Speed and Acceleration

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
d = distance measured in metres
t = time measured in seconds

Worked example
A car travels from Aberdeen to Stonehaven, a distance of 24 kilometres. Calculate the average speed of the car in metres per second if it takes 15 minutes to complete the journey.

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

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

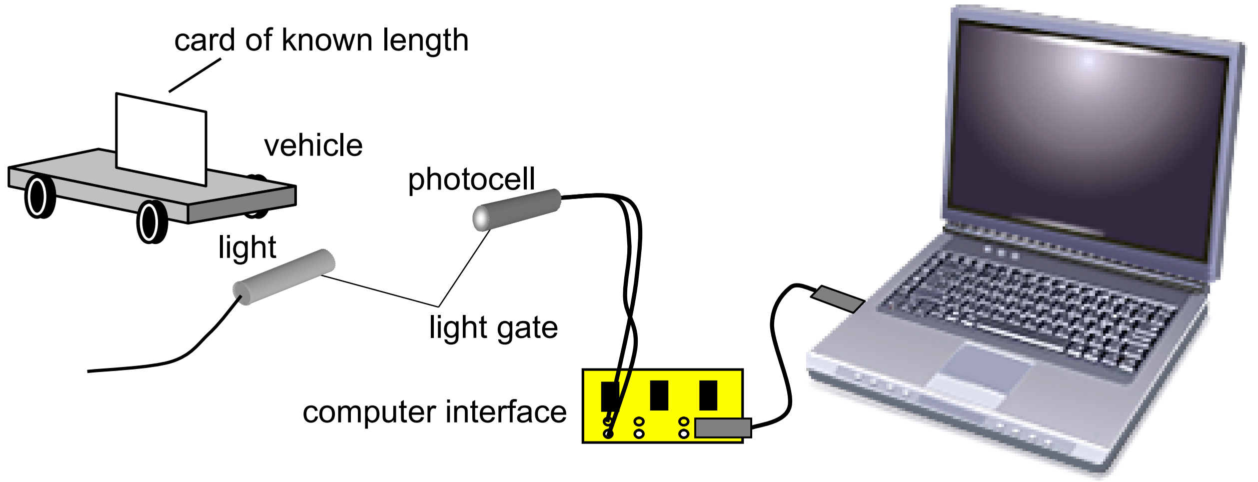
$$v = 26 \cdot 7 \text{ metres per second}$$

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. 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). Acceleration can be calculated using the formula below.

$$\text{acceleration} = \frac{\text{change in speed}}{\text{time taken for change}} \quad \text{or} \quad a = \frac{\Delta v}{t}$$

where a = acceleration measured in metres per second per second
Δv = change in speed measured in metres per second
t = time measured in seconds

Worked example
A cheetah can accelerate from rest to 24 metres per second in 3 seconds. Calculate its acceleration.

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

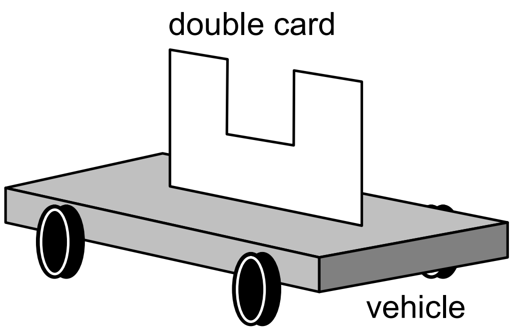
$$a = \frac{24}{3}$$

$$a = 8 \text{ metres per second per second}$$

Using Light Gates to Measure Acceleration

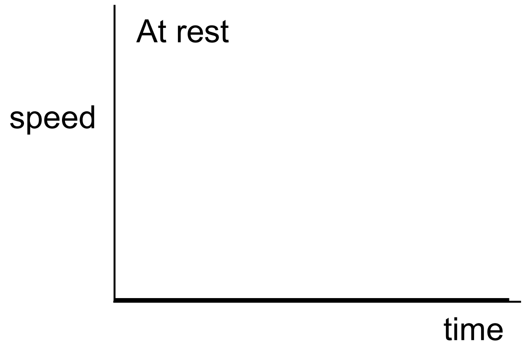
Just as light gates can be used to measure speed, light gates can be used to measure acceleration also.

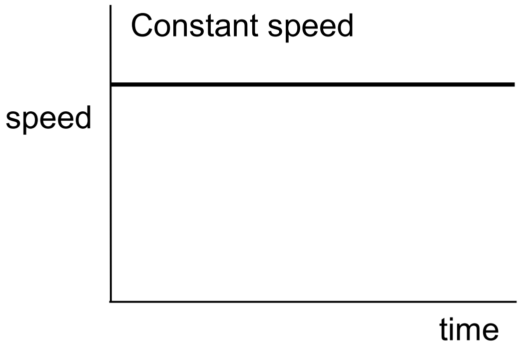
To calculate acceleration you need to know an initial speed and a final speed. This is achieved by using a double card. The same effect can also be achieved by using a single card and two light gates.

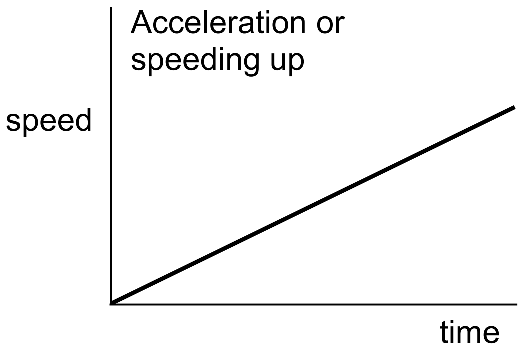


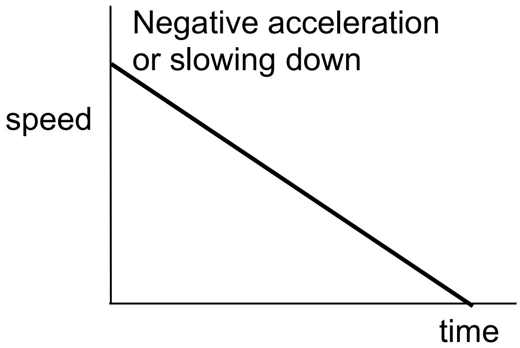
Speed-Time Graphs

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

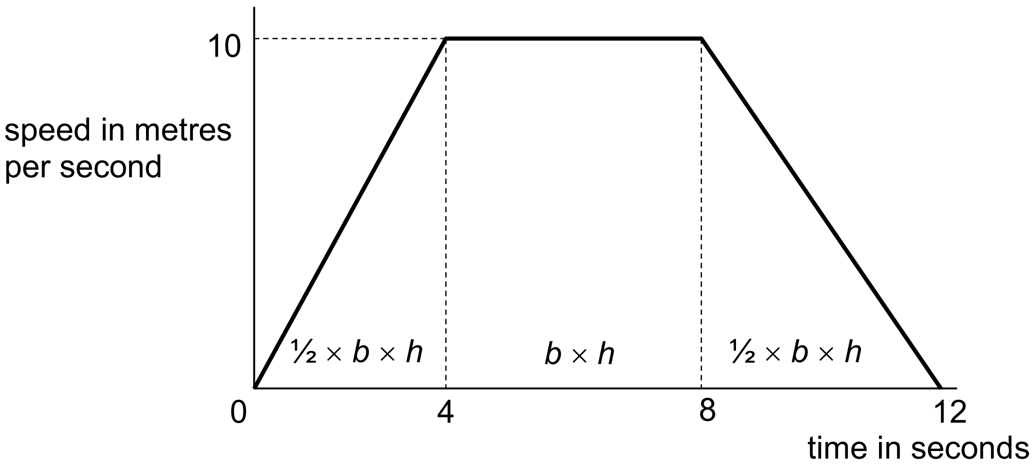








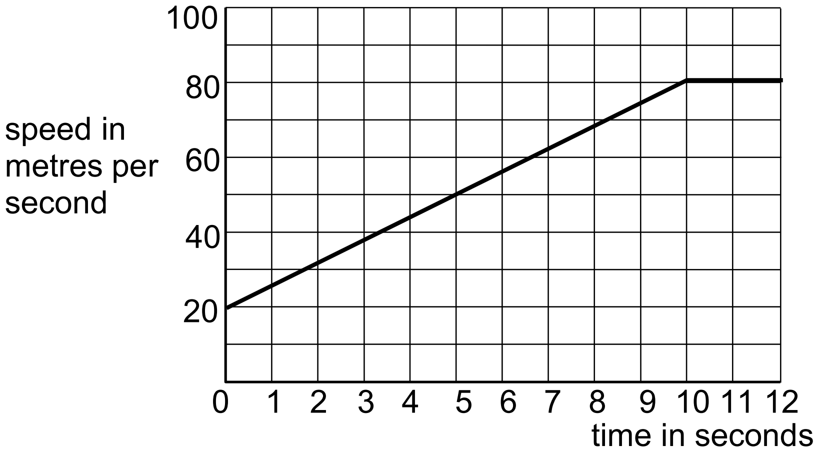
A speed time graph can tell us how far an object has travelled. The distance travelled is equal to the area under the graph. The graph can be split into sections and the area of each calculated. The sum of these is equal to the distance travelled.



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

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 metres per second to 80 metres per second in a time of 10 seconds as shown in the graph below. Calculate its acceleration between 0 seconds and 10 seconds.



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

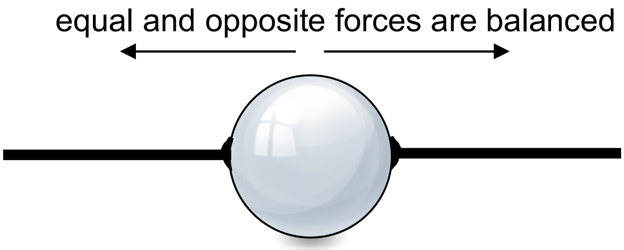
$$a = \frac{60}{10}$$

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

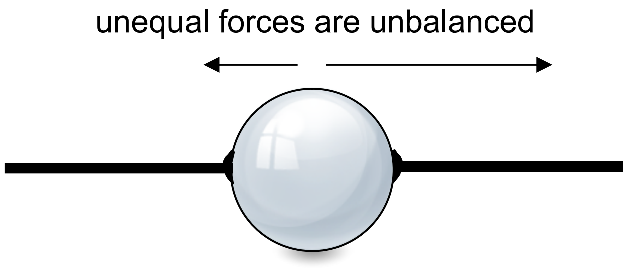
Forces, Motion and Energy
Force is measured in newtons. When a force is applied to an object it can change its shape, its speed or its direction of travel.

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.



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 newtons. Total force to the left = 12 newtons.
Resultant force = 3 newtons 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
m = mass measured in kilograms
a = acceleration measured in metres per second per second

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 newtons. The forces of friction acting on the cyclist are 60 newtons.

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

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

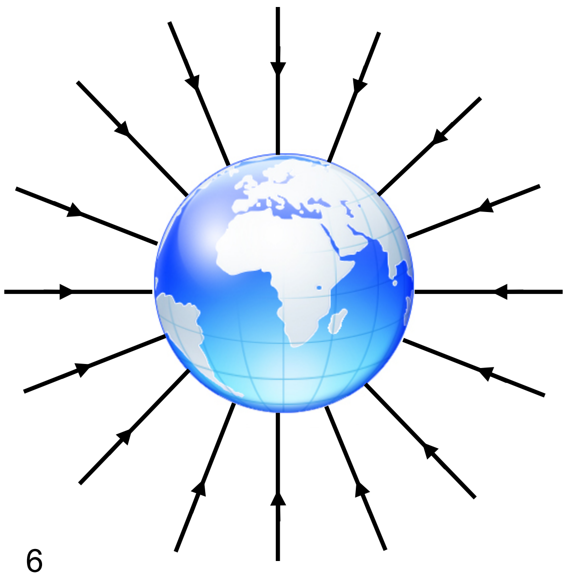
(*a*) Resultant force = 200 – 60 = 140 N.

(*b*)

$$F = m \times a$$
$$140 = 70 \times a$$
$$a = \frac{140}{70}$$
$$a = 2 \text{ metres per second per second}$$

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 newtons per kilogram 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.

$$\text{weight} = m\,g$$

where weight = is measured in newtons
m = mass measured in kilograms
g = gravitational field strength and is 9·8 newtons per kilogram on Earth

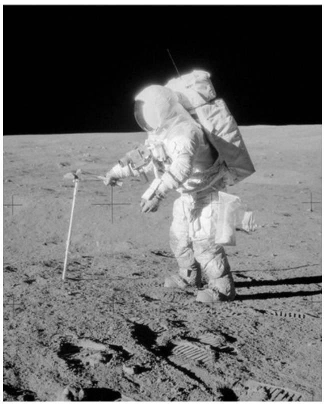
Worked example
A pupil has a mass of 50 kilograms. Calculate her weight.

weight = mass × gravitational field strength
weight = $m\,g$
weight = 50 × 9·8
= 490 newtons

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. The table below shows values of g for the moon and different planets.

Planet	***Gravitational field strength (newtons per kilogram)***
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 kilograms. Calculate the weight of the hammer on the moon.



weight = $m\,g$
weight = 1·2 × 1·6
= 1·92 newtons

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.

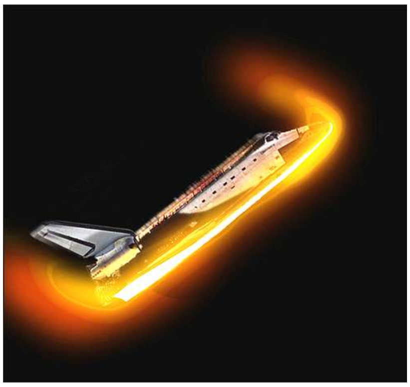
Risks and Costs
Pollution of space with debris from satellites and spacecraft. There is a risk that some debris may fall to Earth and reach the Earth's surface. The risk of being hit is infinitely small though

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.

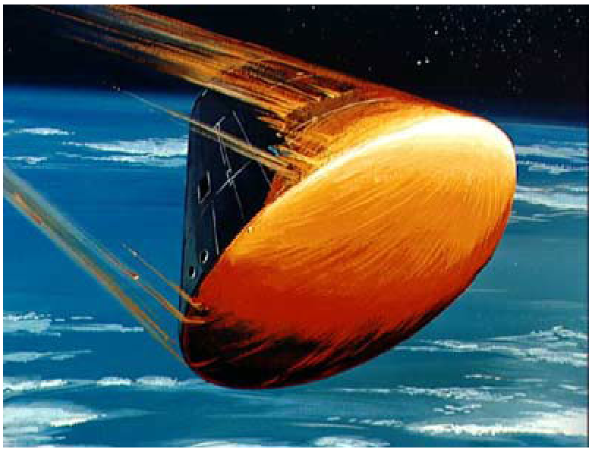
Re-entry and Heat

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.

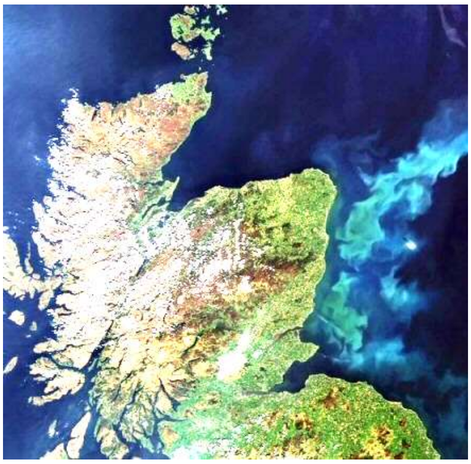


Older spacecraft such as the American Apollo missions and Russian Soyuz missions used a system called ablation to prevent damage to the re-entry modules like the one shown opposite.

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.

Satellites

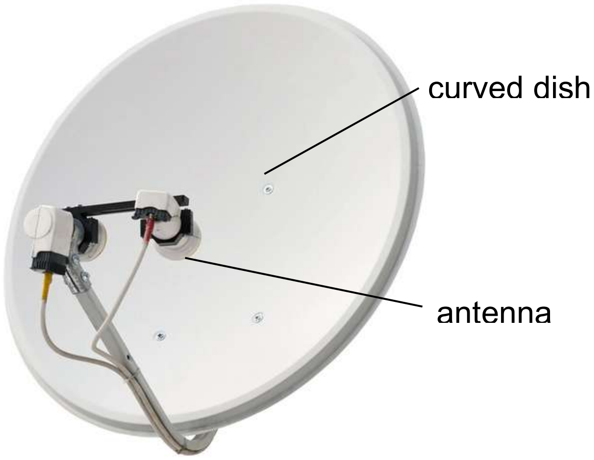
A satellite is in orbit around the Earth and although satellite technology is common now, the first satellite was only launched in 1957.

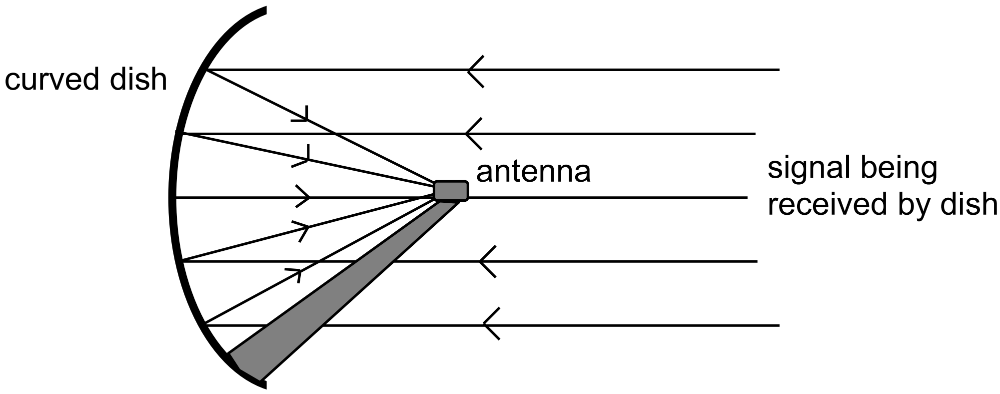


Satellites can be either orbiting or geostationary. Orbiting satellites orbit at a lower height above the Earth's surface and can be used to map the ground, observe weather or be used for military purposes.

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.

Satellites often carry receivers and transmitters which consist of a curved reflector with an aerial or antenna in front. The signals being received by the satellite can be quite weak. The curved dish collects these signals and focuses them onto the antenna. The bigger the dish, the more signals it can collect and the stronger the final signal will be.





Cosmology

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.

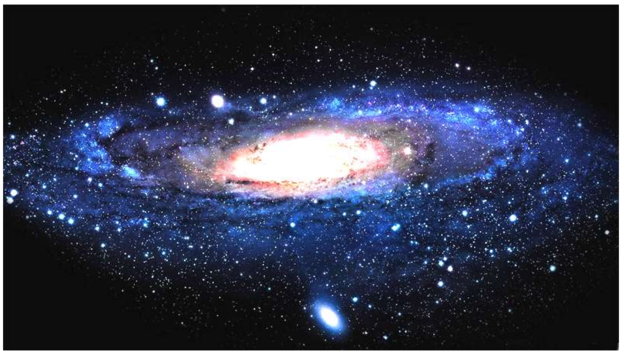
Galaxy - a grouping of solar systems.

Universe - all the matter that we know of.

Exo-planet – a planet outside our solar system.

A light Year

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 300 000 000 metres per second and there are 31 500 000 ($60 \times 60 \times 24 \times 365$) seconds in a year it means that in 1 year light travels 9·5 million million kilometres.

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

Exoplanets

An exoplanet, or extrasolar planet, is a planet outside our Solar System. More than a thousand such planets have been discovered. There are at least 100 billion planets in the Milky Way, with at least one planet on average per star. Around 1 in 5 Sun-like stars have an "Earth-sized" planet which might be able to support life so the nearest would be expected to be within 12 light-years distance from Earth. Astronomers have estimated that there could be as many as 40 billion Earth-sized planets orbiting in the habitable zones of Sun-like stars and red dwarfs within the Milky Way.

Most of the known exoplanets are giant planets—estimated to be the size of Jupiter or Neptune—because the larger and more massive planets are more easily detected.

The discovery of exoplanets leads to the next question—could they support life. In order to support life, conditions on the planet's surface must be right.

Life on Other Planets
For life to exist on other planets they must fulfil certain conditions.

Orbit around the star
Some planets do not have a circular orbit around their star like the Earths. This means that the temperature on the planet's surface can vary between extremes which make it uninhabitable.

Distance of orbit from the Sun
If a planet orbits very close to the Sun it will be too hot to allow life. If its orbit is too far away from the planet it will be too cold for life to survive.

Planet size
Factors such as the size, mass and density of a planet affect its gravitational field strength. If a planet has a high value (Earth's is 9·8 newtons per kilogram) any living organism would need very strong bones to support it—assuming it was large enough to need bones. The gravitational field strength also affects the ability of a planet to hang onto its atmosphere. If it is too low the atmosphere will disappear into space.

Presence of water
Life as we know it requires water so it would have to be present at temperatures which allow it to be in liquid form.

Presence of an atmosphere
Life as we know it requires oxygen in an atmosphere. This has to be at a certain concentration to allow life to develop, too much or too little is a bad thing. The atmosphere also protects life on the planet's surface from harmful radiation from the star.

Speed and Acceleration

Average and Instantaneous Speed

1. 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.

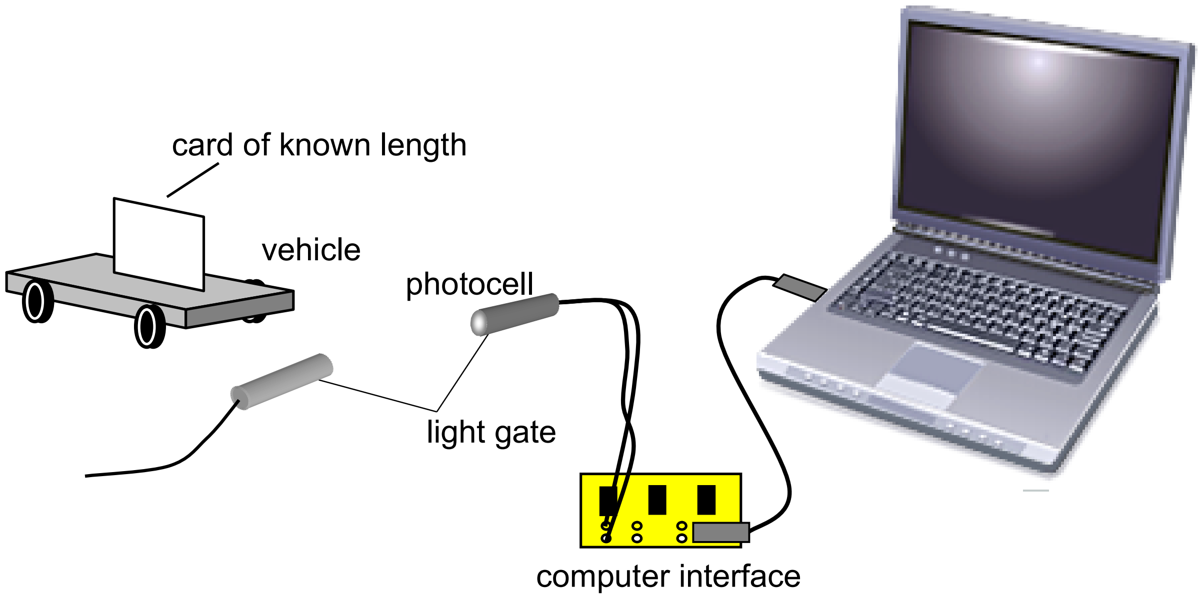
C The reading on a car speedometer.

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

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

2. A pupil is given a 50 metre 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.

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



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

4. In which of the two questions above (question 2 and 3) is the instantaneous speed measured and in which is the average speed measured?

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

6. Calculate the missing values in the table below.

Speed	***Distance***	***Time***
(*a*)	10 metres	4 seconds
(*b*)	500 metres	10 seconds
2 metres per second	30 metres	(*c*)
0·5 metres per second	60 metres	(*d*)
8 metres per second	(*e*)	120 seconds
0·2 metres per second	(*f*)	3 minutes

7. An ice hockey player strikes the puck and it moves off at 10 metres per second. Calculate the time it will take to travel 8 metres.

8.

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

(*b*) Speed skaters also compete in races which are 10 000 metres long. Calculate the time it would take the skater to complete the course if they travelled at an average speed of 12·5 metres per second.

9. A car travels a distance of 2000 metres along a motorway in 60 seconds. Calculate the average speed of the car.

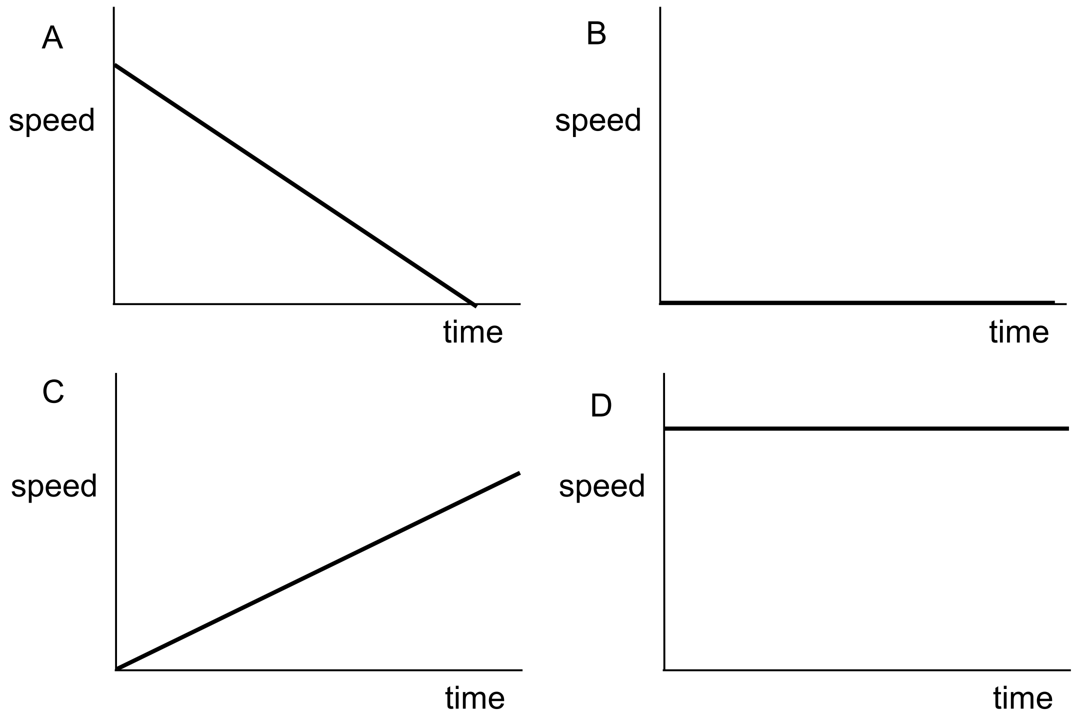
10. Someone standing on the Earth's equator will travel 28·8 kilometres in 1 minute due to the spin of the Earth. Calculate the speed they are travelling at in metres per second.

11. A cyclist pedals for 50 minutes at a speed of 12 metres per second. Calculate the distance she will have travelled.

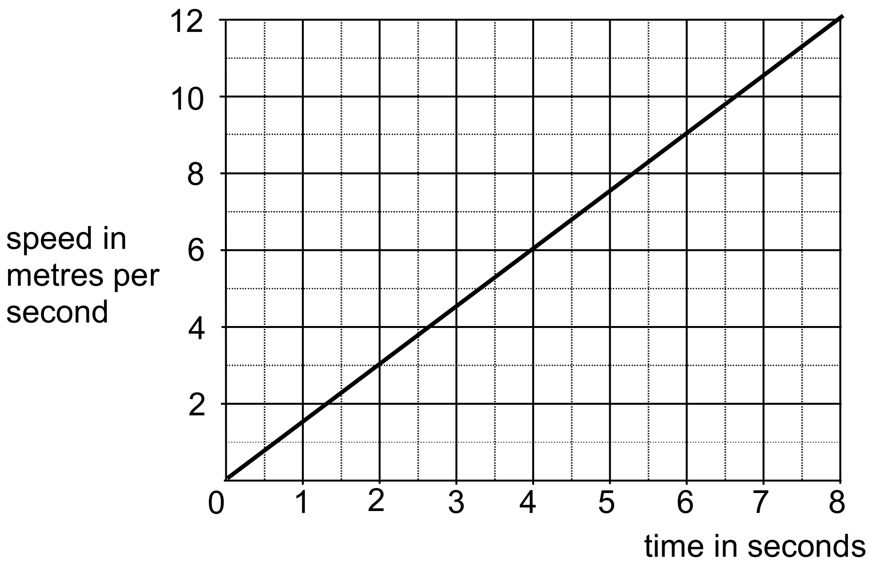
12. Calculate the time it will take a train travelling at an average speed of 80 kilometres per hour to complete a journey 60 kilometres long.

Speed-Time Graphs

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



14. The speed time graph below shown the motion of a car over 8 seconds.



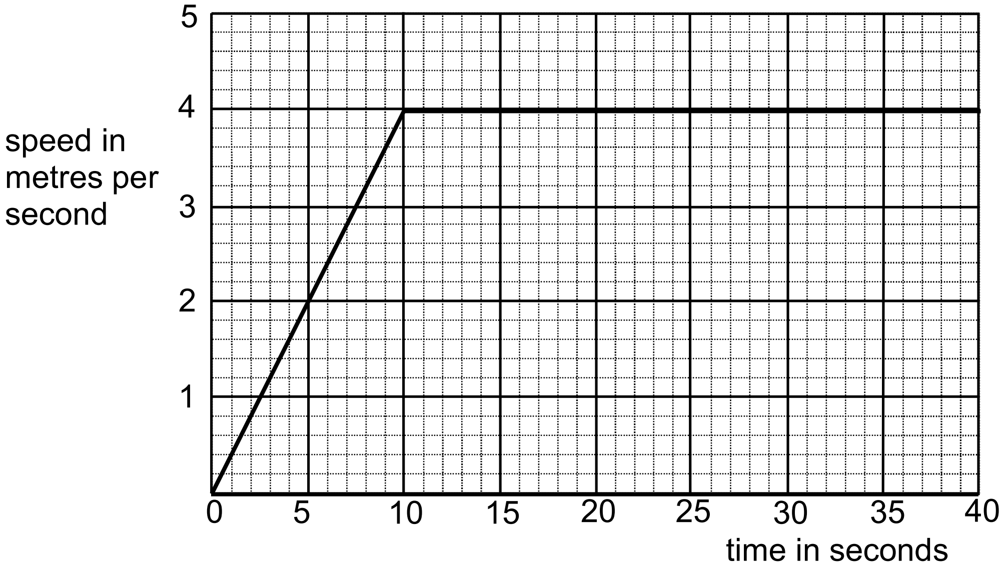
(*a*) State the speed of the car after:

(i) 2 seconds;

(ii) 6 seconds.

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

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

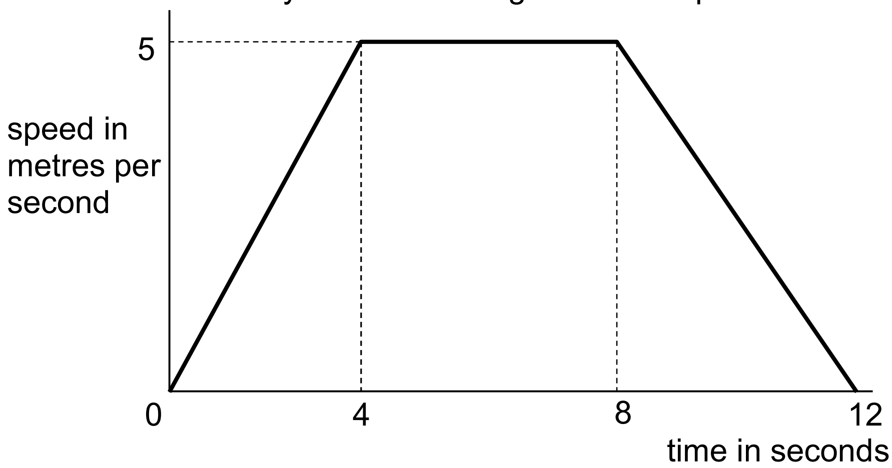


(*a*) Describe the motion of the cyclist over the 40 seconds.

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

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

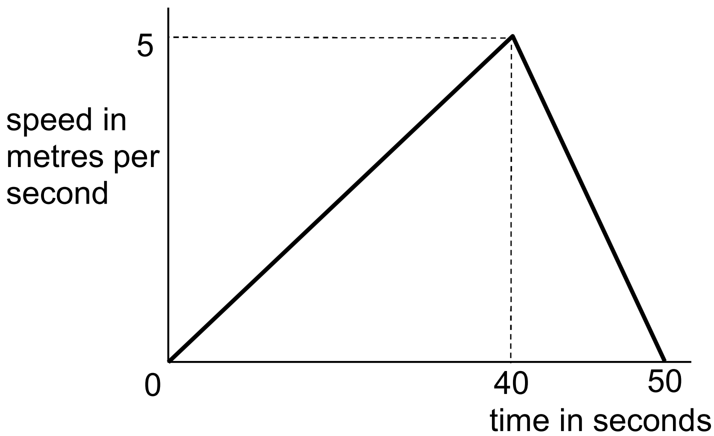
16. A sprinter warming up for a race produces the following speed-time graph. Calculate the distance they travelled during the warm-up.



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

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

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



Extension Questions

18. Pupils photograph a car travelling along the road outside their school. The camera they use takes photographs every 0·2 seconds.

The first and third photographs are shown below.

first photograph

third photograph

(*a*) Find the time between the first and third photograph if each is taken 0·2 seconds apart.

(*b*) The pupils measure the distance the car travelled between the photographs and find that it travelled 15 metres. Calculate the average speed of the car.

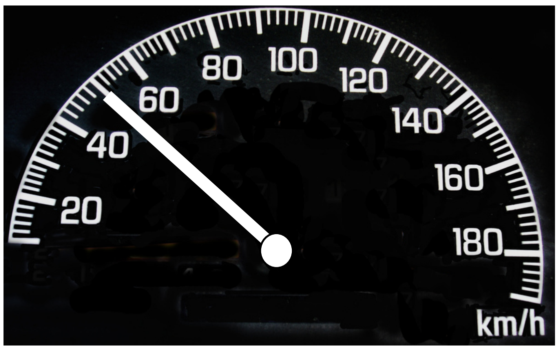
19. Two teachers travel to work at the same school.

Teacher A drives to work at an average speed of 5 metres per second. His journey is 9000 metres long.

Teacher B takes the bus which travels at an average speed of 3 metres per second. Her journey is 6000 metres long.

Find which teacher gets to the school first.

20. Tara and Stefina are travelling to school in a car. They both look at the speedometer.



Stefina says that the car is travelling at an instantaneous speed of 50 kilometres per hour.

Tara says that the car is travelling with an average speed of 50 kilometres per hour.

Which of the girls made the correct statement? Explain your answer.

21. A pupil wants to measure the speed his Scalextric car goes on a track.

He has the following items to help him:
a stopwatch;
a ball of string;
a tape measure;
a marker pen.

(*a*) Describe how the pupil could find the distance the car would travel in 10 laps.

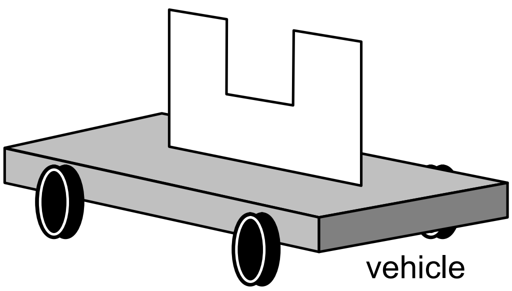
(*b*) Describe how the pupil could use this information to calculate the average speed of the car.

(*c*) The car travels 40 metres in 32 seconds. Calculate the speed of the car.

(*d*) The pupil now wants to find the cars instantaneous speed as it travels along the straight. Describe how he could do this and what additional apparatus he might need.

Acceleration

22. The apparatus used in question 3 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 still be found experimentally using a single card but with two light gates. Explain how this arrangement works.

23. Calculate the missing values in the table below.

Acceleration	***Change in speed***	***Time taken for change***
(*a*)	20 metres per second	5 seconds
(*b*)	100 metres per second	20 seconds
(*c*)	60 metres per second	20 seconds
0·5 metres per second per second	(*d*)	50 seconds
2 metres per second per second	(*e*)	10 seconds
2·5 metres per second per second	(*f*)	8 seconds
5 metres per second per second	55 metres per second	(*g*)
4 metres per second per second	20 metres per second	(*h*)
8 metres per second per second	64 metres per second	(*i*)

24. The space shuttle, starting from rest on the launch pad, could reach a speed of 1000 metres per second after 45 seconds. Calculate the acceleration of the shuttle.

25. A high speed lift in a high rise tower accelerates from rest at 3·5 metres per second per second. Calculate the final speed of the left if it accelerates at this rate for 4 seconds.

26. A cruise liner manoeuvres out of harbour at a speed of 1 metre per second. It then accelerates to a speed of 9 metres per second. Calculate the time this will take if the liner accelerates at 0·04 metres per second per second.

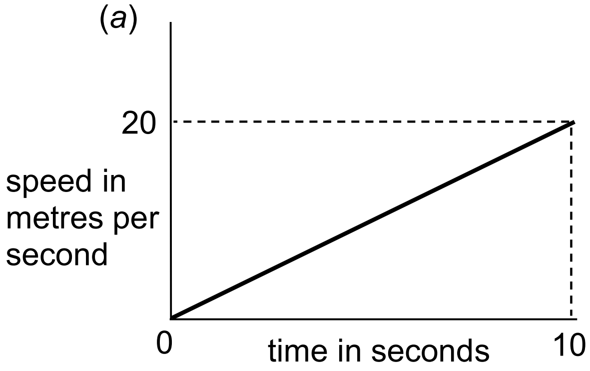
27. An object which is speeding up has a positive acceleration. What is happening to an object which has a negative acceleration?

28. (*a*) A high speed bullet train leaves a station and accelerates from rest to 60 metres per second in a time of 120 seconds. Calculate the acceleration of the train.

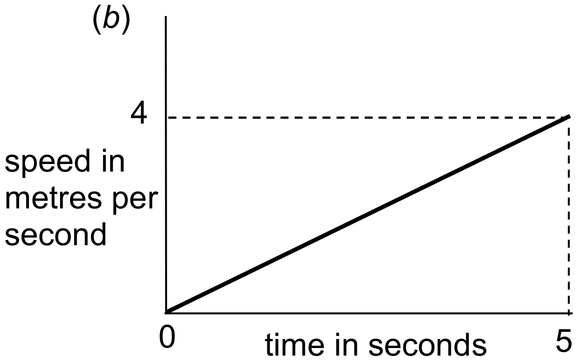
(*b*) The train is travelling at its top speed of 80 metres per second and brakes to slow down with an acceleration of –0·8 metres per second per second. Calculate the time it will take for the train to stop.

29. Calculate the acceleration shown in each of the following graphs.

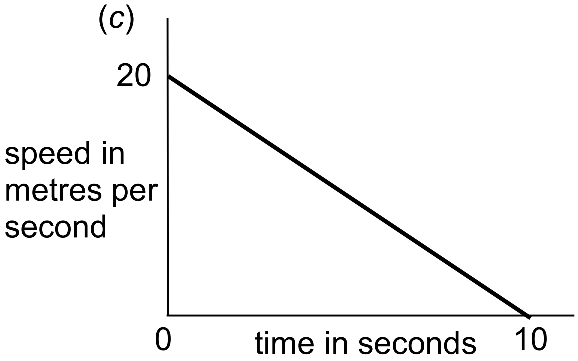
(*a*)



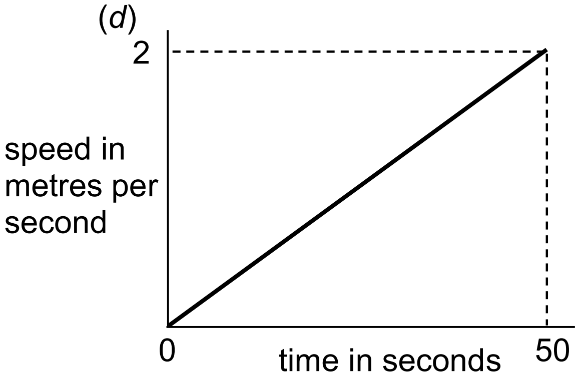
(*b*)



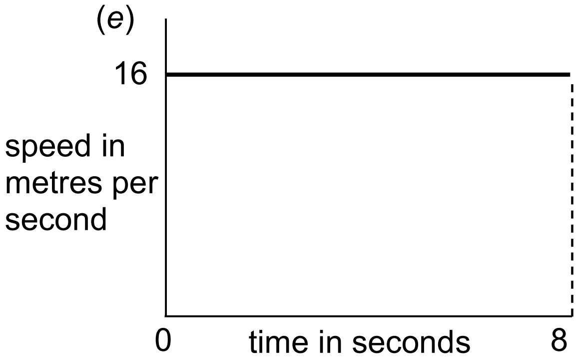
(*c*)



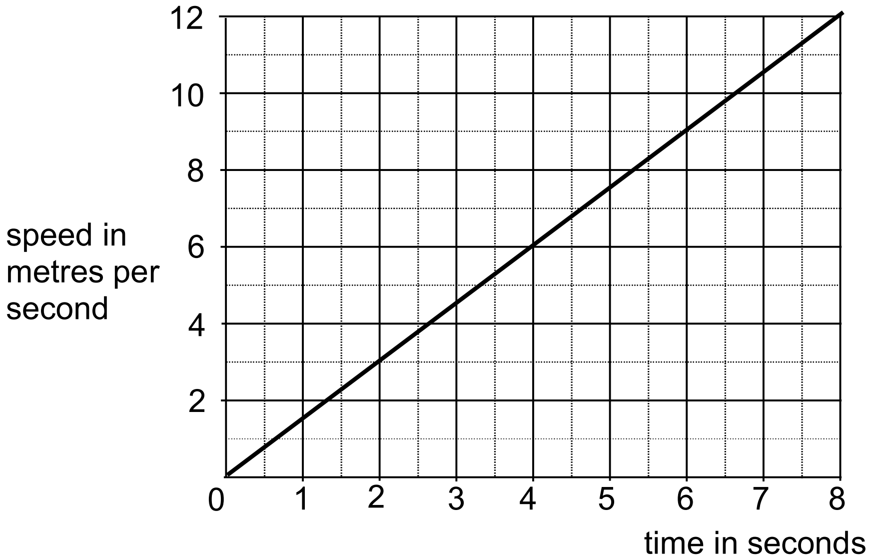
(*d*)



(*e*)



30. The speed time graph below shown the motion of a car over 8 seconds.



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

(i) 2 seconds;

(ii) 6 seconds.

(*d*) Calculate the acceleration of the car over the 8 seconds of its motion.

Forces, Motion and Energy

Newtons Laws of Motion – Balanced and unbalanced forces

31. 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.

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

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

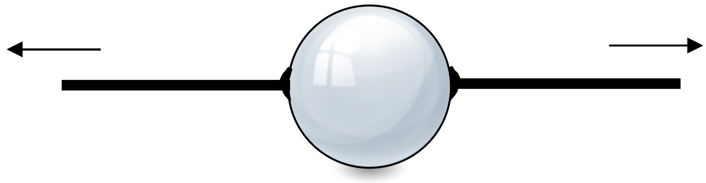
(*a*) A cyclist applies the brakes on his cycle.

(*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.

34. 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 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?

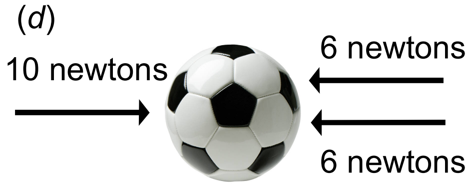
35. State whether the footballs shown below remain stationary or will move. If they move, in which direction will they move?

(*a*)

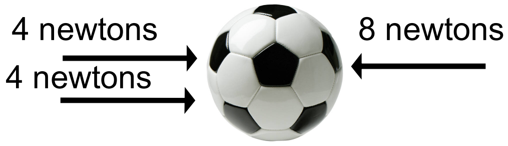
(*b*)

(*c*)

(*d*)



(*e*)



(*f*)

36. A car is stationary at traffic lights.

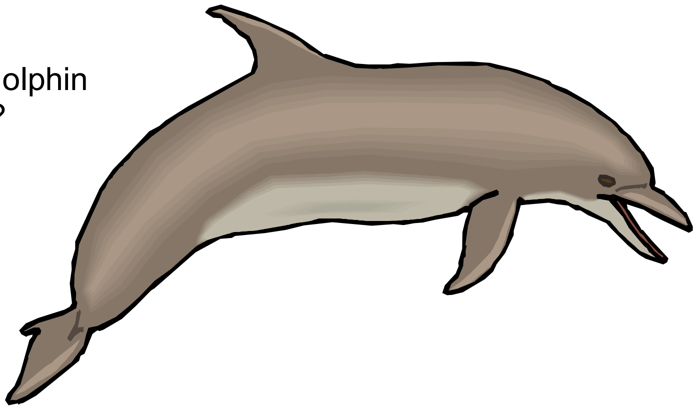
(*a*) What can be said about the forces acting on it?

(*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 two of these.

37. 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?

38. Copy and complete the following sentences using the words below

less than **the same as** **increases** **greater than**

A car starts on a journey and accelerates along a straight, flat road. The driving force from its engine must be __________ the force of air resistance acting on it. As it speeds up the force from the air resistance __________ . The speed of the car will eventually become constant when the air resistance is __________ the engine force.

39. 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.

40. (*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?

41. Calculate the missing values in the table below.

Force	***Mass***	***Acceleration***
(*a*)	10 kilograms	2 metres per second per second
(*b*)	0·5 kilograms	200 metres per second per second
50 newtons	5 kilograms	(*c*)
10 newtons	1 kilogram	(*d*)
20 newtons	(*e*)	4 metres per second per second
30 newtons	(*f*)	0·6 metres per second per second

42. A jogger with a mass of 50 kilograms accelerates at 0·5 metres per second per second. Calculate the unbalanced force required to produce this acceleration.

43. A car has a total mass of 1200 kilograms. Calculate the force required to accelerate the car at 2 metres per second per second.

44. Calculate the acceleration of a car that has a mass of 800 kilograms and is acted on by an unbalanced force of 2400 newtons.

45. A force of 180 newtons is applied by a cyclist to his bicycle to produce an acceleration of 3 metres per second per second. Calculate the combined mass of the cyclist and bicycle.

46. (*a*) A car travelling along a flat straight road slows down with an acceleration of –2 metres per second per second. What braking force must be applied if the car has a mass of 1000 kilograms?

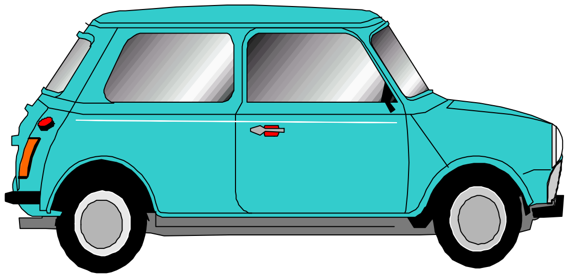
(*b*) A road surface is often covered with special grit near dangerous road junctions.

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

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

Extension questions

47. A television programme decides to compare the brakes on old and new models of the same car.



(*a*) An old mini is tested and can slow down from 16 metres per second to rest in a time of 4 seconds.

(i) Calculate the negative acceleration of the car.

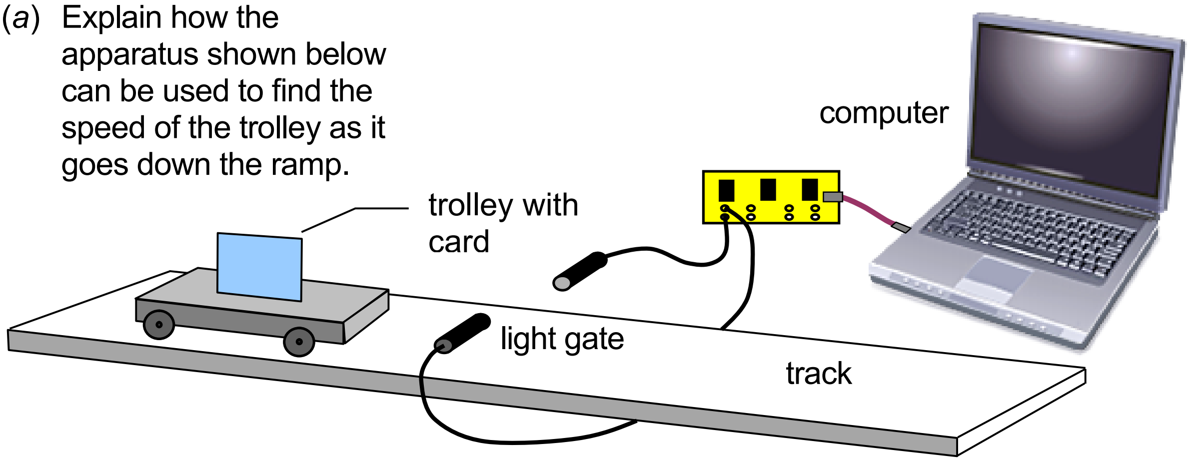
(ii) The mini car a mass of 800 kilograms. Calculate the braking force applied to the car.

(*b*) A modern mini has far more efficient brakes. It can accelerate at –5 metres per second per second. Calculate the time it will take to come to a stop if it starts at 16 metres per second.

(*c*) Some roads have a special surface which consists of small pieces of grit. What effect has this on the negative acceleration of the car compared to a normal road? Explain your answer.

48. A computer and light gate are used to measure the speed of a trolley rolling down a flat ramp which has been placed at an angle.

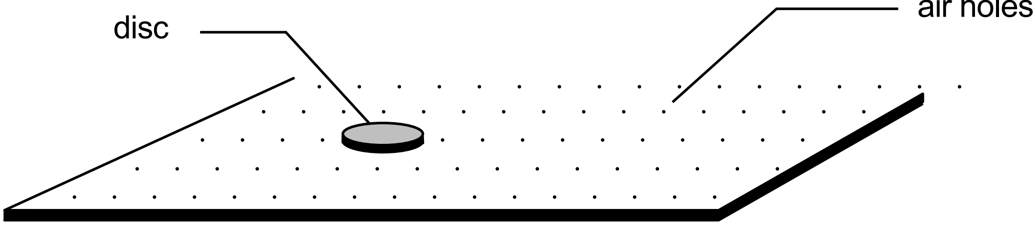
(*a*) Explain how the apparatus shown below can be used to find the speed of the trolley as it goes down the ramp.



(*b*) The card is 10 centimetres long. The computer records the time the card takes to pass through the light gate as 0·08 seconds. Calculate the speed of the trolley.

(*c*) Explain how the apparatus could be modified to allow it to measure the acceleration of the trolley.

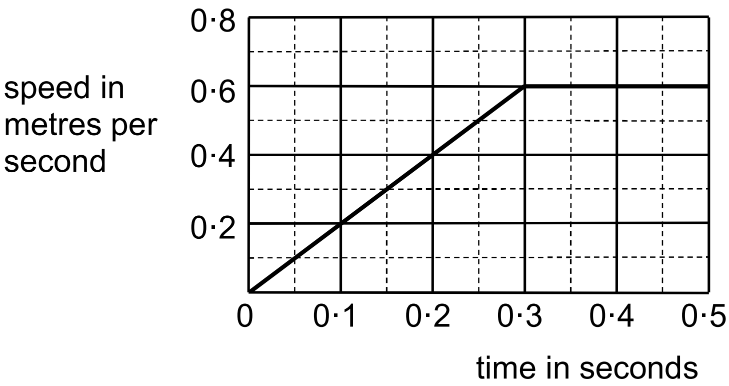
49. A disc is placed on 'air bed' which consists of a metal plate with tiny holes through which air is pumped. This causes the disc to float on a cushion of air. The disc has a mass of 0·5 kilograms.



(*a*) The disc is given a push with a force of 1 newton. Calculate the acceleration of the disc.

(*b*) The 'air bed' is described as a frictionless surface. Explain what this means.

(*c*) A graph of the discs motion over the first half second is shown below.



(i) Describe the motion of the disc over this time.

(ii) Calculate how far the disc travelled during the first half second of its motion.

(iii) How long after the disc was first pushed was it released?

Weight and Gravity

50. 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 is wrong with the others.

51. State the value of gravitational field strength on Earth.

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

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

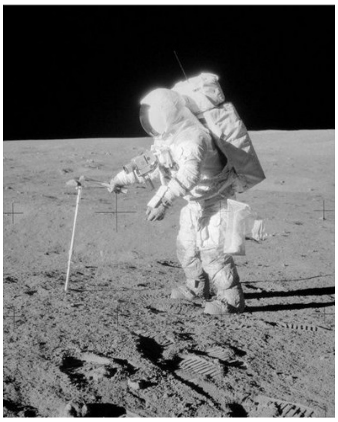
Mass	***Weight***
1 kilogram	(*a*)
0·5 kilograms	(*b*)
4 kilograms	(*c*)
(*d*)	9·8 newtons
(*e*)	49 newtons
(*f*)	30 newtons

54. A pupil says that her weight is 50 kilograms.

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

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

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



56. An astronaut has a hammer with a mass of 0·8 kilograms on the moon

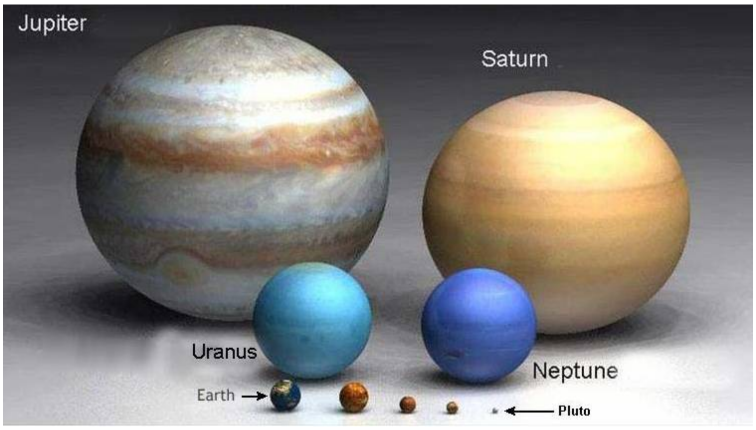
(*a*) Calculate the hammer's weight on Earth where the value of *g* is 9·8 newtons per kilogram.

(*b*) Calculate the hammer's weight on the moon where the value of *g* is 1·6 newtons per kilogram.

57. A satellite orbits the earth at a height of 2000 kilometres where the value of gravitational field strength is 5·7 newtons per kilogram. Calculate the weight of the satellite if it has a mass of 900 kilograms.

Extension questions

58. 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 (newtons per kilogram)***
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 the surface of mars has a mass of 174 kilograms. Calculate its weight on the Martian surface.

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

(i) a 60 kilogram person on Earth;

(ii) a 60 kilogram person on Jupiter?

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

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

Space exploration

59. 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.

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 on the previous page.

(*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'?

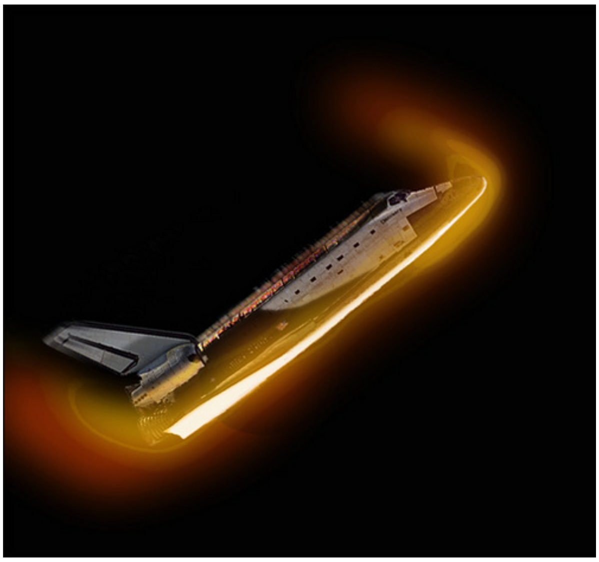
(*d*) How do modern maps of the earth depend upon the exploration of space?

(*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.

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



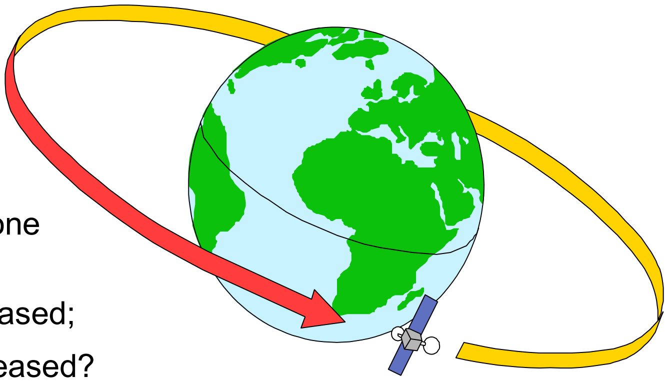
(*a*) Why is so much heat generated when the shuttle enters the Earth's atmosphere?

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

61. 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.

Satellites

62. 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:

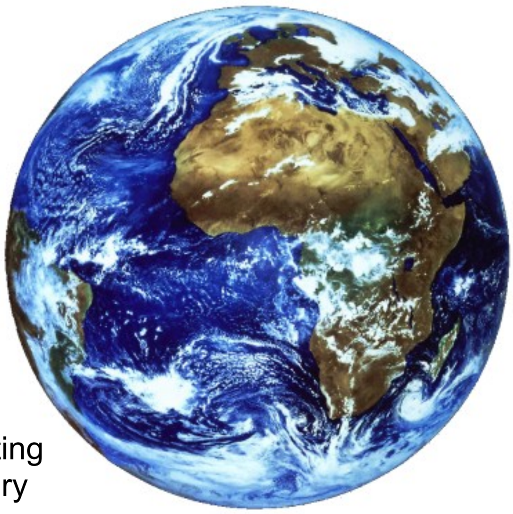
(i) the height of the orbit is increased;

(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 Earths surface?

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

63. The image opposite is taken by a geostationary weather satellite.



(*a*) (i) Explain what is meant by a geostationary satellite.

(ii) Explain why a geostationary satellite is especially useful for taking images of an area of the earth over a period of time.

(*b*) Scientists also use polar orbiting satellites.

(ii) How does the orbit height of a polar orbiting satellite compare to that of a geostationary satellite?

(ii) How would the image produced from a polar orbiting satellite differ from that shown above?

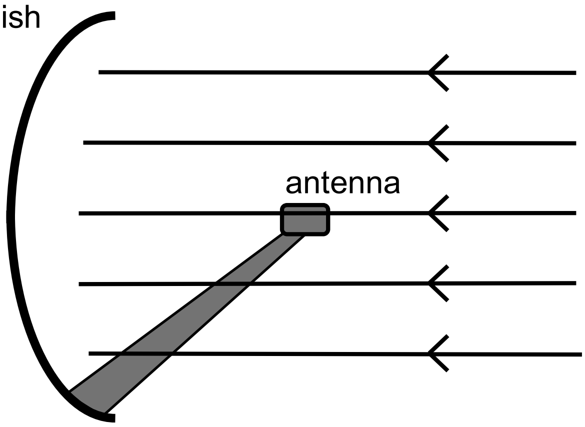
64. A satellite receiver consists of a large curved dish with an antenna placed in front of it.

(*a*) State the function of the antenna.

(*b*) State the function of the curved dish.

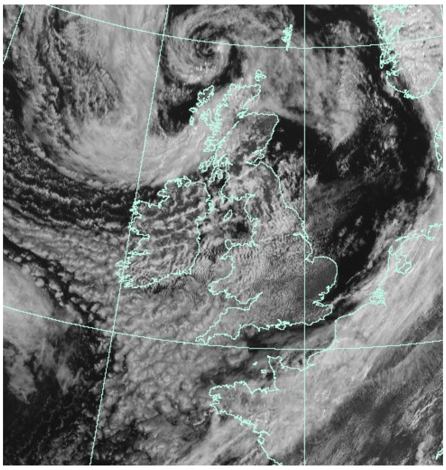
(*c*) State one way in which the strength of the received signal could be made stronger.

(*d*) Copy and complete the diagram below to show how the satellite dish acts on the incoming signal.



EXTENSION QUESTIONS

65. 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 the time for the satellite to make one orbit of the Earth?

Cosmology

The Universe

66. 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 -	a planet orbiting a star outside our solar system.
(*h*) exo-planet	all the matter that we know of.

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

68. (*a*) How many seconds are there in one year?

(*b*) If light travels at 300 000 000 metres per second, how far will it travel in one year?

69. How long does it take light to travel from the Sun to the Earth?

70. The nearest star to our solar system is Alpha Centauri. How many light years away is it?.

71. Our solar system is in the galaxy called the Milky Way. How wide is the Milky Way in light years?

EXTENSION QUESTIONS

72. Read the passage below on exoplanets then answer the questions which follow.

An exoplanet, or extrasolar planet, is a planet outside our Solar System. More than a thousand such planets have been discovered. There are at least 100 billion planets in the Milky Way, with at least one planet on average per star. Around 1 in 5 Sun-like stars have an "Earth-sized" planet which might be able to support life so the nearest would be expected to be within 12 light-years distance from Earth. Astronomers have estimated that there could be as many as 40 billion Earth-sized planets orbiting in the habitable zones of Sun-like stars and red dwarfs within the Milky Way.

Most of the known exoplanets are giant planets—estimated to be the size of Jupiter or Neptune—because the larger and more massive planets are more easily detected. The discovery of exoplanets leads to the next question—could they support life. In order to support life, conditions on the planet's surface must be right.

Orbit around the star
Some planets do not have a circular orbit around their star like the Earths. This means that the temperature on the planet's surface can vary between extremes which make it uninhabitable.

Distance of orbit from the Sun
If a planet orbits very close to the Sun it will be too hot to allow life. If its orbit is too far away from the planet it will be too cold for life to survive.

Planet size
Factors such as the size, mass and density of a planet affect its gravitational field strength. If a planet has a high value (Earth's is 9·8 Newtons per kilogram) any living organism would need very strong bones to support it—assuming it was large enough to need bones. The gravitational field strength also affects the ability of a planet to hang onto its atmosphere. If it is too low the atmosphere will disappear into space.

Presence of water
Life as we know it requires water so it would have to be present at temperatures which allow it to be in liquid form.

Presence of an atmosphere
Life as we know it requires oxygen in an atmosphere. This has to be at a certain concentration to allow life to develop, too much or too little is a bad thing. The atmosphere also protects life on the planet's surface from harmful radiation from the star.

(*a*) What is an exo-planet?

(*b*) How many light years away from Earth is is thought the nearest planet would be that is able to support life?

72 continued

(*c*) Why would it be difficult for a planet to support life if it's orbit took it too close to the star?

(*d*) A planet has a very low gravitational field strength. Why might this make it inhospitable to life?

(*e*) Name two things which have to be present on a planet for life to develop on it?

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

The fastest speed that anything can travel, is at 300 000 000 metres per second. With our current technology, the fastest spaceships only travel at 11 000 metres per second. 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 150 000 000 000 metres 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 1000 000 000 000 000 000 000 metres 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 300 000 000 metres per second?

(*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 metres per second to travel from the Earth to the Sun.

72 continued

(*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?

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

Speed and Acceleration

Average and Instantaneous Speed

1. A Average
B Instantaneous
C Instantaneous
D Instantaneous
E Instantaneous
F Average

2. 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.

3. 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.

4. Average speed is measured in question 2 and instantaneous speed in question 3.

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

6. (*a*) 2·5 metres per second
(*b*) 50 metres per second
(*c*) 15 seconds
(*d*) 30 seconds
(*e*) 960 metres
(*f*) 36 metres

7. 0·8 seconds

8. (*a*) 14·3 metres per second
(*b*) 800 seconds

9. 33·3 metres per second

10. 480 metres per second

11. 36 000 metres (36 kilometres)

12. 0·75 hours or 45 minutes.

Speed-Time Graphs

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

14. (*a*) (i) 3 metres per second
(ii) 9 metres per second
(*b*) 48 metres

15. (*a*) 0-10 seconds, cyclist accelerates, 10-40 seconds, cyclist travels at a constant speed.
(*b*) 140 metres
(*c*) 3·5 metres per second

16. 40 metres

17. (*a*) Accelerates for 40 seconds then slows down for 10 seconds.
(*b*) 125 metres

Extension Questions

18. (*a*) 0·4 seconds
(*b*) 77·5 metres per second.

19. Teacher A takes 1800 seconds, Teacher B takes 2000 seconds so Teacher A gets to school first.

20 Stefina is correct as the speedometer shows an instantaneous speed that the car is travelling at that moment in time.

21. (*a*) Measure the length of the track by laying the string along it then measuring the length of the string. Multiply by 10 to get the total distance travelled.
(*b*) Time the car over 10 laps then divide the distance travelled by the time taken.
(*c*) 1·25 metres per second
(*d*) He could use a light gate and photocell attached to a computer. A card of known length would be attached to the car and when it breaks the beam the computer can calculate the speed from the length of the card divided by the time the light beam is broken.

Light Gates and Acceleration

22. (*a*) acceleration = $\frac{\text{change in speed}}{\text{time taken for change}}$ or $a = \frac{\Delta v}{t}$

(*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.

23. (*a*) 4 metres per second per second
(*b*) 5 metres per second per second
(*c*) 3 metres per second per second
(*d*) 25 metres per second
(*e*) 20 metres per second
(*f*) 20 metres per second
(*g*) 11 seconds
(*h*) 4 seconds
(*i*) 8 seconds

24. 22·2 metres per second per second

25. 14 metres per second

26. 200 seconds

27. It is slowing down

28. (*a*) 0·5 metres per second per second
(*b*) 100 s

29. (*a*) 2 metres per second per second
(*b*) 0·8 metres per second per second
(*c*) –2 metres per second per second
(*d*) 0·04 metres per second per second
(*e*) 0 metres per second per second

30. (*a*) (i) 6 metres per second
(ii) 12 metres per second
(*b*) 1·5 metres per second per second

Forces, Motion and Energy

Newton's Laws of Motion – Balanced and unbalanced forces

31. (*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.

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

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

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

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

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

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

38 A car starts on a journey and accelerates along a straight, flat road. The driving force from its engine must be **greater than** the force of air resistance acting on it. As it speeds up the force from the air resistance **increases**. The speed of the car will eventually become constant when the air resistance is **the same as** the engine force.

39. (*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.

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

41. (*a*) 20 newtons
(*b*) 100 newtons
(*c*) 10 metres per second per second
(*d*) 10 metres per second per second
(*e*) 5 kilograms
(*f*) 50 kilograms

42. 25 newtons

43. 2400 newtons

44. 3 metres per second per second

45. 60 kilograms

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

Extension questions

47. (*a*) (i) –4 metres per second per second
(ii) 3200 newtons
(*b*) 3·2 seconds
(*c*) The negative acceleration will be greater as the grit creates more friction between the tyres and the road surface.

48. (*a*) 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.
(*b*) 1·25 metres per second.
(*c*) The single light gate is replaced by two light gates or the single card is replaced by a double card. This allows an initial and final speed to be found. The time between the two speed readings is also measured and acceleration calculated from change in speed divided by time.

49. (*a*) 2 metres per second per second
(*b*) The disc floats on a cushion of air and as no surfaces rub together there is virtually no friction between the air bed surface and the disc.
(*c*) (i) Initial acceleration followed by constant speed.
(ii) 0·21 metres
(iii) After 0·3 seconds.

Weight and Gravity

50. 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.

51. 9·8 newtons per kilogram

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

53. (*a*) 9·8 newtons
(*b*) 4·9 newtons
(*c*) 39·2 newtons
(*d*) 1 kilograms
(*e*) 5 kilograms
(*f*) 3·06 kilograms

54. (*a*) Her mass is 50 kilograms.
(*b*) 490 newtons

55. 12 740 newtons

56. (*a*) 7·84 newtons
(*b*) 1·28 newtons

57. 5130 newtons

Extension questions

58. (*a*) 644 newtons
(*b*) (i) 588 newtons
(ii) 1560 newtons
(*c*) 7 kilograms
(*d*) 56·5 newtons

Space exploration

59. *(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.

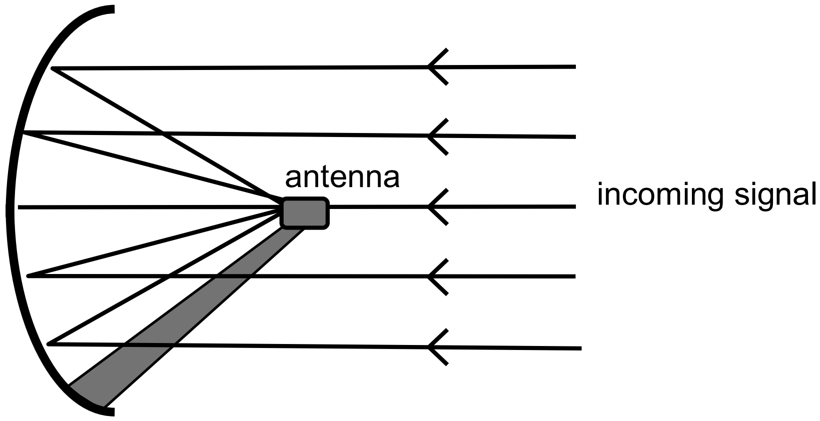
60. (*a*) There is a lot of friction with the Earth's atmosphere due to the high speed of the shuttle.
(*b*) It is covered in heat resistant tiles which are thicker on the underside where most heat is produced.

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

62. (*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.

63. (*a*) (i) It always remains above the same point on the Earth's surface.
(ii) It will always have the same view of the Earth below with no missing data or images as it orbits the earth.
(*b*) (i) It orbits at a lower height.
(ii) The satellite is closer to the earth so its view will be over a smaller area.

64. (*a*) To receive the satellite signal.
(*b*) To reflect the signals onto the receiver.
(*c*) Use a larger dish.
(*d*)



65. (*a*) It orbits the earth at a fixed height, never getting any nearer or further away.
(*b*) Geostationary
(*c*) The orbit takes longer.

Cosmology

The Universe

66. (*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.
(*h*) Exoplanet - a planet orbiting a star outside our solar system.

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

68. (*a*) 31 536 000 seconds
(*b*) 946 000 000 000 000 metres

69. 8·5 minutes

70. 4·2 light years

71. 100 000 light years

EXTENSION QUESTIONS

72. (*a*) A planet that is outside our solar system.
(*b*) 12 light years.
(*c*) The temperature on the planet surface would be too high.
(*d*) The low gravitational field means that the atmosphere would escape into space.
(*e*) There needs to be water and an atmosphere.

73. (*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) 1 000 000 000 000 metres
(*g*) This is impossible to say as it is constantly expanding.