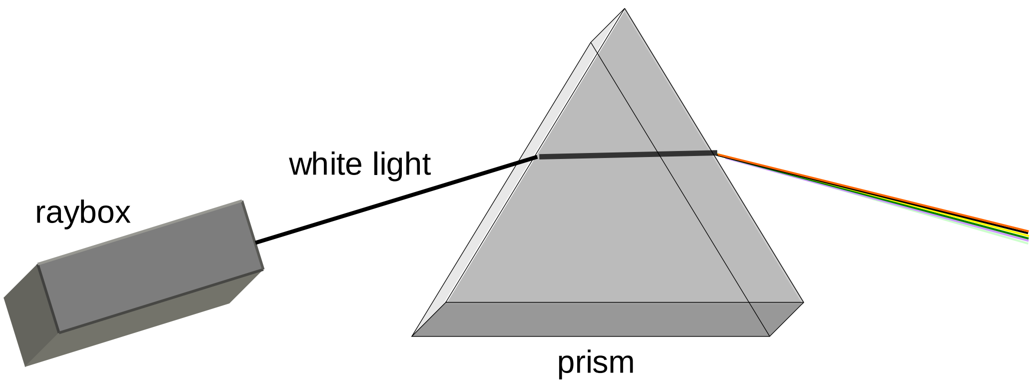


Match the letters, A, B and C, with the following labels:

eyepiece lens objective lens light-tight tube

(*b*) The diameter of the objective lens of the telescope is made larger. What effect has this on the image seen by the observer?

126. A ray of white light is directed into a glass prism as shown below.

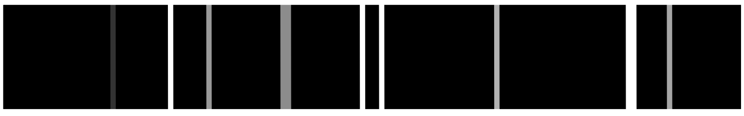


(*a*) Describe what happens to the white light as it passes through the prism.

(*b*) (i) State the component colours of white light.

(ii) Which colour in the visible spectrum has the highest frequency?

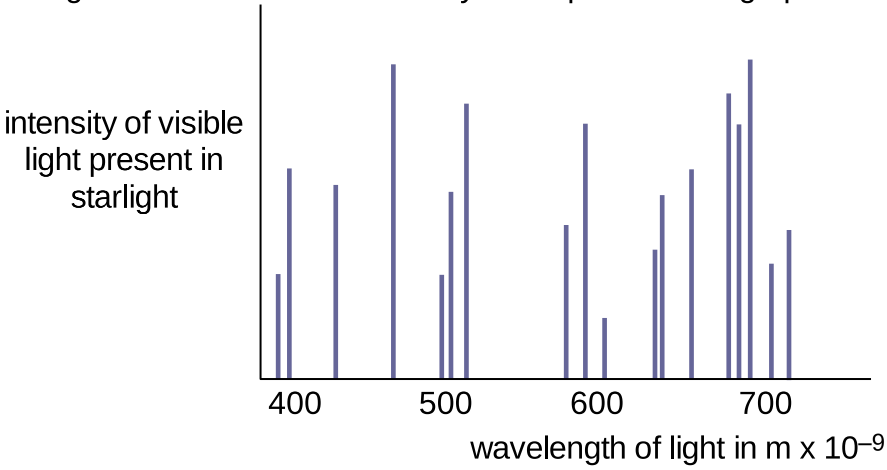
(*c*) The light from a star can be analysed by astronomers by splitting it into its component wavelengths. A line spectrum is produced like the one shown below.



(i) State the difference between a line spectrum and a continuous spectrum.

(ii) What information can astronomers obtain about a star from the line spectrum?

127. The light from a distant star is analysed to produce the graph shown below.



(*a*) What colour of visible light has a wavelength of:

(i) 400×10^{-9} m;

(ii) 700×10^{-9} m?

(*b*) What information can be obtained about a star from the graph above?

EXTENSION QUESTIONS

128. A probe is sent to analyse the atmosphere surrounding a Moon orbiting Saturn. The line spectrum produced is shown below.

spectral lines from moons atmosphere

Use the spectral lines from the elements shown below to identify which are present in the atmosphere sampled.

hydrogen

helium

mercury

nitrogen

129. Read the passage below on a journey through space then answer the questions which follow.

The fastest speed that anything can travel, is at 3×10^8 m s^{-1}. With our current technology, the fastest spaceships only travel at 11 000 m s^{-1}. The Apollo Moon missions took about 3 days to travel from the Earth to the Moon as they only travelled at their maximum speed for a short time. Whilst light will take eight and a half minutes to reach the Earth from the Sun, a spaceship travelling from the Earth to the Sun would have to travel a distance of $1{\cdot}5 \times 10^{11}$ m which would take much, much longer. Not only would the journey take a long time, the spaceship would be exposed to many dangers. The level of ionising radiation would be very high, there would be a risk of being struck by tiny meteorites and there would be extremes of temperature—minus 180 °C in the shade and 115 °C in sunlight—and that is just near the Earth!

The Earth is part of our solar system which orbits the star in the middle—the Sun. The Sun is just one of many stars which are found in the galaxy of which we are part. The galaxy is called the Milky Way and contains 100 000 million other stars. The Milky Way consists of a spiral of stars and is about 1×10^{21} m wide.

The Milky Way is not the only galaxy there is. It is estimated there are hundreds of billions of galaxies. That means there are vast number of stars, some of which will have orbiting planets and some of these may also contain life. The universe itself is probably about 93 billion light years but that's only for what we can observe. Scientists have been able to calculate that the universe is about 13 billion years old and it is constantly expanding. No one knows what lies beyond the edge of the universe.

(*a*) What travels at a speed of 3×10^8 m s^{-1}?

(*b*) If an Apollo space ship could travel at its maximum speed all the time, calculate how long it would take to reach the moon if it was 363 000 000 m away.

(*c*) Calculate the time it would take a spaceship travelling at 11 000 m s^{-1} to travel from the Earth to the Sun.

(*d*) What dangers would a spaceship be exposed to as it left the Earth?

(*e*) In which Galaxy is the Earth found?

(*f*) (i) What is meant by the term 'a light year'?

(ii) How wide is the Milky Way?

(iii) Calculate the number of light years it would take light to travel from one side of the Milky Way to the other.

(*g*) How wide is the observable universe?

Velocity and Displacement

Vectors and Scalars

1. Vectors have magnitude and direction, scalars have magnitude only.

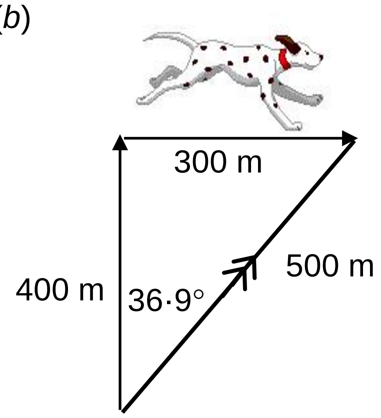
2.

	Quantity	***Vector or Scalar***
(*a*)	force	vector
(*b*)	speed	scalar
(*c*)	velocity	vector
(*d*)	distance	scalar
(*e*)	displacement	vector
(*f*)	acceleration	vector
(*g*)	mass	scalar
(*h*)	weight	vector
(*i*)	time	scalar
(*j*)	energy	scalar

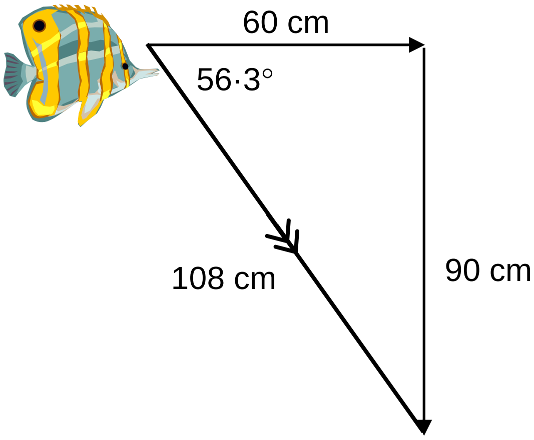
3. (*a*) 250 m
(*b*) 150 m to the right.

4. (*a*) 410 m
(*b*) 250 m to the right.

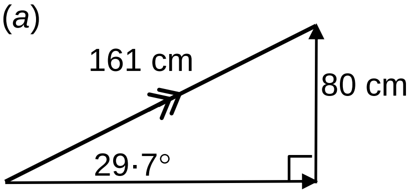
5. (*a*) 700 m
(*b*)



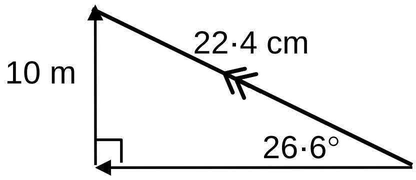
6. (*a*) 150 cm
(*b*)



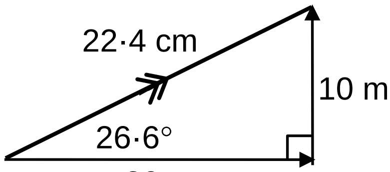
7. (*a*)



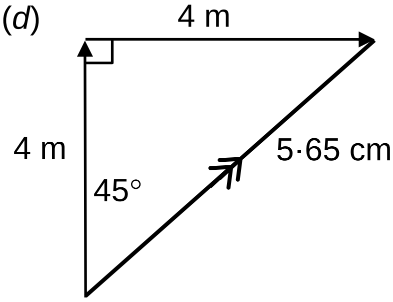
(*b*)



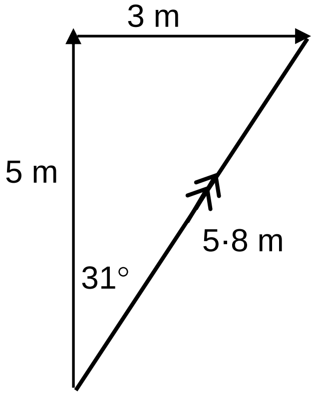
(*c*)



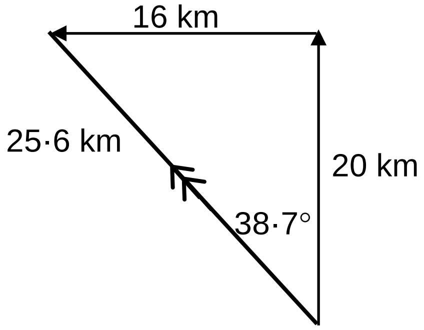
(*d*)



8.

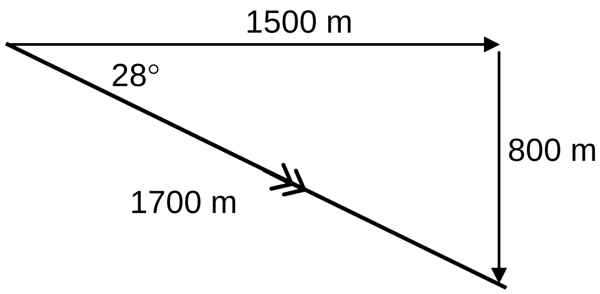


9.



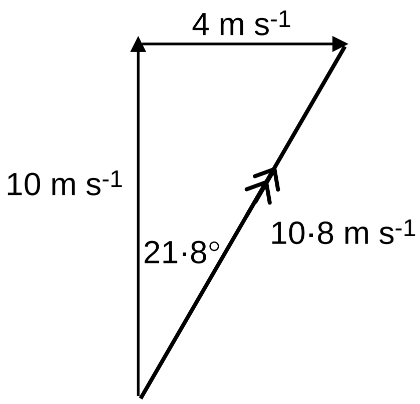
10. (*a*) 2300 m

(*b*)

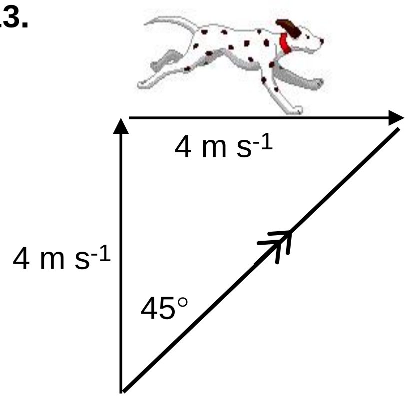


11. 130 m s^{-1} forwards.

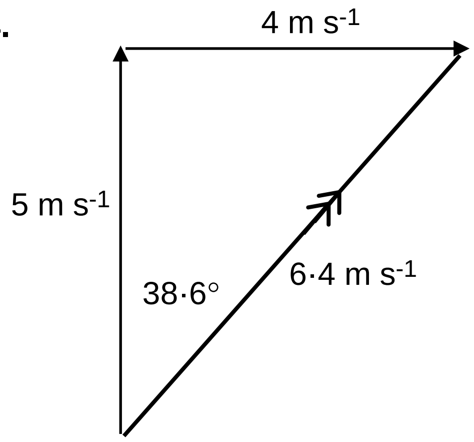
12.



13.

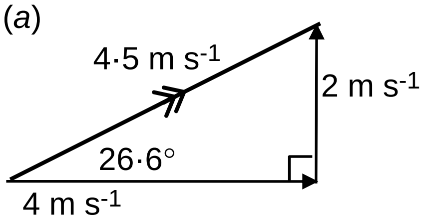


14.

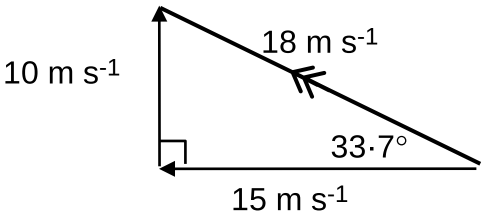


15.

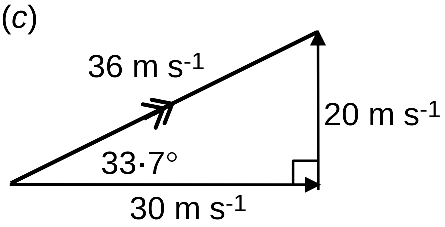
(*a*)



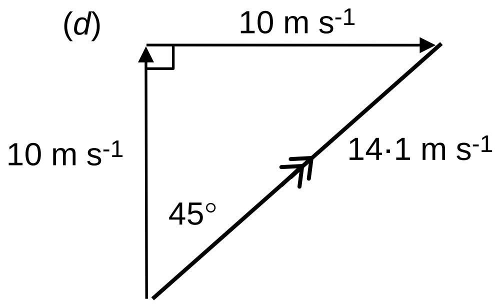
(*b*)



(*c*)



(*d*)



16. 2·6 m s^{-1} at 16·7° to the right.

17. 19·3 m s^{-1} at 21·3° to the east.

18. 4·03 m s^{-1} at 60·3° to the east.

Average and Instantaneous Speed

19. A Average
B Instantaneous
C Instantaneous
D Instantaneous
E Average

20. Measure the length of the track to find the distance she runs. Someone stands at the finish line with the stopwatch. When the race is started the stopwatch is started and stopped when the girl crosses the finish line. Speed is calculated from the distance of the race divided by the time the runner took.

21. $d = v \times t$ or $v = \frac{d}{t}$

22. (*a*) 2·5 m s^{-1}
(*b*) 50 m s^{-1}
(*c*) 15 s
(*d*) 30 s
(*e*) 960 m
(*f*) 36 m

23. 0·8 s

24. (*a*) 14·3 m s^{-1}
(*b*) 800 s

25. 33·3 m s^{-1}

26. 480 m s^{-1}

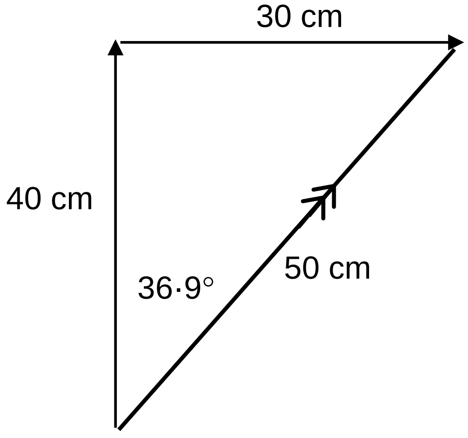
27. 36 000 m (36 km)

28. 0·75 hours or 45 minutes.

Extension Questions

29. (*a*) (i) 160 m
(ii) 4·57 m s^{-1}
(*b*) (i) 80 m forwards along the track.
(ii) 2·3 m s^{-1} forwards along the track.
(*c*) (i) 0 m
(ii) 0 m s^{-1}

30. (*a*) (i) 70 cm
(ii) 10 cm s^{-1}
(*b*) (i)



(ii) 7·1 cm s^{-1}

Speed-Time Graphs

31. B rest,
D travelling at a constant speed,
A slowing down,
C speeding up.

32. (*a*) (i) 3 m s^{-1}
(ii) 9 m s^{-1}
(*b*) 48 m

33. (*a*) 0-10 s cyclist accelerates, 10-40 s cyclist travels at a constant speed.
(*b*) 140 m
(*c*) 3·5 m s^{-1}

34. 40 m

35. (*a*) Accelerates for 40 s then slows down for 10 s.
(*b*) 125 m

Light Gates and Acceleration

36. The vehicle passes through the light gate. As it does so the card blocks the beam of light to the photocell. The computer measures the time the light is blocked. Speed can be calculated from the length of the card divided by the time the beam is blocked.

37. (*a*) $\text{acceleration} = \dfrac{\text{final speed - initial speed}}{\text{time taken for change}}$ or $a = \dfrac{v - u}{t}$

(*b*) The two cards give two speeds, an initial speed and a final speed. The computer also records the time interval between the two cards passing through the light gate.
(*c*) The single card gives an initial speed as it passes through the the first light gate and a final speed as it passes through the second light gate. The time between passing through each light gate is also recorded by the computer.

38. $v = u + at$

39. (*a*) 4 m s^{-2}
(*b*) 5 m s^{-2}
(*c*) 100 m s^{-1}
(*d*) 35 m s^{-1}
(*e*) 30 m s^{-1}
(*f*) 20 m s^{-1}
(*g*) 11 s
(*h*) 5 s
(*i*) –2 m s^{-2}
(*j*) 20 m s^{-2}

40. 22·2 m s^{-2}

41. 14 m s^{-1}

42. 200 s

43. (*a*) 0·5 m s^{-2}
(*b*) 100 s

Acceleration Graphs

44. 0·25 m s^{-2}

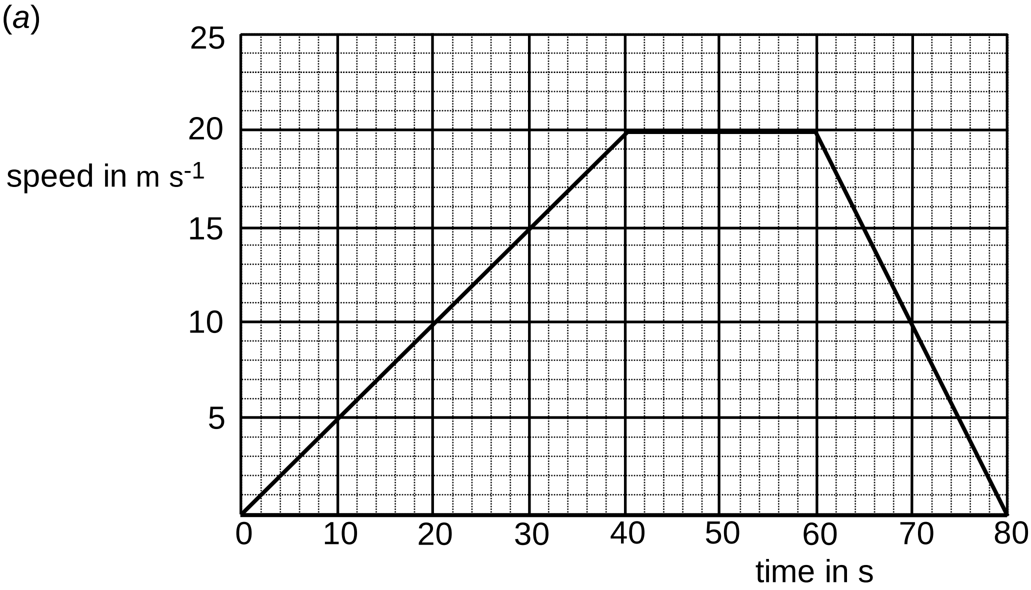
45. (*a*) 0·625 m s^{-2}
(*b*) –1·25 m s^{-2}

46. (*a*) 20 m s^{-2}
(*b*) 6·7 m s^{-2}
(*c*) –40 m s^{-2}

Extension Questions

47. (*a*) (i) 0·75 m s^{-2}
(ii) 0 m s^{-2}
(iii) 1 m s^{-2}
(iv) –2·5 m s^{-2}
(*b*) 28 m

48. (*a*)



(*b*) 0-40 s - 5 m s^{-2}, 40 – 60 s - 0 m s^{-2}, 60 – 80 s - –1 m s^{-2}
(*c*) 1000 m
(*d*) 12·5 m s^{-1}

49. (*a*) A to B – accelerates, B to C – slowing down or negative acceleration.
(*b*) B
(*c*) 4·8 m
(*d*) 4·5 m s^{-1}
(*e*) A to B 10 m s^{-2}, B to C –20 m s^{-2}

50. (*a*) (i) 3 m s^{-1}
(ii) 4 m s^{-1}
(*b*) Skipper
(*c*) (i) 0·75 m s^{-2}
(ii) 2·0 m s^{-2}
(*d*) Tibby had travelled 32 m and Skipper had travelled 27 m so Tibby was ahead.

Newton's Laws

Newtons Laws of Motion – Balanced and unbalanced forces

51. (*a*) There are no unbalanced forces acting on the ball so it remains at rest.
(*b*) There is an unbalanced force exerted by the snooker cue so the ball accelerates in the direction of the force.

52. Its shape, speed and direction of travel can change.

53. (*a*) Negative acceleration of the cyclist.
(*b*) Acceleration of the ball.
(*c*) Cushion changes shape.
(*d*) Negative acceleration of the ball.

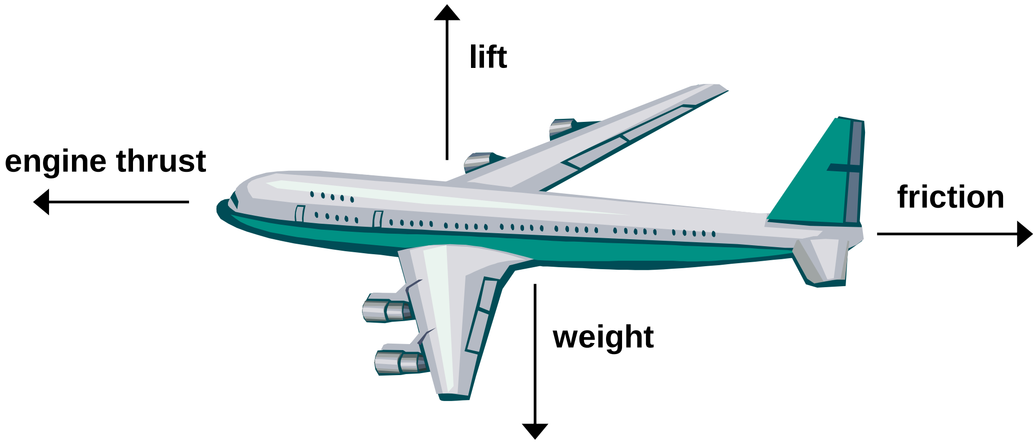
54. (*a*) Ball accelerates in direction of stretched elastic.
(*b*) No unbalanced force so no movement.
(*c*) (i) Balanced forces
(ii) Zero force.

55. (*a*) No.
(*b*) Yes, to the right.
(*c*) Yes, to the right.
(*d*) Yes, to the left.
(*e*) No.
(*f*) Yes, to the right.

56. (*a*) Balanced.
(*b*) Now unbalanced.
(*c*) (i) Balanced.
(ii) Air resistance, friction between tyres and road, friction in the engine and other moving parts.

57. (*a*) Friction due to water resistance.
(*b*) The dolphin will travel at a constant speed.

58



59. (*a*) The car will have a greater acceleration due to its smaller mass.
(*b*) The engine producing a larger force will give the car greater acceleration.

60. (*a*) The acceleration will decrease.
(*b*) The car will have greater acceleration.

61. (*a*) 20 N.
(*b*) 100 N
(*c*) 10 m s^{-2}
(*d*) 10 m s^{-2}
(*e*) 5 kg
(*f*) 50 kg

62. 25 N

63. 2400 N

64. 3 m s^{-2}

65. 60 kg

66. (*a*) 2000 N
(*b*) (i) Friction is increased.
(ii) Negative acceleration will be greater.

67. (*a*) 1000 N
(*b*) 0·5 m s^{-2}

68. 7 m s^{-2}

69. (*a*) 100 000 N
(*b*) 100 000 N

70. (*a*) (i) 500 N
(ii) 475 N
(*b*) To the left, towards the teachers.

Work Done, Force and Distance

71. work = force × distance in direction of force $E_w = F d$

72. (*a*) 5 J
(*b*) 2000 J
(*c*) 40 m
(*d*) 0·5 m
(*e*) 10 N
(*f*) 100 N

73. 6·3 m

74. 3 000 000 J

75. (*a*) (i) 50 m
(ii) Converted to heat energy by the brakes.
(*b*) –0·5 m s^{-2}

Weight and Gravity

76. Pupil A should state that weight is measured in newtons
Pupil B makes the correct statement.
Pupil C should state that mass is a measure of the amount of matter in an object.

77. 9·8 N kg^{-1}

78. weight = mass × gravitational field strength $w = m g$

79. (*a*) 9·8 N
(*b*) 4·9 N
(*c*) 39·2 N
(*d*) 1 kg
(*e*) 5 kg
(*f*) 3·06 kg

80. (*a*) Her mass is 50 kg.
(*b*) 490 N

81. 12 740 N

82. (*a*) 7·84 N
(*b*) 1·28 N

83. 5130 N

84. (*a*) It decreases.
(*b*) 11·25 N

85. (*a*) The gravitational field strength will decrease as the rocket moves away from the earth but will increase again as it approaches the Moon.
(*b*) The gravitational fields of the Earth and the Moon pull in opposite directions. The Moon's is much weaker so at a point nearer the Moon they will balance each other out.

Extension questions

86. (*a*) 644 N
(*b*) (i) 588 N
(ii) 1560 N
(*c*) 7 kg
(*d*) 56·5 N

Newton's Laws and Space Flight

87. (*a*) 1 460 000 kg
(*b*) (i) 29 400 000 N or 29 400 kN
(ii) 14 308 000 N
(iii) Unbalanced force = 15 092 000 N, acceleration = 10·34 m s^{-2}
(*c*) To reduce the mass of the shuttle as the rockets are no longer providing any thrust.
(*d*) (i) Air resistance and gravity.
(ii) The atmosphere gets thinner and gravitational field strength decreases.
(iii) The acceleration will increase.

88. (*a*) The exploding gunpowder pushes the cannonball forwards and the cannon backwards with the same force.
(*b*) The air escaping from the balloon is pushed backwards and an equal and opposite force pushes the balloon forwards.

89. The water is pushed downwards out of the rocket which causes an equal and opposite force on the rocket upwards.

90. Both the astronaut and the spaceship move backwards as there is an equal an opposite force on both no matter who pushed.

Free Fall and Terminal Velocity

91. (*a*) A represents force from engine and B represents air resistance and friction.
(*b*) The forces will be equal and opposite.
(*c*) Terminal.

92. (*a*) The heat generated by the friction with the air at high speed heats the outside of the capsule to a high temperature.
(*b*) Their maximum speed reached when all the forces are balanced and there is no acceleration.
(*c*) Parachutes are deployed to increase the amount of air resistance.

Extension Questions

93. (*a*) 10 m s^{-2}
(*b*) 545 m
(*c*) As there is now more air resistance, this slows down his rate of acceleration.
(*d*) 7·7 m s^{-2}

Projectiles

94. (*a*) Projectile path
(*b*) (i) None
(ii) Gravity
(*c*) As the ball travels forwards at a constant velocity it simultaneously accelerates downwards.

95. (*a*) (i) Equal distances.
(ii) Increasing distances.
(*b*) The ball has no unbalanced forces acting on it in the horizontal direction but there is an unbalanced force due to gravity acting in the vertical direction.

96. (*a*) 0 m s^{-1}.
(*b*) (i) Constant speed.
(ii) Acceleration.
(*c*) 5 s
(*d*) 5 s
(*e*) (i) 9·8 m s^{-1}
(ii) 49 m s^{-1}

97. (*a*) (i) 0 m s^{-1}
(ii) 49 m s^{-1}
(*b*) (i) 8 m s^{-1}
(ii) 8 m s^{-1}
(*c*) (i) 122·5 m
(ii) 40 m

Satellite motion

98. (*a*) Projectile
(*b*) (i) It does not affect it.
(ii) The cannonball takes longer to reach the Earth's surface.
(*c*) (i) Satellite motion.
(ii) The surface of the Earth is moving away from the cannonball as quickly as the cannonball descends towards the Earth.

99. (*a*) The period of the orbit.
(*b*) (i) It will take longer.
(ii) It will take less time.
(*c*) (i) A geostationary satellite.
(ii) Telecommunications, transmitting TV signals, weather observation.

Space exploration

100. (*a*) To explore the surface of Mars.
(*b*) The Mars Rover was able to photograph the surface of Mars. It was able to find evidence that there had once been liquid water on Mars.
(*c*) To send a manned mission to Mars.

101. (*a*) 60 years ago.
(*b*) Satellites are used to allow mobile phones to function and for the transmission of satellite broadcasts such as Sky television.
(*c*) There are many more employed in industries which are 'spin-offs' of space exploration.
(*d*) Satellites high above the Earth can accurately map the ground below.

Re-entry and Heat

102. (*a*) There is a lot of friction with the Earth's atmosphere due to the high speed of the shuttle.
(*b*) It is covered in heat resistant tiles which are thicker on the underside where most heat is produced.

103. The edge of the wing will have become very hot and been so badly damaged that it caused the shuttle to break up.

104. (*a*) (i) It is turning from a solid into a liquid ie. melting.
(ii) It is turning from a liquid into a gas ie. vaporising.
(*b*) It is going into changing the state of the substance rather than increasing its temperature.
(*c*) Latent heat.

105. Heat energy = mass $\times$ latent heat

106. (*a*) Latent heat of fusion.
(*b*) Latent heat of vaporisation.

107. (*a*) $2{\cdot}24 \times 10^6$ J
(*b*) 167 000 J
(*c*) $3{\cdot}6 \times 10^6$ J kg^{-1}
(*d*) $1{\cdot}0 \times 10^6$ J kg^{-1}
(*e*) 20 kg
(*f*) 0·05 kg

108. (*a*) $10{\cdot}02 \times 10^5$ J
(*b*) $67{\cdot}8 \times 10^5$ J

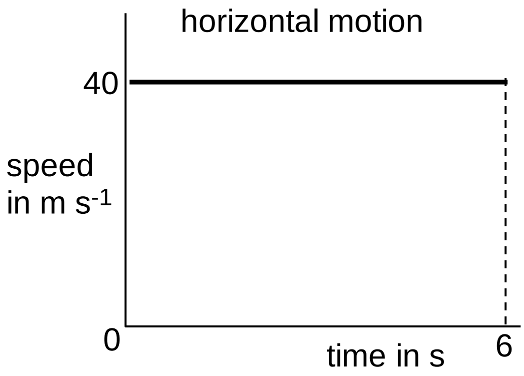
109. (*a*) Heat energy.
(*b*) Its high speed causes a lot of friction with the Earth's atmosphere.
(*c*) The heat energy is absorbed by the heat shield causing it to melt.

110. The astronaut needs to have an environment to supply him or her with a breathable atmosphere as space is a vacuum. The suit must also protect them from extremes of temperature and from cosmic radiation.

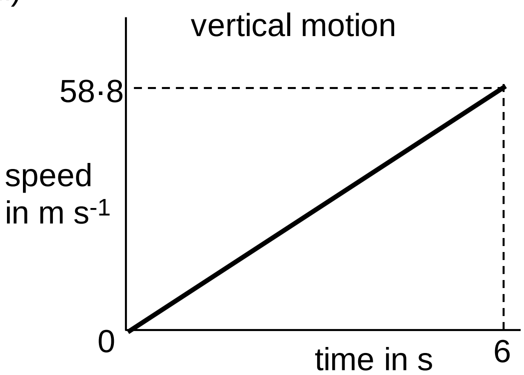
Extension Questions

111. (*a*) The satellite is in orbit at a fixed height above the Earth's surface.
(*b*) Geostationary satellite.
(*c*) (i) The pull of gravity is less.
(ii) The time taken to make one orbit will increase.

112. (*a*) (i) None
(ii) Gravity
(*b*)



(*c*) (i) 9·8 m s^{-2}
(ii) 58·8 m s^{-1}
(iii)



(*d*) Horizontal distance = 240 m, vertical distance = 176·4 m

113. (*a*) 0·7 s
(*b*) 3 m s^{-1}
(*c*) 29·4 m s^{-1}

114. (*a*) There is no atmosphere so fluids boil at lower temperatures and there are extremes of heat.
(*b*) (i) 720 J
(ii) 500 000 J.
(iii) The space debris contains much more kinetic energy.
(*c*) The temperature in space fluctuates through extremes of temperature and the human body has to be kept at a constant temperature.

Cosmology

The Universe

115. It is the distance that light will travel in one year.

116. $9{\cdot}46 \times 10^{15}$ m

117. $1{\cdot}53 \times 10^{11}$ m

118. 4·2 light years

119. 30 021 light years

120.

Term	***Definition***
(*a*) Solar system -	a star and its associated planets.
(*b*) Moon -	a body revolving around a planet.
(*c*) Planet -	a body revolving around a star.
(*d*) Sun -	the star at the centre of our solar system.
(*e*) Galaxy -	a grouping of solar systems.
(*f*) Universe -	all the matter that we know of.
(*g*) Star -	a ball of burning gas at the centre of a solar system.

121. The Big Bang tries to explain the beginning of the universe as we know it. It is a process of expansion in our universe that is still going on today and started with a very small concentration of matter at extremely high density and temperatures called a singularity. The dense mass contained only hydrogen and a small amount of helium. it began expanding rapidly outward. The first stars were probably formed when the universe was 200 million years old as matter began to form into stars and planets.

Evidence for the Big Bang theory:
Red shift – all objects in the universe are moving away from each other. Evidence for this is provided by the shift in the spectrum of distant stars towards the red end of the spectrum due to the Doppler effect.

Cosmic Microwave Background
The relatively uniform background radiation is the remains of energy created just after the Big Bang.

Quantity of Hydrogen and Helium in the universe
The composition of the universe has been measured and found to be along with 1% of the more interesting These are the values predicted by the big bang model.

Telescopes and waves
122.

Wave	***Detector***
(*a*) Visible light -	the eye or photographic film.
(*b*) X-rays -	photographic film.
(*c*) Radio -	aerial and radio receiver.
(*d*) Television -	aerial and television receiver
(*e*) Gamma radiation -	Geiger counter, photographic film.
(*f*) Infrared -	IR camera or film.
(*g*) Ultraviolet -	fluorescent material.
(*h*) Microwaves -	aerial and microwave receiver.

123. (*a*) A – radio waves
B - microwaves
C - infrared
D – X rays
(*b*) 3×10^{8} m s^{-1}
(*c*) (i) Radio waves.
(ii) Gamma radiation.

124. (*a*) Radio waves
(*b*) It has a very large dish.
(*c*) There is no atmosphere to block or distort the images received.

125. (*a*) A - objective lens
B - light-tight tube
C - eyepiece lens
(*b*) The image will be brighter.

126. (*a*) It splits into its component colours or wavelengths.
(*b*) (i) Red, orange, yellow, green, blue, violet.
(ii) Violet
(*c*) (i) A continuous spectrum has every wavelength present. A line spectrum has only a number of wavelengths present.
(ii) The elements present in the star.

127. (*a*) (i) Red light.
(ii) Violet light
(*b*) The elements present in the star.

EXTENSION QUESTIONS

128. Helium and nitrogen.

129. (*a*) Light and other waves in the electromagnetic spectrum.
(*b*) 9·17 hours.
(*c*) 158 days
(*d*) Cosmic radiation, extremes of temperature and space debris and small meteorites.
(*e*) The Milky Way.
(*f*) (i) The distance light travels in one year.
(ii) 1×10^{12} m
(iii) 105 699 light years.
(*g*) This is impossible to say as it is constantly expanding.