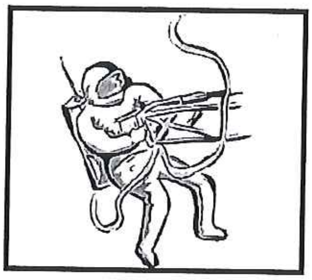
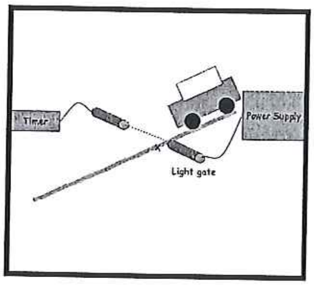
May 2018

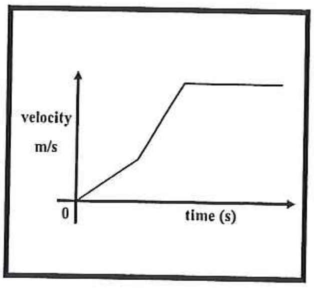
Our Lady's High School

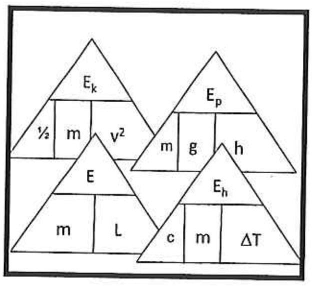
North Lanarkshire Council

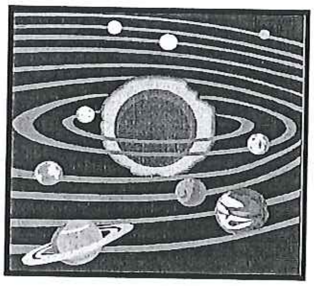
N4 N5 Physics

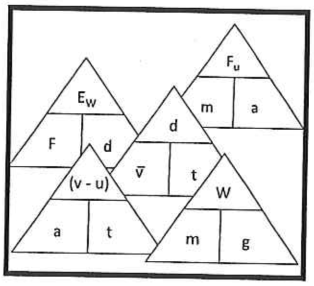


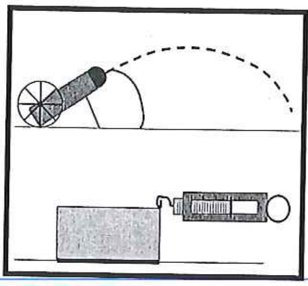


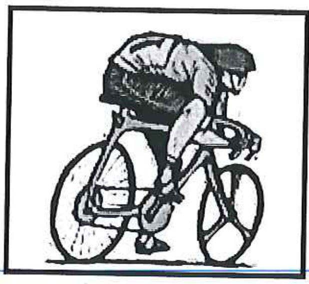


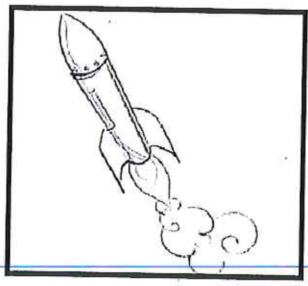












Dynamics & Space

Summary Notes

N5 Physics - Dynamics and Space Key Areas

Vectors and Scalars

- ☐ I can state the difference between a vector quantity and a scalar quantity.
- ☐ I can classify these quantities as either vector or scalar: force, speed, velocity, displacement, distance, acceleration, mass, time, weight and energy.
- ☐ I can add and subtract vectors in a straight line to find the resultant.
- ☐ I can use a scale diagram or Pythagoras and SOH CAH TOA to calculate the resultant of two vectors at right angles.
- ☐ I can work out displacement and distance using a scale diagram or calculation.
- ☐ I can solve problems using $d = v\,t$ and $s = v\,t$.
- ☐ I can describe an experiment to measure average speed.
- ☐ I can describe an experiment to measure instantaneous speed.

Velocity-Time Graphs

- ☐ I can draw speed-time and velocity-time graphs on graph paper.
- ☐ I can sketch speed-time and velocity-time graphs accurately on plain paper.
- ☐ I can use a velocity- time graph to describe the motion of an object.
- ☐ I can calculate displacement by working out the area under a velocity-time graph.

Acceleration

- ☐ I can define acceleration in terms of initial velocity, final velocity and time.
- ☐ I can solve problems using $a = \frac{v - u}{t}$.
- ☐ I can calculate acceleration from a velocity-time graph.
- ☐ I can describe an experiment to measure acceleration.

Newton's Laws

- ☐ I can state Newton's First Law.
- ☐ I can describe what is meant by balanced forces and give examples of these.
- ☐ I can define friction.

- ☐ I can apply Newton's First Law and balanced forces to explain constant velocity, making reference to frictional forces.
- ☐ I can apply Newton's Second Law using $F_{un} = m\,a$ including solving problems where more than one force is acting in a straight line or at right angles.
- ☐ I can define gravitational field strength.
- ☐ I can solve problems using $W = m\,g$.
- ☐ I can state Newton's Third Law.
- ☐ I can use Newton's Third Law to recognise and complete Newton's Pairs of forces.
- ☐ I can apply Newton's Third Law to explain motion resulting from a 'reaction' force.
- ☐ I can state the link between acceleration due to gravity and gravitational field strength.
- ☐ I can use Newton's laws to explain free fall and terminal velocity.

Energy

- ☐ I can state the principle of 'conservation of energy'.
- ☐ I can apply the principle of 'conservation of energy' to identify and explain apparent energy loss.
- ☐ I can solve problems using $E_w = F\,d$.
- ☐ I can define gravitational potential energy in terms of work done, force due to gravity and height.
- ☐ I can solve problems using $E_p = m\,g\,h$.
- ☐ I can define kinetic energy in terms of mass and speed.
- ☐ I can solve problems using $E_k = \frac{1}{2}\,m\,v^2$.
- ☐ I can solve problems using the principle of 'conservation of energy'.

Projectile Motion

- ☐ I can explain why projectiles follow a curved path in terms of horizontal and vertical motion.
- ☐ I can solve problems using projectile motion from a horizontal launch using
  - Horizontal ONLY: $range = v_h\,t$ (and area under the horizontal velocity against time graph)
  - Vertical ONLY: $a = \frac{v_v - u_v}{t}$ and height = area under the vertical velocity against time graph
- ☐ I can explain the orbit of a satellite in terms of projectile motion, horizontal velocity and weight.

Space Exploration

- ☐ I can give a basic description of our current understanding of the universe.
- ☐ I can use the following terms correctly and in context: planet, dwarf planet, moon, Sun, asteroid, solar system, star, exoplanet, galaxy and universe.
- ☐ I can explain some of the benefits of satellites including GPS, weather forecasting, communications, scientific discovery, and space exploration (Hubble telescope and ISS).
- ☐ I can state the definition of a geostationary satellite in terms of orbital altitude and period.
- ☐ I can state what happens to the orbital period of a satellite as its altitude increases.
- ☐ I can explain some of the challenges of space travel and how these might be solved including
    - travelling large distances, attaining high velocity using ion drive to produce a small force for a long time
    - travelling large distances using a 'catapult' from a fast moving asteroid, moon or planet
    - manoeuvring a spacecraft in a zero friction environment, possibly to dock with the ISS
    - maintaining sufficient energy to operate life support systems in a spacecraft, with the possible solution of using solar cells with area that varies with distance from the Sun.
- ☐ I can explain some of the risks of manned space exploration and how these might be solved including
    - fuel load on take-off
    - potential exposure to radiation
    - pressure differential
    - problems of re-entry to a planet's atmosphere.
- ☐ I can apply Newton's Laws to space travel, rocket launch and landing including solving problems using $F_{un} = m\,a$.
- ☐ I can solve problems using $W = m\,g$ in different locations in the universe.

Specific Heat Capacity

- ☐ I can define specific heat capacity in terms of heat energy, mass and change in temperature.
- ☐ I can define temperature in terms of kinetic energy.
- ☐ I can explain the link between temperature and heat energy.
- ☐ I can solve problems using $E_h = c\,m\,\Delta T$.
- ☐ I can solve problems using the principle conservation of energy to determine heat transfer.

Specific Latent Heat

- ☐ I can define specific latent heat (vaporisation and fusion) in terms of heat energy, mass and change of state.
- ☐ I can solve problems using $E_h = m\,l$.

Cosmology

- ☐ I can describe what is meant by a light year.
- ☐ I can use $v = d\,t$ to convert between light years and metres.
- ☐ I can state that the big bang theory says that the universe began at a single point approximately 13.8 billion years ago and has been expanding ever since.
- ☐ I can give examples of how different parts of the electromagnetic spectrum can be used to obtain information about astronomical objects.
- ☐ I can identify continuous and line spectra.
- ☐ I can use given line spectra for known elements to identify the elements present in a star.

NQ5	Unit 2	Dynamics and Space	Summary Notes

A. Vectors and Scalars

1. Average speed.

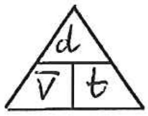
Speed is a measure of the distance an object covers in a set time.
Over a certain distance the speed could change so the average speed is the constant speed required to cover the same distance in the same time.

To find the average speed of this car between A and B

Measure the distance between A and B with a metre stick and the time taken for the car to travel from A to B with a stopwatch.

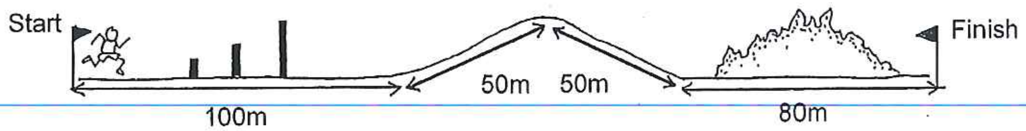
$$\text{average speed} = \frac{\text{distance travelled}}{\text{time taken}}$$

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



term	units
d	m
t	s
$\bar{v}$	ms^{-1}

Example An athlete completes the following assault course in 100s.



(a) Calculate his average speed

$d = 280m$
$t = 100s$
$\bar{v} = ?$

$d = \bar{v}t$

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

$\bar{v} = \frac{280}{100}$

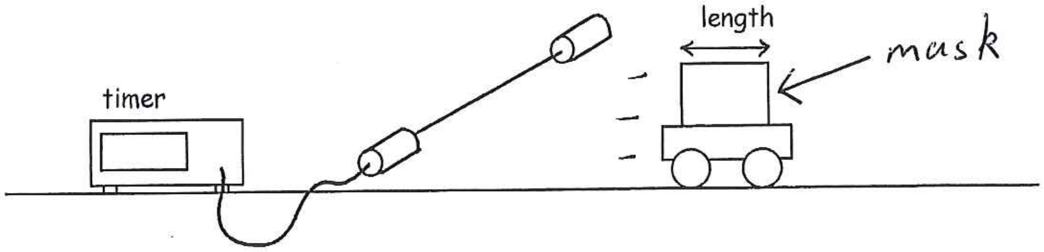
$\bar{v} = 2.8ms^{-1}$

2. Instantaneous Speed

The instantaneous speed is the speed of an object at one particular point in the journey. It is the average speed over a very small distance.

We usually measure instantaneous speed using a light gate or in a car a speedometer is used.

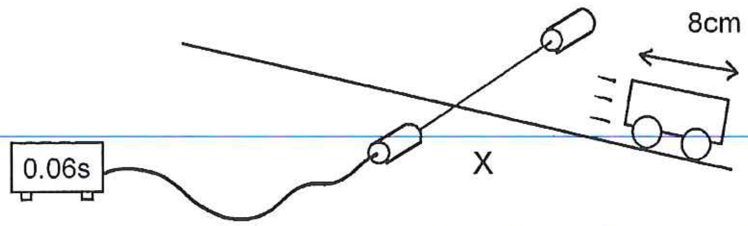
Connect the light gate to a timer. Measure the length of the trolley with a ruler. When the trolley cuts the beam it is travelling a distance equal to its own length in a time measured by the timer.



$$\text{instantaneous speed} = \frac{\text{length of mask}}{\text{time it takes to cut the beam}}$$

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

Example Calculate the instantaneous speed of the trolley at point X?



$d = vt$

$v = d/t$

$v = \frac{0.08}{0.06}$

$v = 1.3\ ms^{-1}$

d = length of card = 0.08 m

t = 0.06 s

v = ?

3. Vectors and Scalars

Scalars are quantities which are defined by their magnitude (size)

Vectors are quantities which are defined by their size and direction.
Fill in the table as you meet new quantities in this unit

Scalar quantity	Vector quantity
distance	displacement
speed	velocity
mass	acceleration
time	force
energy	weight
temperature	

4. Distance and Displacement

Distance is defined as the total magnitude of a journey.
The symbol for distance is d. It is a Scalar quantity.

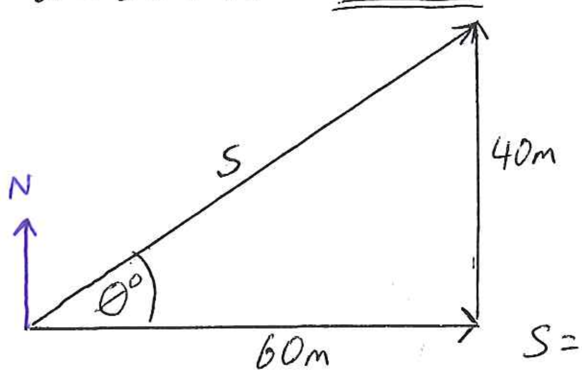
The displacement is defined as the shortest distance between two points in a given direction from the starting point.
The symbol for displacement is S. It is a Vector quantity.
If there are two separate parts of the journey we add the distance vectors together to get the resultant displacement. We add vectors together nose to tail.

Example A jogger ran 60m East then 40m North.

(a) What distance did she travel?
(b) What was her displacement from the starting point?

a) $d = 60 + 40 = 100\,m$

b)



$s^2 = 40^2 + 60^2 = 5200$

$s = \sqrt{5200} = 72.1\,m$

$\tan\theta° = \frac{40}{60}$

$\theta° = \tan^{-1}\left(\frac{40}{60}\right) = 33.7°$

$S = 72.1\,m$ at $33.7°$ North of East

(056.3°)

5. Speed and Velocity

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

$$\text{velocity} = \frac{\text{displacement}}{\text{time taken}} \qquad v = \frac{s}{t}$$

Velocity is the speed of an object in a particular direction

Example The runner from the last example ran the 60m East then 40m North in a time of 20s.

(a) What was her average speed?
(b) What was her average velocity?

a) $V = \frac{d}{t}$

$V = \frac{100}{20}$

$V = 5ms^{-1}$

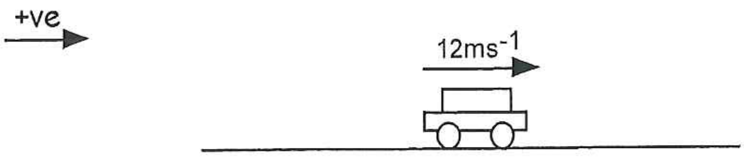
b) $V = \frac{s}{t}$

$V = \frac{72.1}{20}$

$V = 3.6ms^{-1}$ at 33.7° North of East

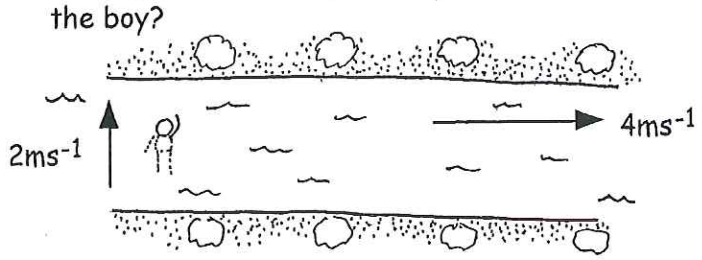
6. Velocity Vectors

When indicating the direction of an object, whether it's moving up or down or left or right we choose a direction to be positive. In the following example we have chosen to the right as the positive direction. The velocity of an object can be shown using a velocity vector. The following diagram indicates the car is travelling to the right with a velocity of $12ms^{-1}$.

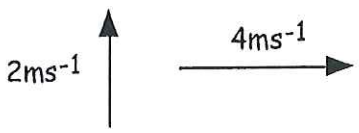


7. Adding Velocity Vectors.

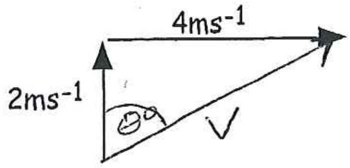
Example A boy swims across a river with a velocity of $2 ms^{-1}$ (North). The river is flowing with a velocity of $4 ms^{-1}$ (East.) What is the resultant velocity of the boy?

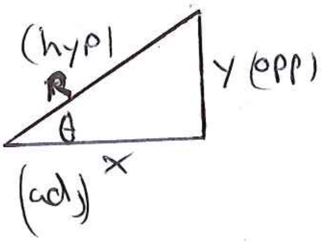


velocity vectors



add vectors nose to tail





$$R^2 = x^2 + y^2$$

$$R = \sqrt{x^2 + y^2}.$$

$$\tan\theta = \frac{y}{x}.$$

$$\theta = \tan^{-1}\left(\frac{y}{x}\right).$$

Magnitude of Resultant velocity

$$V^2 = 4^2 + 2^2 = 20$$

$$V = \sqrt{20} = 4.5 ms^{-1}$$

Direction of Resultant velocity

$$\tan\theta^\circ = \frac{4}{2}$$

$$\theta^\circ = \tan^{-1}\left(\frac{4}{2}\right)$$

$\theta^\circ = 63.4^\circ$ East of North

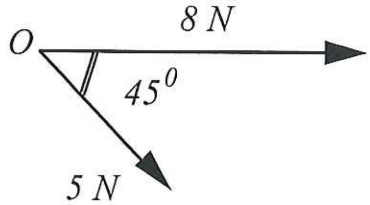
Velocity = $4.5 ms^{-1}$ at 63.4° East of North

Adding Vectors by Scale Diagram

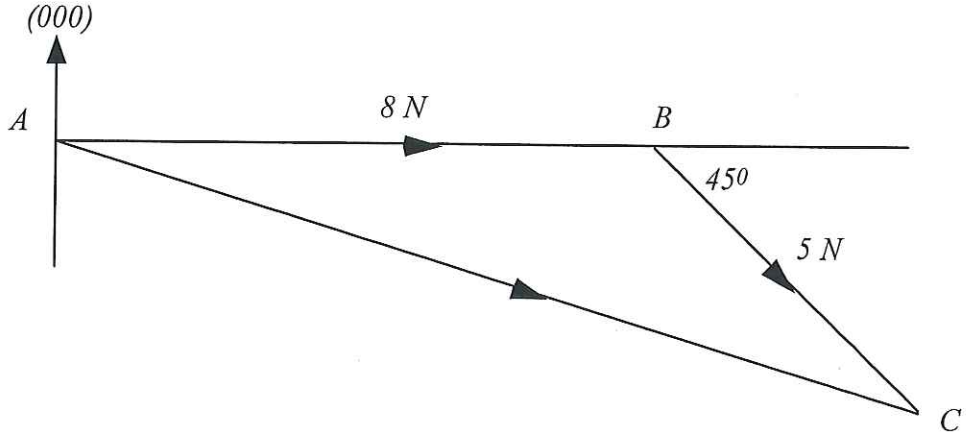
When vectors are being added, their magnitude and direction must be taken into account. This can be done using a scale diagram and adding the vectors 'tip to tail', then joining the starting and finishing points. The final sum is known as the resultant, the single vector that has the same effect as the sum of the individuals.

Example

Find the resultant force acting at point O.



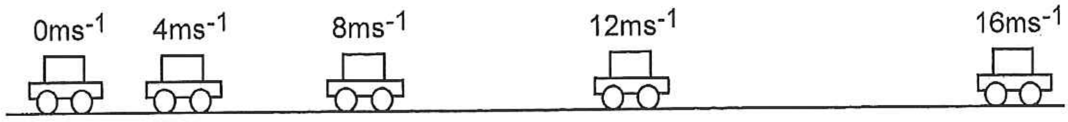
Step 1: Choose a suitable scale, e.g. 1 cm to 1 N.
Step 2: Arrange arrows "tip to tail".
Step 3: Draw in resultant vector, measuring its length and direction.



1 cm to 1 N.	AC	=	12.2 cm
	Force	=	12.2 N
			Using a protractor, angle BAC measures 12^0
	Bearing	=	$90^0 + 12^0 = 102^0$
	Resultant Force	=	12.2 N at (102)

8. Acceleration

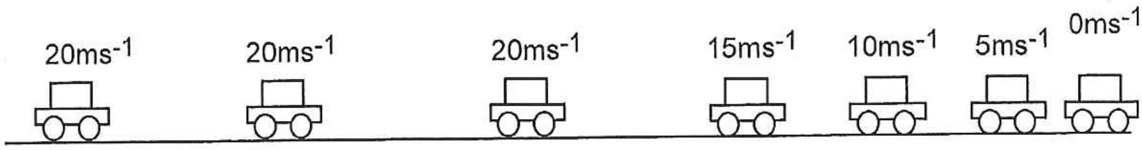
Acceleration tells you by how much the velocity of an object has changed each second. The velocity of the following car is increasing by $4ms^{-1}$ each second.



so the acceleration = 4m/s/s or $4ms^{-2}$

If an object has an acceleration of $-4ms^{-2}$ then its velocity is decreasing at a rate of $4ms^{-1}$ each second.

This car is travelling a constant velocity of $20ms^{-1}$. The brakes are applied and the car decelerates at $5ms^{-2}$.



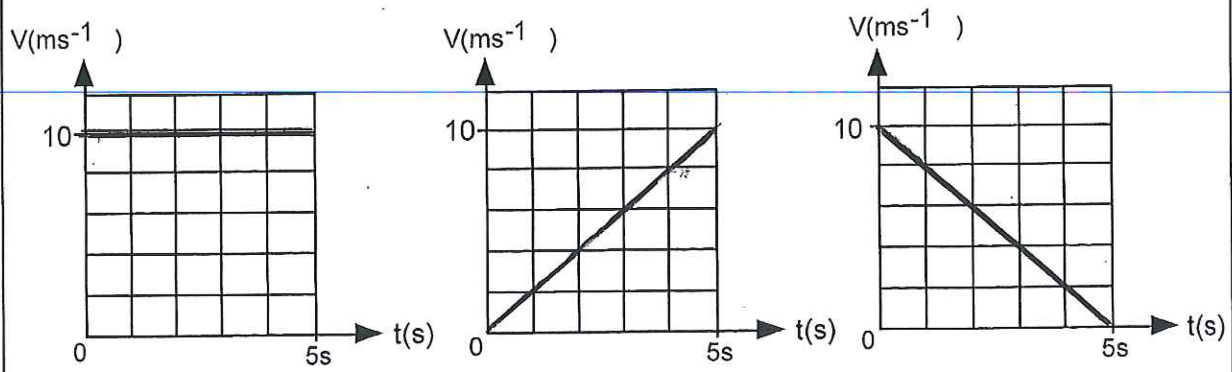
Its acceleration = -5m/s/s or $-5ms^{-2}$

If the object's velocity changes by the same amount each second we say that the object has a constant acceleration.

9. Velocity-Time Graphs.

A velocity time graph describes the motion of an object.

These velocity-time graphs show 3 important motions. Draw the graph which describes the motion indicated underneath



Object travelling at a constant velocity of $10ms^{-1}$ for 5s.

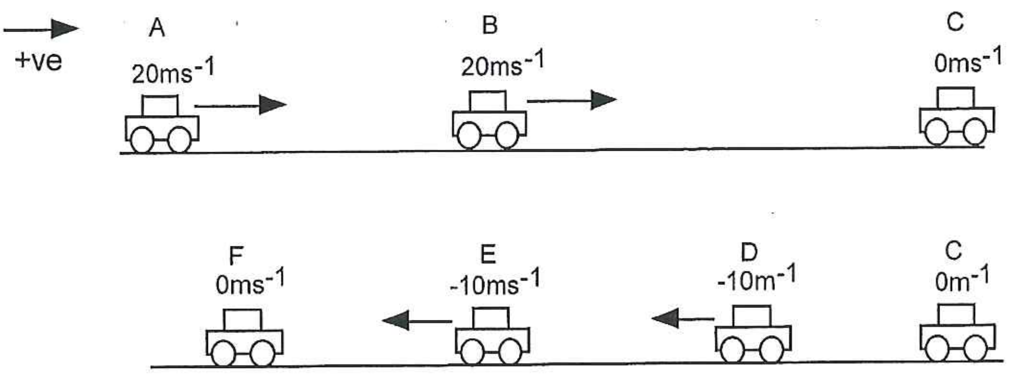
Object accelerating at a constant rate from rest to $10ms^{-1}$ in 5s.

Object decelerating at a constant rate from $10ms^{-1}$ to rest in 5s

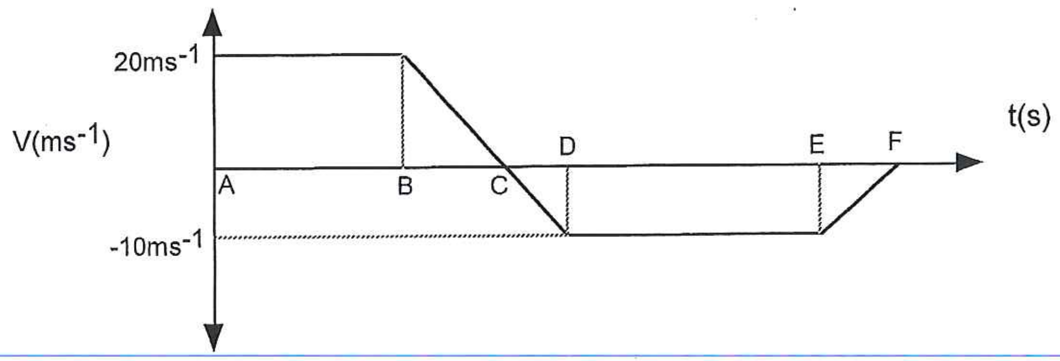
10. Velocity-Time Graphs when Object Changes Direction.

Velocity is a vector quantity so a velocity time graph can show an object changing direction. When looking at an object changing direction it is important to say which direction is positive and which is negative.

In the following example we have chosen to the "right" as the positive direction. The diagram shows a car travelling along the road at a constant velocity of $+20ms^{-1}$. It decelerates to rest. It then reverses until its velocity reaches $-10ms^{-1}$ then it continue on at this constant velocity for a few seconds before decelerating to rest.



The following velocity time graph describes the motion of the car. Positive velocities are shown above the time axis. The negative velocities are shown below the axis.



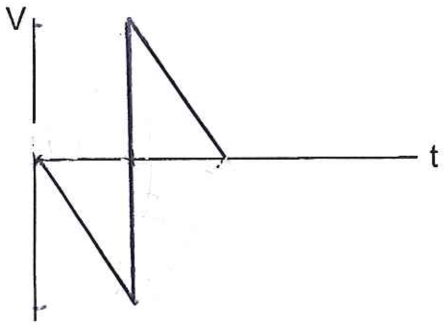
We can tell from the graph that the car changed direction at point C because the velocities changed from positive to negative.

A to B shows the car travelling at a constant velocity of $20ms^{-1}$.
B to C car slows down to $0ms^{-1}$.
C to D car reverses from rest to $-10ms^{-1}$.
D to E car continues to reverse at a constant velocity of $-10ms^{-1}$.
E to F car slows down to $0ms^{-1}$.

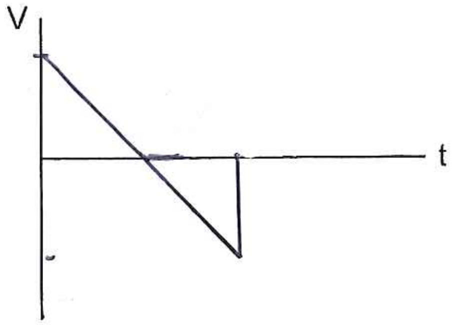
Example Draw the velocity time graphs to describe the following motion.
In these examples up is positive

+ve

Ball dropped from rest and bouncing once



Ball thrown up in the air and caught.



11. Acceleration Formula

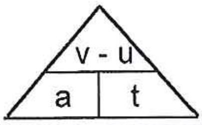
We know that acceleration is the change in the velocity of an object each second.

acceleration = change in the object's velocity / time taken for the change

We can write this in a simpler form using letters

u = initial velocity of the object
v = final velocity of the object
a = acceleration
t = time for the change of velocity to take place.

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



Term	Units
u	ms^{-1}
v	ms^{-1}
a	ms^{-2}
t	s

Example A car accelerates from rest to $24ms^{-1}$ in a time of 3s.
Calculate its acceleration.

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

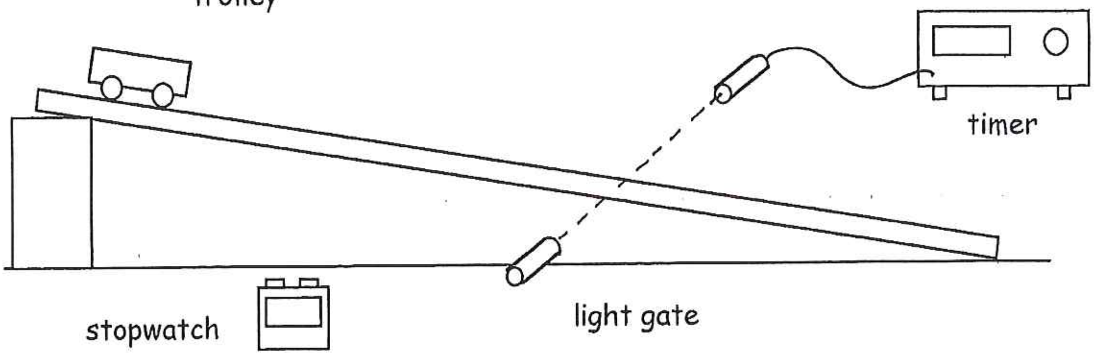
$a = \frac{24 - 0}{3}$

$a = 8ms^{-2}$

u = 0
$v = 24ms^{-1}$
a = ?
t = 3s

12. Measuring Acceleration

Use a light gate, a ruler and a stopwatch. Set up the following apparatus



initial speed **u** = 0 (the trolley starts from rest)

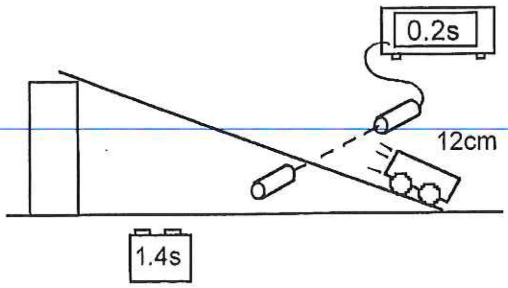
final speed **v** = instantaneous speed at light gate v = length of trolley / time to cut the beam

Stopwatch records the time **t** between velocities u and v.

Then we use $a = \frac{v - u}{t}$ to calculate the acceleration of the trolley

Example

Look at this experiment. Use the information to calculate the acceleration of the trolley. The trolley starts from rest and accelerates down the slope at a constant rate.

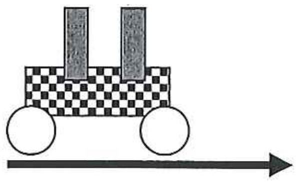


$V = \frac{d}{t} = \frac{0.12}{0.2} = 0.6 ms^{-1}$

$a = \frac{V-u}{t} = \frac{0.6-0}{1.4} = 0.43 ms^{-2}$

Measuring Acceleration (Double Mask Method)

To measure acceleration three quantities must be measured: **initial and final speeds** and the **time taken for the change in speed**. A trolley with a double mask, a light gate and timer can be used.



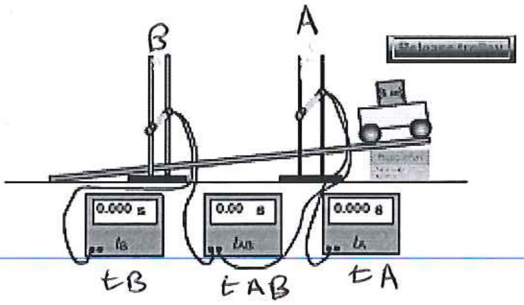
- When the first part of the mask cuts the light beam, the time is measured, the width of the mask is known and so the initial instantaneous speed is calculated
- The final instantaneous speed can be calculated when the second part of the mask cuts the beam

$$speed = \frac{mask\ width}{time\ to\ cut\ beam}$$

- The time for the change in speed is also measured (time between first and second part of mask cutting gate)
-

$$acceleration = \frac{final\ speed - initial\ speed}{time\ for\ change}$$

<u>Measuring Acceleration – light gates and timers and stop clock.</u>



Initial speed u = $\frac{\text{length of card}}{\text{time to cut gate A}}$ final speed v = $\frac{\text{length of card}}{\text{time to cut gate B}}$

t = tAB – time to travel between light gates

use $a = \frac{v - u}{t}$ to calculate the acceleration.

13 Rearranging uvat

Example A cyclist accelerates from $3ms^{-1}$ at a rate of $2.6ms^{-2}$. Calculate his final speed if he accelerates for 4s?

$V = u + at$

$V = 3 + (2.6 \times 4)$

$V = \underline{13.4ms^{-1}}$

$u = 3ms^{-1}$

$v = ?$

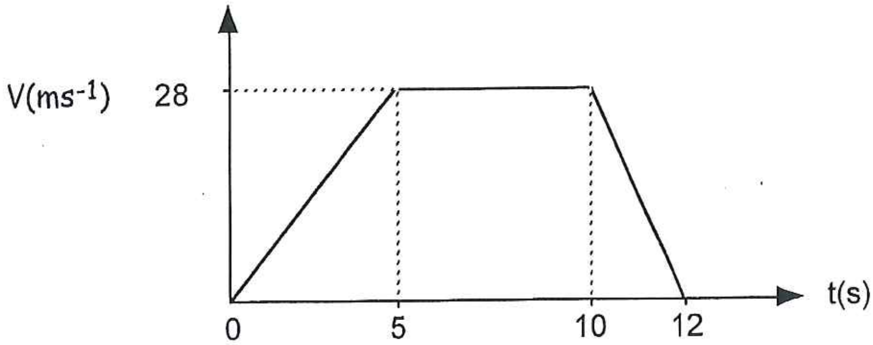
$a = 2.6ms^{-2}$

$t = 4s$

14. Acceleration from Velocity Time Graphs.

This velocity time graph represents the velocity of a skier travelling down a slope.

Example Calculate the acceleration during 0 - 5s and 10 - 12s



Acceleration between 0 s and 5 s

$a = \frac{V-u}{t} = \frac{28-0}{5}$

$a = \underline{5.6ms^{-2}}$

Acceleration between 10 s and 12 s

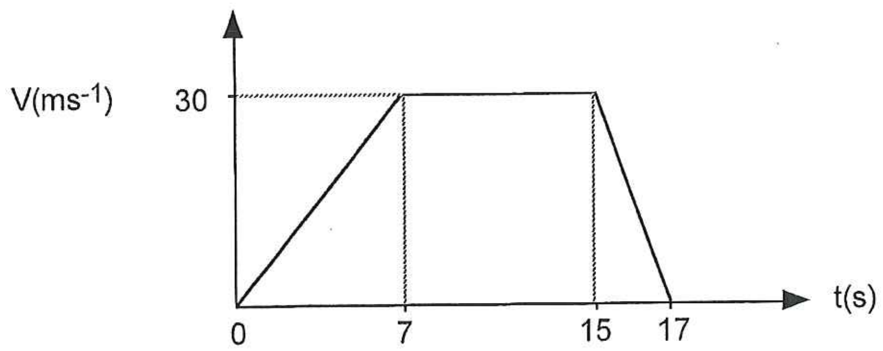
$a = \frac{V-u}{t} = \frac{0-28}{2}$

$a = \underline{-14ms^{-2}}$

15. Calculating the Displacement From a Velocity-Time Graph

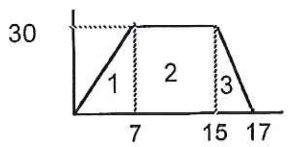
The displacement of an object = the area under the velocity time graph

Example The following graph shows how the velocity of a car varied over a 17s journey.
(a) Calculate how far the car travelled during the 17s?
(b) What was its average velocity?

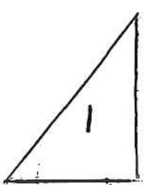


displacement = area under the graph.

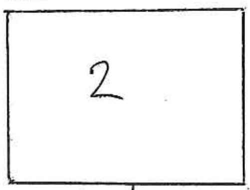
Split the area up into shapes whose areas we can easily work out.



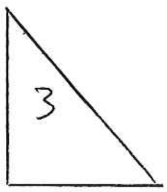
Displacement s = Area 1 + Area 2 + Area 3



$A = \frac{1}{2} l \times b$
$A = \frac{1}{2}(7 \times 30)$
$A = 105$



$A = l \times b$
$A = 8 \times 30$
$A = 240$



$A = \frac{1}{2} l \times b$
$A = \frac{1}{2}(2 \times 30)$
$A = 30$

$d = 105 + 240 + 30 = \underline{375 m}$

Average velocity $\bar{v} = \frac{s}{t}$

$\bar{v} = \frac{375}{17}$

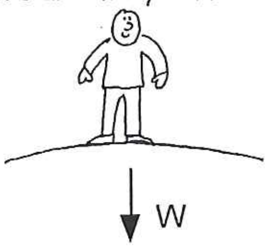
$\bar{v} = \underline{22 \cdot 1 ms^{-1}}$

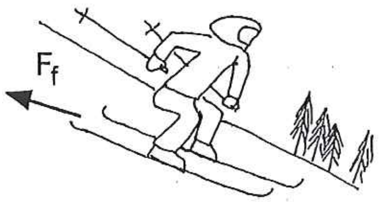
B. Newtons Law's of Motion

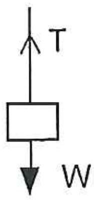
16. What is a Force?

Force changes the speed direction or shape of an object.
Force is a vector quantity because it is important to state its size and direction.
Force is measured in units called Newtons or N for short.
Force is measured using a Newton balance.

There are many different types of forces. Here are some important forces.







The force that pulls objects down to the centre of the Earth is called Weight

The force which acts between touching surfaces and tries to stop them moving is called Friction

The force carried through a stretched rope or wire is called Tension

17. Mass and Weight

The mass of an object is a measure of how much stuff or matter an object contains. Mass is measured in kilograms or kg for short.
Your mass stays the same no matter where in the universe you are.

The weight of an object = mass of the object x gravitational field strength.

$$W = mg$$

Term	Unit
W	N
m	kg
g	Nkg^{-1}

The gravitational field strength, g, is the downward Force acting on 1kg of mass. Here are the g values of different bodies.

Body	g (Nkg^{-1})
Earth	9.8
Moon	1·6
Mars	3·7
Venus	8·8
Jupiter	25·9

Compared to Earth we would feel heavier on Jupiter and lighter on the moon.

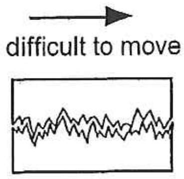
Example An astronaut of mass 86kg travels to Mars. What is his weight on Mars.

$W = mg$ $M = 86kg$

$W = 86 \times 3.7$ $g = 3.7 Nkg^{-1}$ (Data sheet)

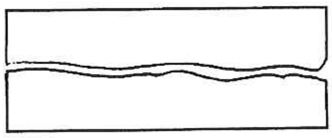
$W = 318.2 N$

18. Friction

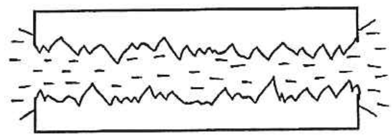


Friction is a force which acts between two surfaces. It is caused by the surfaces being rough. It tries to stop the surfaces moving. It always acts against the direction of motion.

Decreasing friction by



smoothing surfaces

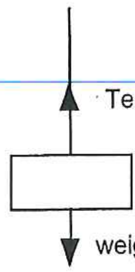


separating surfaces.

If an object moves through a fluid, like air or water, friction can be decreased by making the object streamlined. A streamlined object has a smooth, rounded surface. It cuts through the fluid with little turbulence.

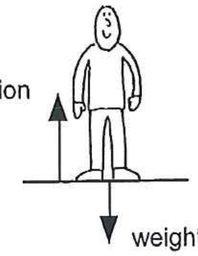
19. Tension

If you hang a box from a rope or a wire. The upward force stopping it falling is delivered through the rope or wire. This force is called tension.



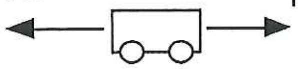
20. Reaction Force

When you stand on the floor your weight pulls you downwards. However you don't crash through the floor. This is because the floor applies an equal and upward force on you called the reaction force.



21. Newton's 1st Law

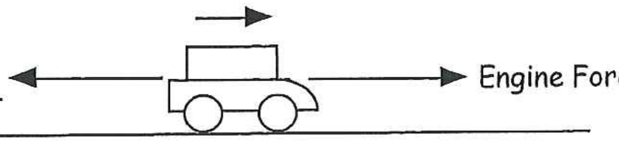
When the forces on an object are equal in size but opposite in direction we say the forces are balanced.



Newton's 1st Law - If the forces on an object are zero or balanced the motion of the object does not change.

Example This car is travelling along the road at a **constant speed**.
State the size of the frictional force.

Frictional Force = 1000N



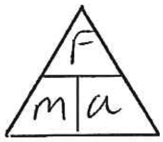
Engine Force = 1000N

22. Newtons' 2nd Law

If the forces on an object are unbalanced we can calculate the unbalanced force. It is this unbalanced force which makes the object accelerate.

Newton's 2nd Law - If an unbalanced force, F_{UM}, acts on a mass **m**,, the mass accelerates at **a** ms^{-2}

$F_{UN}=ma$

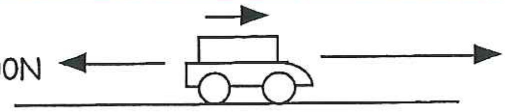


Term	Unit
F_u	N
m	kg
a	ms^{-2}

The bigger the unbalanced force the faster the acceleration.
The bigger the mass the slower the acceleration.

Example The forces acting on this car are shown. The mass of the car is 800kg

Frictional Force = 400N



Engine Force = 1600N

(a) Calculate the unbalanced force F_{UN}= 1600 - 400 = 1200

(b) Calculate the acceleration of the car.

$F_{UN}=ma$

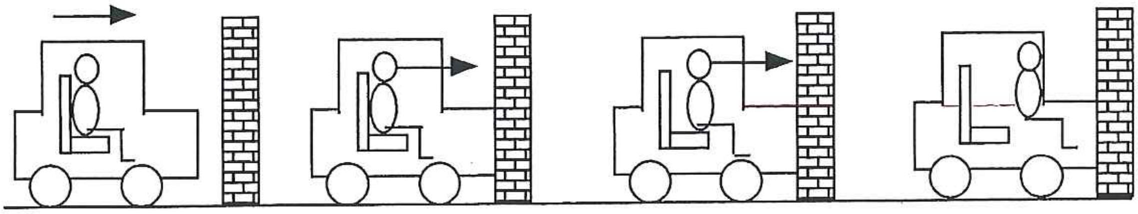
$a = \frac{F_{UN}}{m} = \frac{1200}{800}$

$a = 1.5\ ms^{-2}$

F_{UN}= 1200N
M = 80kg
a = ?

23. Newton's Laws and Seat Belts

When a car crashes into a wall, the wall applies an unbalanced force to the car to decelerate it. If you are **NOT** wearing a seat belt you will continue to move at a constant speed until the windscreen applies an unbalanced force to decelerate you. A seat belt is designed to apply this unbalanced force to you to decelerate you to rest.

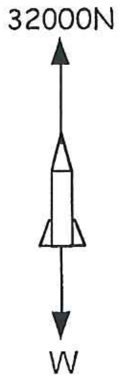


NO SEAT BELT WORN

24. Newton's Laws and Space Travel

At lift off a rocket accelerates upwards. So the upward thrust has to be bigger than the weight of the rocket.

Example The thrust on this 2000kg rocket shown is 32,000N at lift off from Earth.



Calculate (a) the weight of the rocket. (hint $g=9.8Nkg^{-1}$).

$W = mg$
$W = 2000 \times 9.8$
$W = 19600N$

(b) the unbalanced force on the rocket.

$F_{un} = 32,000 - 19,600$
$F_{un} = 12,400N$

(c) the acceleration of the rocket.

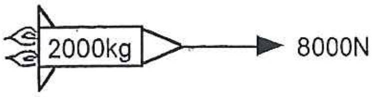
$F_{un} = ma$

$a = \frac{F_u}{m} = \frac{12400}{2000}$

$a = 6.2 ms^{-2}$

Example

In deep space a **stationary** probe's rockets are fired.
The rocket thrust created is 8000N
(assume friction is negligible)



(a) Calculate the acceleration of the probe.

$F_{UN} = ma$

$a = \frac{F_u}{m} = \frac{8000}{2000}$

$a = 4\,ms^{-2}$

$F_{UN} = 800N$
$M = 2000kg$
$a = ?$

(b) After 3s the rockets are switched off. The probe's been accelerating from rest for 3s. What is the speed of the probe at 3s?

$V = u + at$
$V = 0 + (4 \times 3)$
$V = 12\,ms^{-1}$

$u = 0$
$v = 12\,ms^{-1}$
$a = 4\,ms^{-2}$
$t = 3s$

(c) Describe the motion of the probe 20s after the rockets have been switched off?

The probe will travel at a constant speed of $12\,ms^{-1}$.

(d) Using Newton's laws describe why you arrived at your answer to question (c)

The forces acting on the probe are balanced. Newton's 1st Law states that it will continue to move with a constant speed.

25. Newton's Laws and Freefall

When a 50kg skydiver jumps from a plane her weight W, pulling her downwards, stays constant but the upwards frictional forces, F_f increases as she speeds up. For each diagram calculate the unbalanced force acting on her and her acceleration at that point. (We are going to take $g = 10Nkg^{-1}$ for simplicity)

Just as she jumps.

W = 500N

$F_u = 500N$

$a = \frac{F_u}{m}$

$a = \frac{500}{50}$

$a = 10ms^{-2}$

She's picked up some speed.

$F_f = 100N$

W = 500N

$F_u = 500 - 100 = 400N$

$a = \frac{F_u}{m}$

$a = \frac{400}{50}$

$a = 8ms^{-2}$

She's still getting faster

$F_f = 300N$

W = 500N

$F_u = 500 - 300 = 200N$

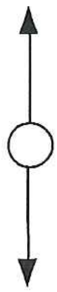
$a = \frac{F_u}{m}$

$a = \frac{200}{50}$

$a = 4ms^{-2}$

She's going so fast friction has increased to equal her weight

$F_f = 500N$



W = 500N

$F_u = 500 - 500 = 0N$

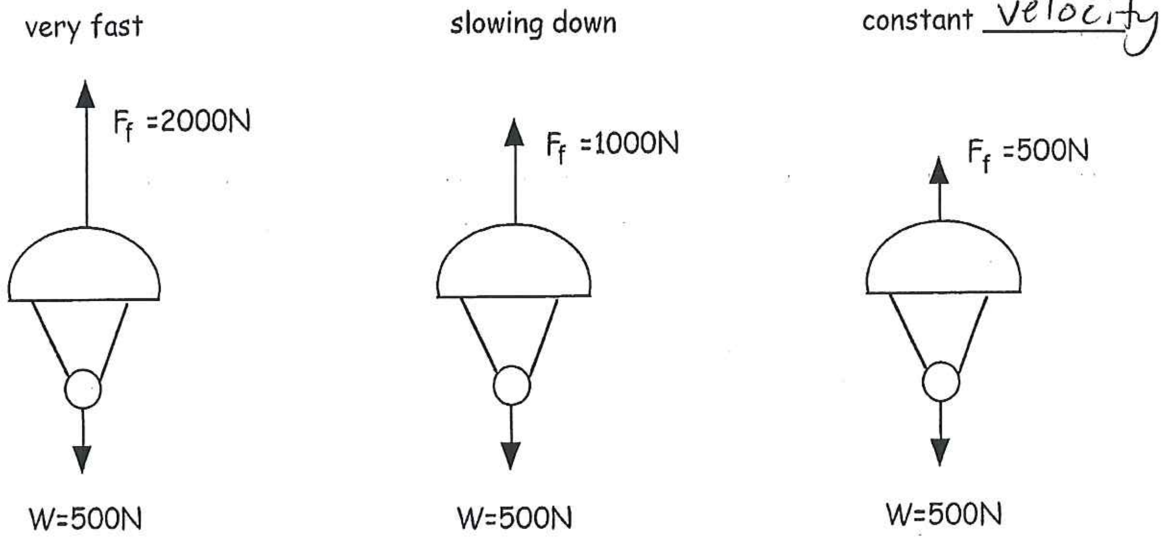
$a = \frac{F_u}{m}$

$a = \frac{0}{50}$

$a = 0ms^{-2}$

As she steps out of the plane her velocity is fairly low, so the air resistance acting on her can be considered to be almost zero.
As she falls, her velocity increases, therefore the air resistance acting on her also increases. The difference between her weight and the air resistance is called the unbalanced force. As time progresses the unbalanced force decreases therefore the acceleration decreases.
At one point the size of the air resistance is the same size as the weight. The forces are now balanced. Therefore by Newton's 1st law, the object will now fall at a constant velocity. This is called terminal velocity.
It is important to realise that even though her acceleration is decreasing she is still getting faster but by a smaller amount each second.

When she puts up her parachute the upward frictional force becomes much greater than her weight so she decelerates. As she slows down her velocity decreases and therefore so does the unbalanced force acting on her. After a few seconds the upward frictional force balances her weight and again she falls at a reduced terminal velocity.

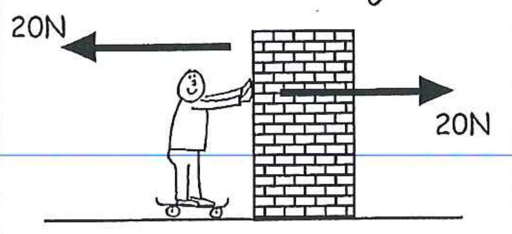


26. Newton's 3rd Law of Motion.

When you apply a force to an object the object will apply an equal and opposite force back on you. These forces are sometimes called Newton's pairs.

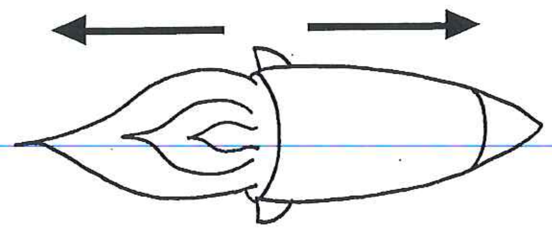
Boy applies a force of 20N to wall

Wall applies a force of 20N to boy



Rocket applies a force of 20,000N on the exhaust gas

Exhaust applies a force of 20,000N on the Rocket



Newton's pairs are NOT balanced forces because they are acting on different objects. In the first example the 20N is being applied separately to the wall and to the boy.

In the 1st example above, there is now an unbalanced force of 20 N acting on the boy. Therefore the boy will accelerate to the left.

In the rocket example there is an unbalanced force of 20,000 N acting on the rocket. Therefore the rocket will accelerate to the right.

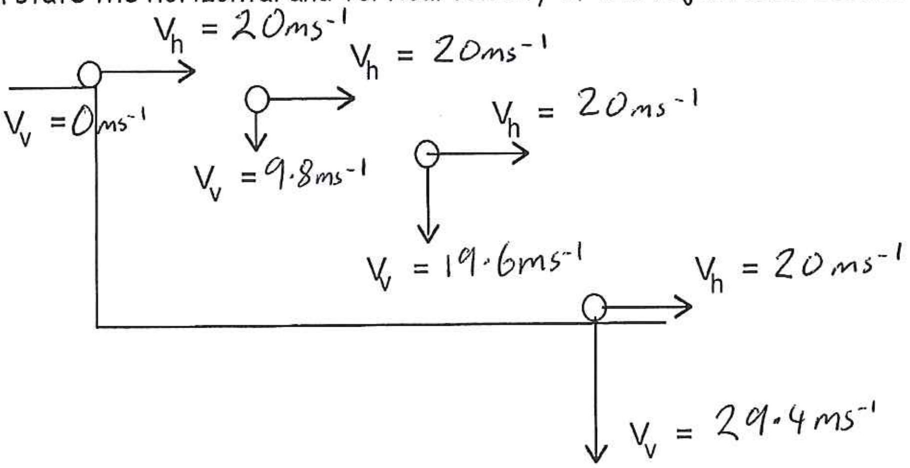
27. Projectile Motion

A projectile is an object which has both a horizontal and vertical motion.

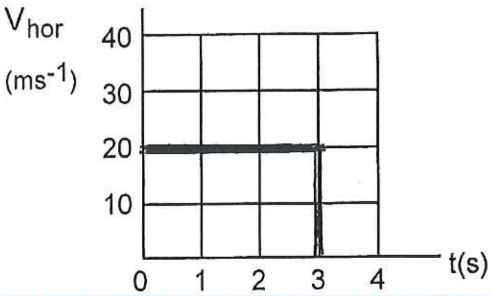
In the horizontal direction the object travels at a constant speed.
In the vertical direction, on Earth, the object accelerates downwards at 9.8 ms^{-2} .

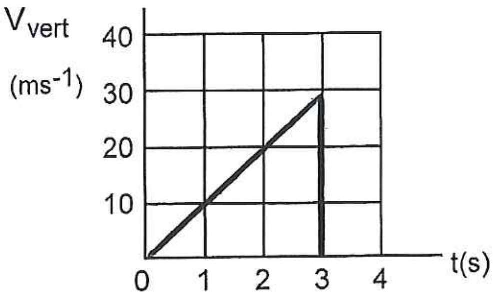
This ball is kicked off a cliff with a horizontal velocity of 20ms^{-1} . It takes 3s to hit the ground. It is travelling horizontally for 3 s and accelerating downwards for 3s at a rate of 9.8 ms^{-2} .

On the diagram state the horizontal and vertical velocity of the object each second as it falls.



The horizontal and vertical motion of a projectile can be described on two velocity time graphs.





To find the horizontal distance travelled we use $d_h = v_h \times t$

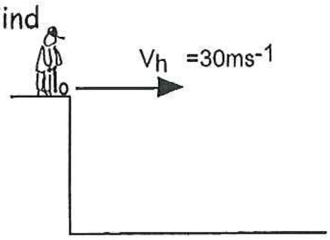
To find the final vertical velocity at time t we use $v_v = u + at$

On different planets g is different so acceleration caused by g will be different.
The g force and the acceleration caused are numerically identical.

On Jupiter g = 25Nkg^{-1} and therefore acceleration caused by this gravity = 25ms^{-2}

On the moon g = 1.6 Nkg^{-1} so acceleration caused by this gravity = 1.6 ms^{-2}

Example. A golfer hits a ball from the top of a raised tee with a horizontal velocity of 30ms^{-1}. It takes the ball 4.5s to hit the ground. Find



(a) the horizontal distance the ball travels.

(b) the final horizontal speed of the ball when it lands.

(c) the final vertical speed of the ball when it lands.

(d) How would your answers to (b) and (c) be different if we did not ignore air friction?

a) $d = vt$

$d = 30 \times 4.5$

$d = \underline{135m}$

b) $V_h = \underline{30ms^{-1}}$

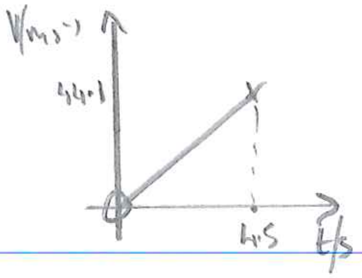
c) $v = u + at$

$V = 0 + (9.8 \times 4.5)$

$V = \underline{44.1ms^{-1}}$

d) Both answers would be smaller.

(e) What is the height of the raised tee?



height = area under graph

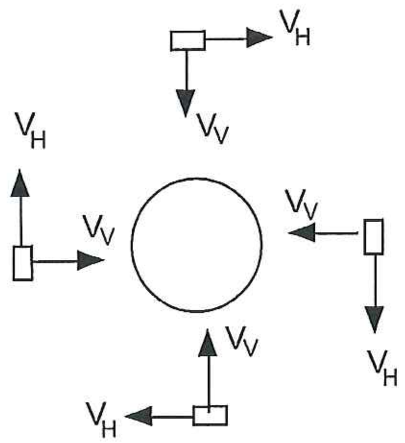
$= \frac{1}{2} \times 4.5 \times 44.1$

$= \underline{99.2m}$

28. Satellites

A satellite is an object which orbits another object. The moon is a satellite of Earth. The Earth is a satellite of the Sun.

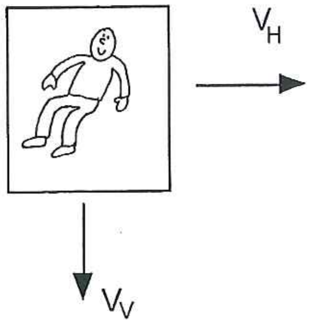
A satellite moves as a projectile. It has a vertical velocity, as it is accelerating towards the ground at a rate of nearly 9.8 ms^{-2}. However the reason it does not hit the ground is because it is given a horizontal velocity. The resultant velocity means that although it falls towards the Earth the Earth is curving away from it.



Draw actual or resultant velocity vector for each picture in red

For each orbital height it is important to calculate the horizontal velocity required to keep the satellite in orbit.

Astronauts appear to be "floating" about in the space station as if they are in zero gravity. However they, and the space station are both in free fall, hurtling towards the Earth. However the space station is given a horizontal velocity and this prevents the station crashing back to Earth.



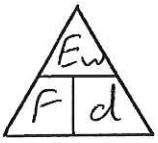
The space station is a satellite of Earth and is moving as a projectile.

29. Work Done

If you pull a box across the floor the box moves. You have transferred energy from yourself to the box. We call this energy transfer Work done. We measure Work Done in Joules or J for short

Work Done = Force applied x distance force is applied

$E_w = Fd$



Term	Unit
E_w	J
F	N
d	m

Example A boy pulls a box a distance of 4m across the floor with a force of 20N. How much work is done by this action?

$E_w = Fd$

$E_w = 20 \times 4$

$E_w = \underline{80J}$

$E_w = ?$

$F = 20N$

$d = 4m$

Work can also be done when a force is applied over a distance to slow an object down. The force is being used to remove or transfer its kinetic energy to heat.

Example A car has 4000J of kinetic energy.

(a) How much work requires to be done to bring the car to a halt?

(b) What braking force must be applied to bring the car to a halt in 50m?

a) $E_w = E_k$

$E_w = 4000J$

b) $E_w = Fd$

$F = \frac{E_w}{d} = \frac{4000}{50}$

$F = \underline{80N}$

$E_w = 4000J$

$F = ?$

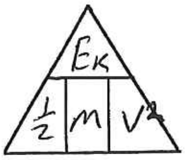
$d = 50m$

Work is only done if the force is applied over a distance. No work is done by simply applying a force to hold a shopping bag in a stationary position.

30. Kinetic Energy E_k

Kinetic energy is the energy possessed by moving objects.

$E_k = \frac{1}{2} mv^2$



Term	Unit
E_k	J
m	kg
v	ms^{-1}

Example A car of mass 800kg moves with a speed of $5ms^{-1}$.
Calculate the kinetic energy of the car.

$E_K = \frac{1}{2} mv^2$

$E_K = \frac{1}{2}(800) \times 5^2$

$E_K = 10,000\ J$

$E_K = ?$

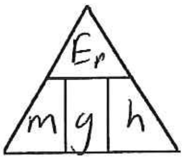
$M = 800kg$

$V = 5ms^{-1}$

31. Gravitational Potential Energy Ep

When work is done to lift an object up, it gains gravitational potential energy. Gravitational potential energy is possessed by objects which are above a certain datum point.

$E_p = mgh$



Term	Unit
E_p	J
m	kg
g	N/kg
h	m

Example A boy of mass 54kg stands on a diving platform 6m above the water. How much gravitational potential energy does he have relative to the water?

$E_p = mgh$

$E_p = 54 \times 9.8 \times 6$

$E_p = 3175.2\ J$

$E_p = ?$

$M = 54kg$

$g = 9.8Nkg^{-1}$

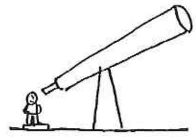
$h = 6M$

C. Space Exploration & Cosmology

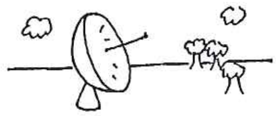
32. Looking into Space.

Up until the 1950s we studied the universe from Earth using terrestrial telescopes which could pick up visible light and radio waves . However lots of interesting parts of the electromagnetic spectrum cannot penetrate our atmosphere and this affected our understanding of the universe.

1. Terrestrial (On Earth) Telescopes



Optical Telescopes - allow us to study the visible light being emitted from distant stars and galaxies

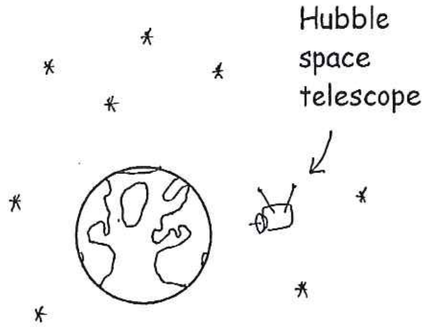


Radio Telescopes - allow us to study the radio waves being emitted from distant stars and galaxies.

Since the 1950's our understanding of the universe has improved vastly due to the following advancements.

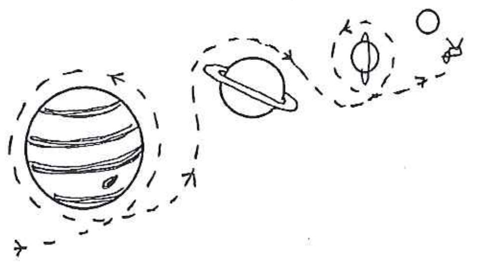
2. Space Telescopes

A lot of interesting electromagnetic radiation like UV, X rays and gamma rays cannot get through the Earth's atmosphere so telescopes like the Hubble telescope are positioned on satellites in orbit around the Earth. They provide extremely clear and detailed images of distant galaxies and can detect signals from all parts of the electromagnetic spectrum.



3. Space Probes

Space probes are sent on journeys of many billions of km to distant planets such as Mercury and Jupiter, and out through the solar system. The space probes Voyager 1 and 2 were launched in 1977 and took amazing photographs of Jupiter's Moons and the rings of Saturn. Voyager 1 is now beyond Pluto but is still sending information back to Earth.



33. Benefits of Space Travel.

1 Technologies Developed through Space Exploration:

The smoke detector and LCD screens which have low energy consumption. Dried and frozen food which stay fresh for months in space. Here are some more examples of other technologies which have been developed as a result of space exploration.

computers, teflon, kevlar, memory foam, cochlear implants and fire resistant chemicals.

2. Satellites

Satellites orbiting the Earth have improved our understanding of our own planet as well as improving communications.

Satellites are placed in orbit around the Earth. A satellite which stays above the same point on the planet is called a geostationary satellite. It has a period of 24 hours. The higher the orbit the longer its period.

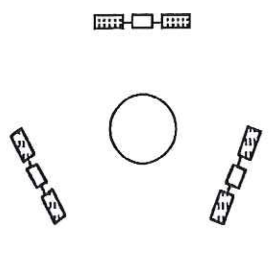
Weather Satellites

Weather satellites allow us to understand the weather on Earth. We can predict and study dangerous storms called hurricanes. We can study the impact of global warming on the planet.

Global Positioning Satellites (GPS)

Global positioning satellites or GPS make use of satellites to allow the position of a receiver on Earth to be pinpointed to within 10cm. It can be used by drivers using satellite navigation systems.

Communications Satellites



Communications satellites allow telephone calls, and TV and radio programmes to be broadcast around the world. It also allows worldwide internet communication.

Agriculture and Forestry.

Satellites allow governments to monitor the quality of the s<u>oil</u> and the health, quantity and quality of c<u>rops</u>. This allows farmers to p<u>lan</u> ahead to maximise production.

Defence and Security.

Satellites allow governments to monitor the a<u>rmy</u> and nu<u>clear</u> capabilities of other countries, to ensure that they are not becoming a threat. During war, satellites allow armies to locate and track enemy p<u>ositions</u>.

Geology.

Satellites allow geologists to locate deposits of o<u>res</u> and m<u>inerals</u>. They can be used to monitor how land masses are moving due to <u>plate</u> tectonics.

Cartography.

Satellites are an accurate method of m<u>apping</u> the planet. As satellites are continually monitoring the Earth, maps can be continually u<u>pdated</u>.

Challenges of space travel include:

- travelling large distances with the possible solution of attaining high velocity by using ion drive (producing a small unbalanced force over an extended period of time)
- travelling large distances using a 'catapult' from a fast moving asteroid, moon or planet
- manoeuvring a spacecraft in a zero friction environment, possibly to dock with the ISS
- maintaining sufficient energy to operate life support systems in a spacecraft, with the possible solution of using solar cells with area that varies with distance from the Sun

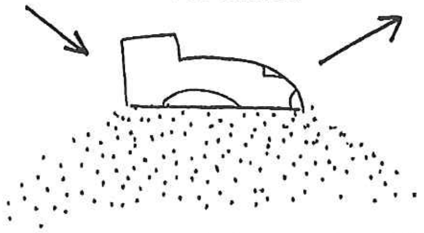
Risks associated with manned space exploration include:

- fuel load on take-off
- potential exposure to radiation
- pressure differential
- re-entry through an atmosphere

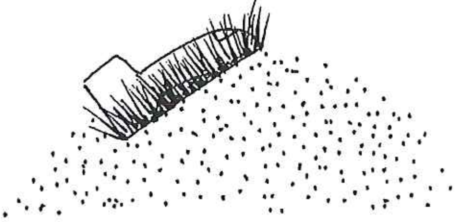
34. Reentry 1 - Frictional Heating

Future space travel will involve space shuttles flying into space and returning safely to Earth. If the space shuttle reenters the Earth's atmosphere at too shallow an angle it will bounce off the upper atmosphere. If it reenters at too steep an angle it will burn up.

Too shallow



Too steep



35. Energy Conservation during Reentry.

When an object reenters the Earth's atmosphere it is travelling very fast. It has a lot of movement or kinetic energy.

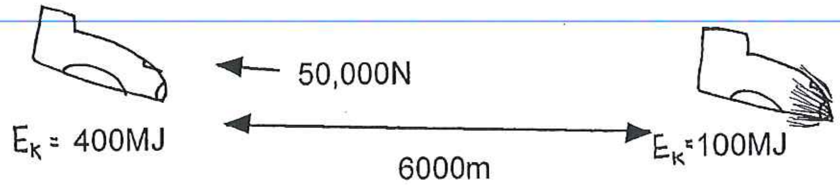
The shuttle uses the force caused by air resistance during reentry to slow itself to a safe landing speed.
The kinetic energy it is losing is transferred to heat due to a air resistance.

We say that the force casued by air resistance has done work over a distance to transfer kinetic energy to heat energy.

$$E_k \text{ lost} = E_W \quad \text{(work done by air friction)}$$

$$\frac{1}{2} m v^2 = Fd$$

This diagram shows air friction acting on a shuttle as it enters the Earth's atmosphere.

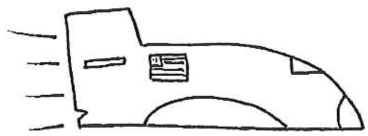


This shuttle has lost 300 MJ of kinetic energy. It has been transferred to heat energy by a force of 50,000 N being applied for 6000 m

The metal body of a spacecraft is covered in a material which prevents the metal melting. This material is called a heat shield. The heat shield protects the metal body by absorbing the heat, and heating up instead of the metal body.

Example

The diagram shows a space shuttle of mass 96,000kg entering the lower atmosphere at a speed of $8000 ms^{-1}$



(a) How much kinetic energy does it have at this point?

$E_K = \frac{1}{2}mv^2$

$E_K = \frac{1}{2}(96\,000) \times 8000^2$

$E_K = 3.072 \times 10^{12}\ J$

(b) After travelling through the atmosphere for 20km its kinetic energy has reduced to 1.2×10^{12} J. How much kinetic energy has been transferred to heat over this distance?

E_K transferred $= 3.072 \times 10^{12} - 1.2 \times 10^{12}$

$= 1.872 \times 10^{12}\ J$

(c) What is the name of the force which has done the work to transfer the kinetic energy to heat energy?

Air resistance

(d) Calculate the size of the frictional force which transfers this energy or does this work during the 20km?

$E_W = Fd$

$F = \frac{E_W}{d} = \frac{1.872 \times 10^{12}}{20 \times 10^3}$

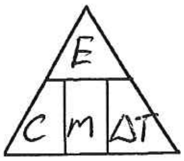
$F = 9.36 \times 10^7\ N$

36. Specific Heat Capacity.

We need a heat shield which absorbs a lot of heat energy, but for only a small rise in its temperature, because you are trying to prevent the shields melting.

The specific heat capacity of a substance tells you the amount of heat energy required to raise the temperature of 1kg of the substance by 1 °C.

$E = mc\Delta T$



Term	Unit
E	J
m	kg
c	$Jkg^{-1}°C^{-1}$
ΔT	°C

The specific heat capacity of water is $4200 Jkg^{-1}°C^{-1}$. This means that to heat 1kg of water by 1°C, the water needs to absorb 4200J of heat energy.

A heat shield has a high specific heat capacity so it can absorb a huge amount of heat energy for only a small change in its temperature. As the shuttle's shields are absorbing most of the heat, the metal body of the shuttle stays intact.

Example On reentry the temperature of the heat shields covering the shuttle's nose cone rose by 4000°C. If the mass of the nose cone shields is 260kg and its specific heat capacity is $3800Jkg^{-1}°C^{-1}$ then calculate the heat energy it absorbed.

$E = c m \Delta T$

$E = 3800 \times 260 \times 4000$

$E = 3.952 \times 10^9 J$

The temperature of a substance is the measure of the average kinetic energy of its particles.

37. Reentry II - Heat Shields Melt.

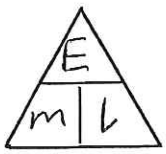
After a few minutes heating up, the shielding material may reach its melting point. The process in which the shields melt requires even more heat energy. The shields absorb more heat energy and melt and so prevent the metal body of the shuttle absorbing the heat and melting. The amount of heat energy required to change the state of 1kg of material is the Specific Latent heat of the material.

38. Specific Latent Heat.

The specific Latent heat of fusion L_f of a material is the amount of heat energy required to change 1kg of solid to 1kg of liquid at a constant temperature.

The specific latent heat of vaporisation L_V of a material is the amount of heat energy required to change 1kg of liquid into 1kg of gas at a Constant temperature.

$E = mL_f$ or $E = mL_V$



Term	Unit
E	J
m	kg
L	$J\,kg^{-1}$

If the liquid substance then freezes or the gaseous substance condenses the energy E is released by the substance.

Example At one point during the re entry 5kg of shield material begins to melt. If the latent heat of fusion of the shield material is 4.8×10^5 Jkg^{-1} calculate the energy absorbed by the shields while melting.

$E = mL$

$E = 5 \times 4.8 \times 10^5$

$E = 2.4 \times 10^6\ J$

39. Cosmology

A light year is the distance light travels in a year. It also tells us how long it would take a beam of light to travel that distance. The distance from Earth to the Sun is 8 light minutes. This means it takes a beam of light 8 minutes to travel from the sun to Earth.

The distance to the centre of our galaxy is 25,000 light years. So it would take a beam of light 25,000 years to travel from the centre of the galaxy to Earth. So in effect when the light arrives at us we are seeing the centre of the galaxy as it was 25,000 years ago.

40. Converting Light Years to Metres

The nearest star to the Sun is Proxima Centauri. It is 4.2 light years from the Sun. So it takes the light 4.2 years to reach us from Proxima Centauri. What distance, in metres has it travelled in this time?

Light travels 3×10^8 m in 1 second. So how far will it travel in 4.2 years.

We need to find out what 4.2 light years is in seconds.

No of days - 4.2 years x 365 = 1533 days

No of hours - 1533 days x 24 hours = 36792 hours

No of minutes - 36792 hours x 60 minutes = 2207520 minutes

No of seconds - 2207520 minutes x 60 seconds = 132451200 seconds

So the question is. How far will light travel in this 132451200 seconds

$v = 3 \times 10^8 ms^{-1}$

$t = 132451200 s$

$d = ?$

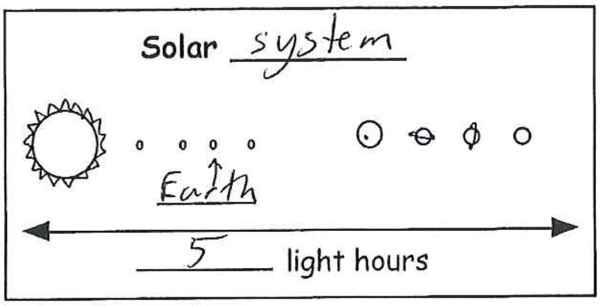
$d = v \times t$

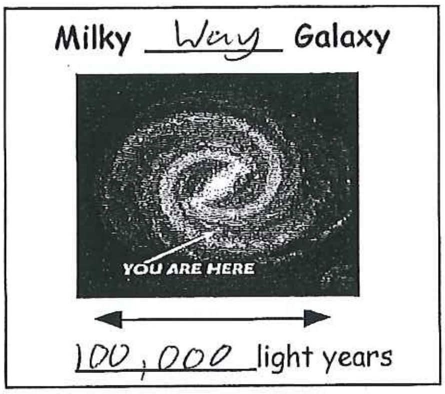
$d = 3 \times 10^8 \times 132451200$

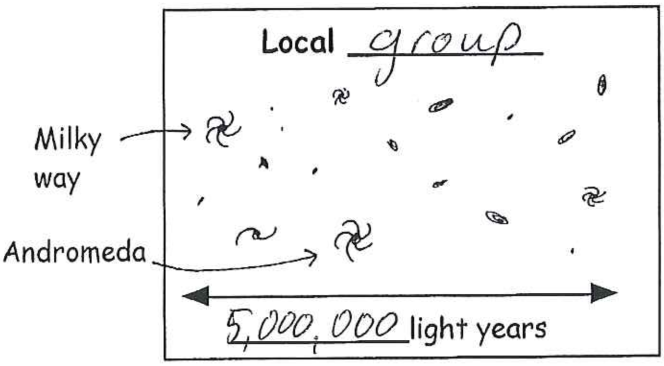
$d = 3.97 \times 10^{16} m$

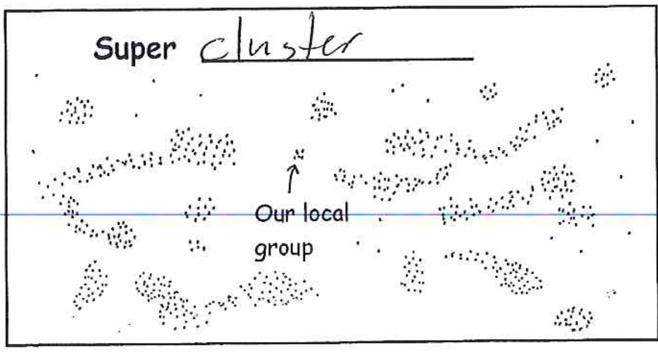
41. The Observable Universe

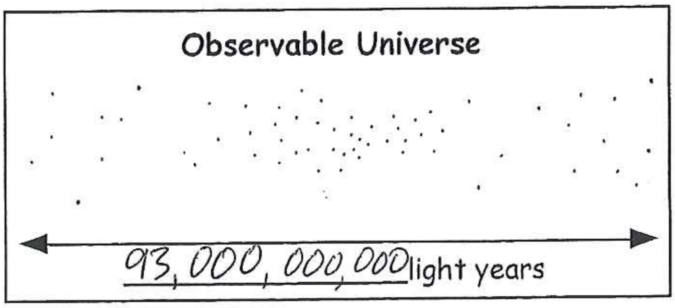
Earth is part of a family of 8 planets which orbit a star called the Sun.
This star family is called the solar system. The solar system is located on the outer arm of a spiral galaxy called the Milky Way.
The Milky Way contains about 400 billion stars.
There are some nearby galaxies, for example Andromeda.
This group of nearby galaxies is called the local group.
Astronomers estimate that there are 100 billion galaxies in the vast universe, mostly clustered together in super clusters. Some parts of the universe are so far away that light has not had time to reach us, so this part of the universe is unobserved.











Location	Distance
to moon	1·28 light seconds
to sun	8 light mins
to Jupiter	43 light minutes
to edge of solar system	22 light hours
to proximi centauri	4.2 light years
across milky way	100,000 light years
to Andromeda	2,538,000 light years
to furthest galaxy	13·3 x10^9 light years

42. The Big Bang.

In the 1920s Edwin Hubble observed that all the galaxies were moving apart. If all these galaxies were moving apart then at one time they must have all been squashed together. Scientists concluded that all the matter and energy and space in the Universe must have been, at one time, squashed into an extremely small space called a singularity. About 13.7 billion years ago this tiny ball must have exploded apart in a hot, dense fireball. As the Universe expanded it cooled down, and some energy turned to mass. A new force called gravity started to clump the mass together to form a nebula, then stars, then galaxies When the stars exploded, planets formed out of the debris.

43. Exo Planets

Exo planets are planets which exist outside our solar system. We can detect them because they cause their star to dim as they pass is front of it. Planets orbiting a star also cause the star to wobble on its axis. For life similar to that on Earth to develop the planet would require

A. to be close to a long lived star which is a stable source of energy.
B. not to be too close to the centre of its galaxy as the planet would be zapped by too much dangerous radiation.
C. to have a solid surface and a supply of a liquid like water.
D. to be the correct distance from its star. Too close, and all the liquid would evaporate. Too far away and the temperature would be too cold for life to form.
E. to be the correct size. Too small, and the atmosphere would be too thin. Too big and the atmosphere would be too dense.
F. a protective magnetic field to deflect the solar wind from the star.

44. Electromagnetic Spectrum.

People have been studying the visible light coming from stars and galaxies for thousands of years. However stars, galaxies and even planets are constantly emitting waves at all wavelengths of the electromagnetic spectrum. The Earth's atmosphere absorbs many of these waves.

The first non-visible radiation we picked up from the universe were radio waves in the 1930s. Since then we have found clever ways of detecting all the electromagnetic waves the universe emits.

Microwave radiation comes from every corner of the Universe. It is believed that this radiation is the heat left over from the Big bang. The microwaves started off as infra red heat but as the universe expanded the infra red was stretched to microwaves.

Infra red radiation or heat energy is given off by most objects in the universe.

UV, X rays and **Gamma rays** are high frequency waves which therefore are high energy waves. These waves are given off by hot stars and extreme astronomical events, for example exploding stars called Supernovas and Black holes.

45. Continuous Emission Spectra.

When a solid or liquid is heated it gives off a complete range of wavelengths of visible light. This is called a continuous emission spectrum. The sun and light bulbs give off continuous emission spectra.
We can analyse the light given off by stars using a spectroscope.
A spectroscope splits light up into a spectrum according to the different wavelengths or frequencies in the light.

Continuous Emission Spectrum

low frequency waves

RED	ORANGE	YELLOW	GREEN	BLUE	INDIGO	VIOLET

high frequency waves

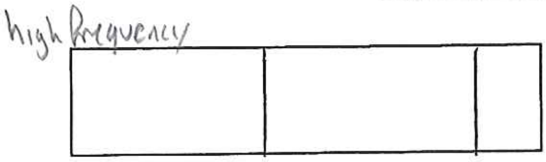
46. Judging the Temperature of a Star.

As a star becomes hotter it gives off increasingly shorter wavelengths of light. We can use this fact to judge how hot a star is.
So, cool stars gives off mostly long wavelengths so appear red in colour. A yellow star is hotter because it gives off more yellow wavelengths and a bluish white star is very hot as it gives off all the colours but with a lot of the very short wavelength blue light.
Our Sun is yellow so it is a medium hot star.

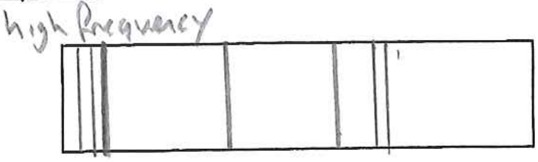
47. Line Emission Spectra.

Each gaseous element, when heated, gives off only certain wavelengths of light. If we look at this light using a spectroscope we see a line emission spectrum. Each line indicates a different frequency of light. We can use the line spectra of elements to identify the elements present in a star.

Line Emission Spectra



line emission spectra of hydrogen



line emission spectra of mercury

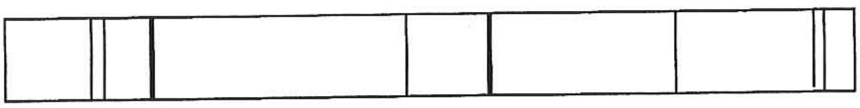
Stars are usually made from many elements, so the line spectra of all these hot elements are usually mixed up. A trained eye is able to pick out the individual elements present

Example The first diagram shows the line spectrum from a distant unknown star.

unknown star

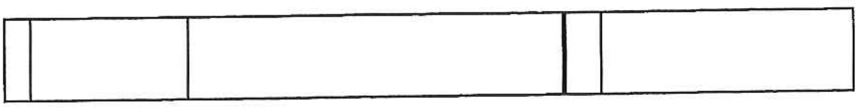
The next 3 diagrams show the spectra from 3 different elements

Element 1



Element 2

Element 3



Which elements are present in the unknown star?

Ans: Elements 2 & 3

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