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Photocopy Master Sheets

Years 9-10

Forces & Motion

Disk filename = "13.Motion"

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Topics Available

Year 7-8 General Science

Disk Filename	Topic Name
01.Energy	Energy
02.Forces	Forces
03.Matter	Solids, Liquids & Gases
04.Mixtures	Separating Mixtures
05.Elements	Elements & Compounds
06.Cells	Living Cells
07.Life	Living Things
08.LifeSystems	Plant & Animal Systems
09.Astronomy	Astronomy
10.Earth	The Earth
11.Ecosystems	Ecosystems

Year 9-10 General Science

Disk Filename	Topic Name
12.Waves	Wave Energy (inc. Light)
13.Motion	Forces & Motion
14.Electricity	Electricity
15.Atoms	Atoms & Elements
16.Reactions	Compounds & Reactions
17.DNA	Cell Division & DNA
18.Evolution	Evolution of Life
19.Health	Health & Reproduction
20.Universe	The Universe
21.EarthScience	Earth Science
22.Resources	Resources & Technology

Year 11-12 Science Courses

Biology
Preliminary Core
Local Ecosystem
Patterns in Nature
Life on Earth
Evolution Aust. Biota
HSC Core
Maintain. a Balance
Blueprint of Life
Search for Better Health
Options
Communication
Genetics:Code Broken?

Chemistry
Preliminary Core
Chemical Earth
Metals
Water
Energy
HSC Core
Production of Materials
Acidic Environment
Chem.Monit.&Mngment
Options
Shipwrecks, Corrosion...
Industrial Chemistry

Earth & Envir. Science
Preliminary Core
Planet Earth...
Local Environment
Water Issues
Dynamic Earth
HSC Core
Tectonic Impacts
Environs thru Time
Caring for the Country
Option
Introduced Species

Physics
Preliminary Core
World Communicates
Electrical Energy...
Moving About
Cosmic Engine
HSC Core
Space
Motors & Generators
Ideas to Implementation
Options
Quanta to Quarks
Astrophysics

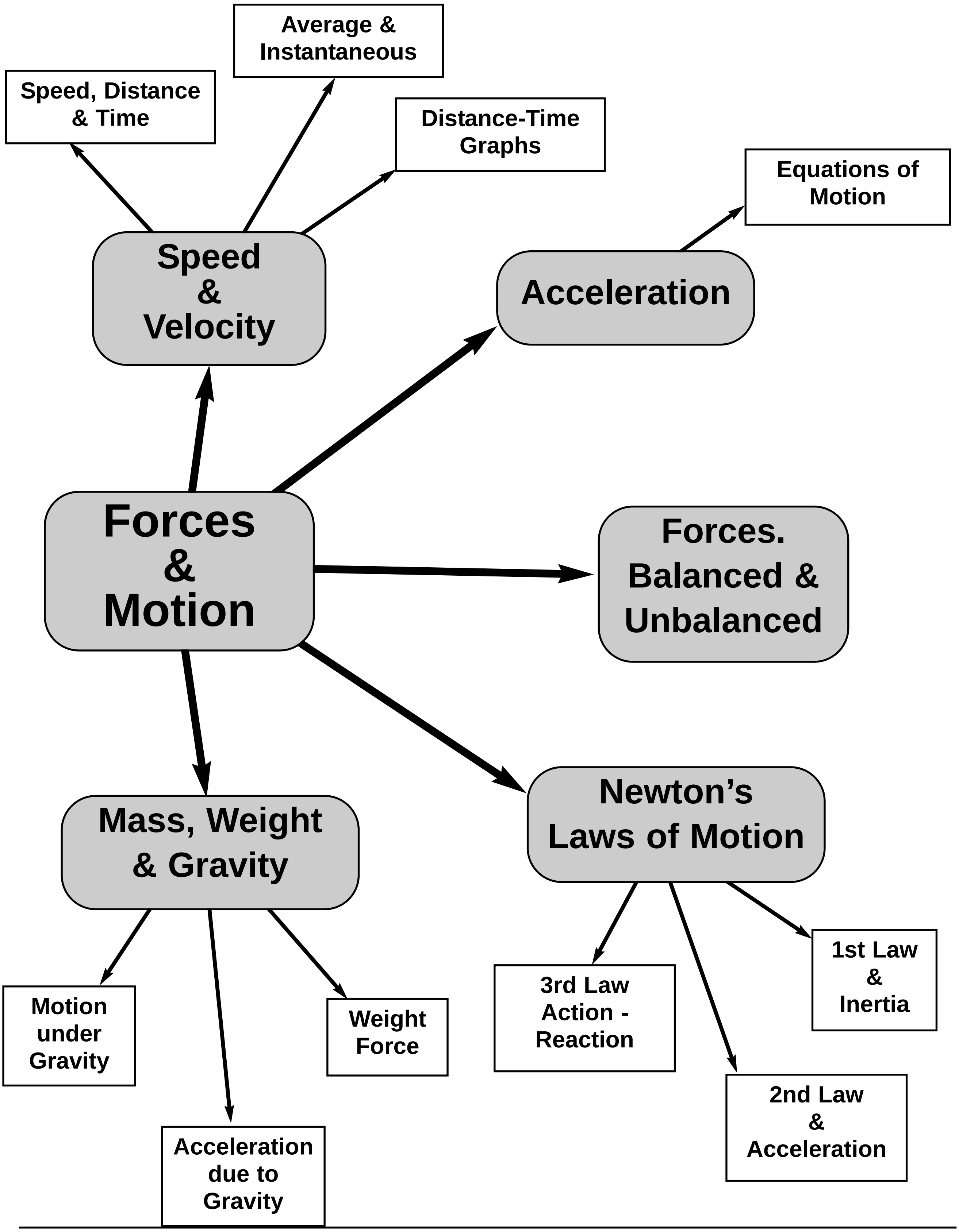
All Topics Available as PHOTOCOPY MASTERS and/or KCiC

Photocopy Masters (PDF files)
Black & White, A4 portrait-orientation
for clear, economical photocopying.

KCiC = Key Concepts in Colour
Full colour, formatted for on-screen study
and data projection. PDF + Powerpoint®

"Mind-Map" Outline of Topic

**This topic belongs to Physics, the study of energy, force and motion.
In this topic you will study the Physics of movement... speed and acceleration and how forces are involved when things move.**



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Make your own "Mind-Map" TITLE PAGE.
Cut out the boxes. Sort them into an appropriate lay-out on a page of your workbook, then glue them down. Add connecting arrows and colour in.

Forces & Motion

Mass, Weight & Gravity

Distance-Time Graphs

Weight Force

Equations of Motion

1st Law & Inertia

Speed & Velocity

Acceleration

Average & Instantaneous

2nd Law & Acceleration

Newton's Laws of Motion

Forces. Balanced & Unbalanced

Acceleration due to Gravity

Speed, Distance & Time

Motion under Gravity

3rd Law Action - Reaction

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Motion under Gravity

3rd Law Action - Reaction

Speed

When something is moving, its position changes as time goes by. It moves some distance in each second (or hour) of time. This idea of <u>distance moved per unit of time</u> gives us our most basic way to study motion... the idea of speed.

Distance, Time & Speed

The faster an object is moving, the more distance it covers in each second, or hour.

We commonly measure speed in kilometres per hour (km/hr) or in metres per second (m/s). Other units are possible, but here we will mostly use only one or the other, of these.

If you walk at a speed of 4 km/hr, it means (of course) that if you keep it up for 1 hour then you will cover a distance of 4 kilometres. If you keep walking at this speed for 2 hours, you will cover 8km, and so on.

In many parts of this topic you will need a calculator to help with the number work involved.

Mathematically,

$$\text{Speed} = \frac{\text{Distance}}{\text{Time}}$$

We can write this relationship in a shorter way with symbols. To avoid confusion later, get used to using the symbols as follows:

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

v = velocity, a technical name for speed. The difference between speed & velocity will be explained later. We will measure speed in either km/hr or in m/s.

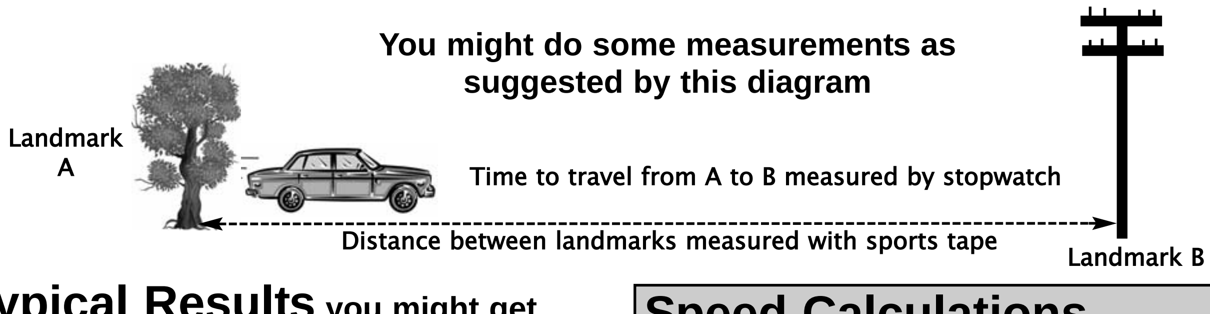
S = distance travelled, in km or m. (Why "S" for distance? Just do it!)

t = time taken, in hours (hr) or seconds (s).

Measuring Speed

The simplest and most basic way to measure how fast something is moving is to use a stop-watch to accurately measure the time taken to move over a measured distance.

You might do some measurements as suggested by this diagram



Typical Results you might get.

<u>Vehicle</u>	<u>Distance</u> (m)	<u>Time</u> (s)
Car	73.5	5.30
Bicycle	73.5	21.0

Speed Calculations

<u>Car</u>

$v = S/t$
$= 73.5 / 5.30$
$= 13.9$ m/s
(about 50km/hr)

<u>Bicycle</u>

$v = S/t$
$= 73.5 / 21.0$
$= 3.50$ m/s
(about 13 km/hr)

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Worksheet 1
Calculating Speed

Student Name...

If v = S / t, then S = v x t and t = S / v

1.
What is the speed of a truck which travels 120 km in 1.5 hours?

$$v = \frac{S}{t} = \frac{\quad}{\quad}$$

=................. km/hr

2.
In a 200m athletics race, a student's time was 25.0 s. What was her speed?

$$v = \frac{S}{t} = \frac{\quad}{\quad}$$

=................. m/s

3.
An aircraft flew 4,000 km in 5 hours. What was its average speed?

4.
A bullet fired from a pistol travelled 50 metres to the target in 0.08s. What was its speed?

5.
A train completed a 440 km trip in 8 hours. What was its average speed?

6.
In a car travelling at 80 km/hr, how far would you travel in 3.5 hr?

7.
An arrow was fired from a bow at a speed of 120 m/s. How far will it move in 0.2s?

8.
A marathon runner can maintain a steady speed of 15 km/hr. How long will it take him to complete the 42 km race?

9.
Sound waves travel through air at 330m/s. If you see a lightning flash, then hear the thunder 8s later, how far away is the lightning? (answer in m <u>and</u> km)

10.
In a parachute, falling steadily at 7.5m/s, how long does it take to reach the ground from 3,000 m high?

Average and Instantaneous Speed

Average Speed

If you go somewhere by car, it is very unlikely that you will travel the whole way at the same speed.

<u>Example</u>: <u>A Drive to the Beach</u>
Total distance = 10 km
Total time taken = 15 min. (= 0.25 hour)

$$v = \frac{S}{t} = \frac{10}{0.25} = 40 \text{ km/hr}$$

This calculated speed is the <u>average</u> speed for the trip. During the drive you may have stopped for traffic lights, slowed down for round-abouts and given way to traffic and pedestrians.

At some moments you were travelling much faster than the average speed, and at other times much slower.

Instantaneous Speed

This refers to your speed at a particular <u>instant</u> of time.

In a car, the reading on the speedometer gives you the speed at that moment.

The "speedo" reading changes instantly if the car speeds up or slows down.

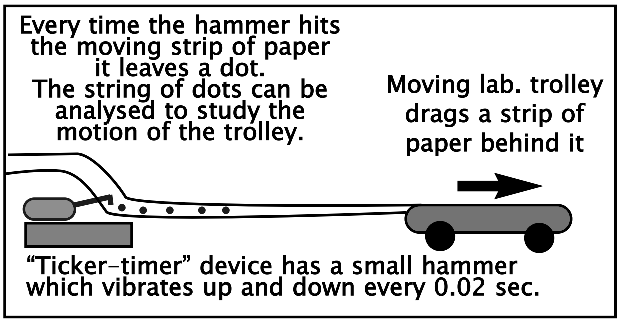
In the scientific study of motion it is the instantaneous speed that is usually of interest. The average speed over a whole journey is not very useful for studying the Physics of motion.

How to Measure Instantaneous Speed

There are a variety of ways to measure instantaneous speed.
The method described here is a very simple one that you may use experimentally.

The "Ticker-Timer"

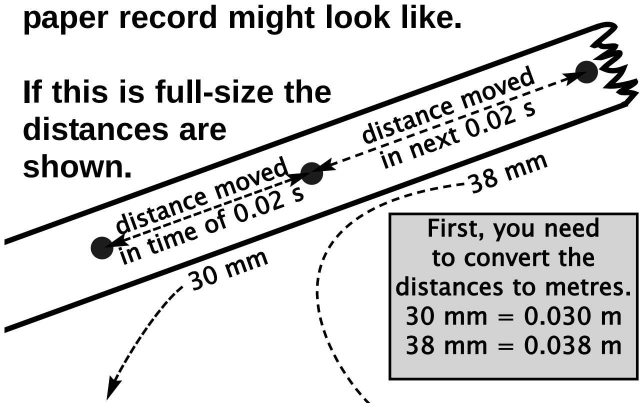
This system works by attaching a long strip of paper to a moving object, such as a laboratory trolley.



When the trolley moves, it drags the paper through the "ticker-timer" device. A small hammer hits the paper every 0.02 second and leaves a dot. The string of dots is a record of both distance and time over very short time intervals.

Here is an example of what part of the paper record might look like.

If this is full-size the distances are shown.



v = S / t
= 0.030/0.02
= 1.5 m/s

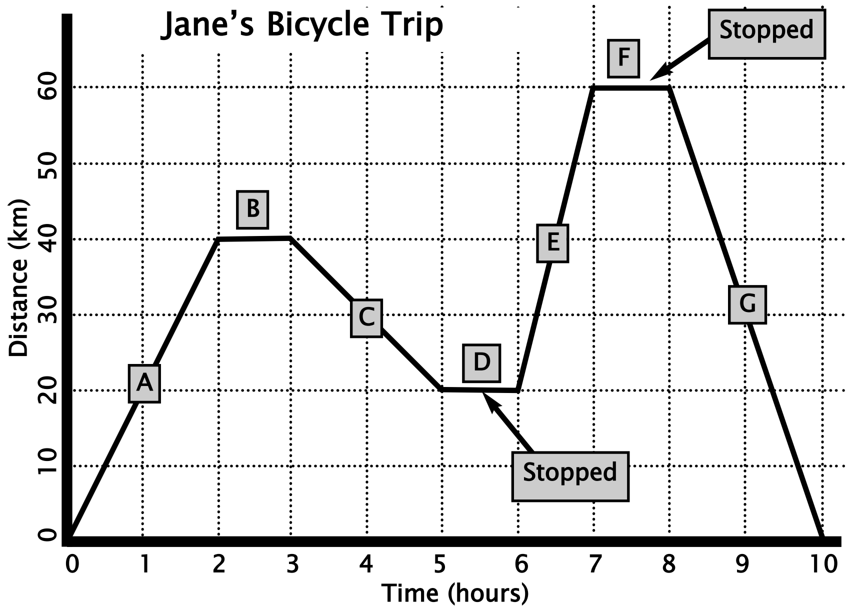
v = S / t
= 0.038/0.02
= 1.9 m/s

Each of these values is really the <u>average</u> speed over the time and distance between dots. However, this is such a short time period that it is taken to be the <u>instantaneous</u> speed.

Distance - Time Graphs

These are sometimes called "travel graphs" because they can be used to describe a journey in terms of distance and time.

How to Read the Graph



<u>Section A</u>
Jane has moved 40km in 2hr.

V = S/t = 40/2 = 20 km/hr.

<u>Section B</u>
Jane stopped for 1hr.
Speed = zero.

<u>Section C</u>
Jane has moved 20km in 2hr.
V = S/t = 20/2 = 10 km/hr.

She has moved back towards the starting point because she ends up only 20km from where she started.

<u>Section E</u>
Jane has moved 40km in 1hr.
V = S/t = 40/1 = 40 km/hr.

<u>Section G</u>
Jane has moved 60km in 2hr.
V = S/t = 60/2 = 30 km/hr.

She has returned to her starting point.

Worksheet 2
Construct a Travel Graph

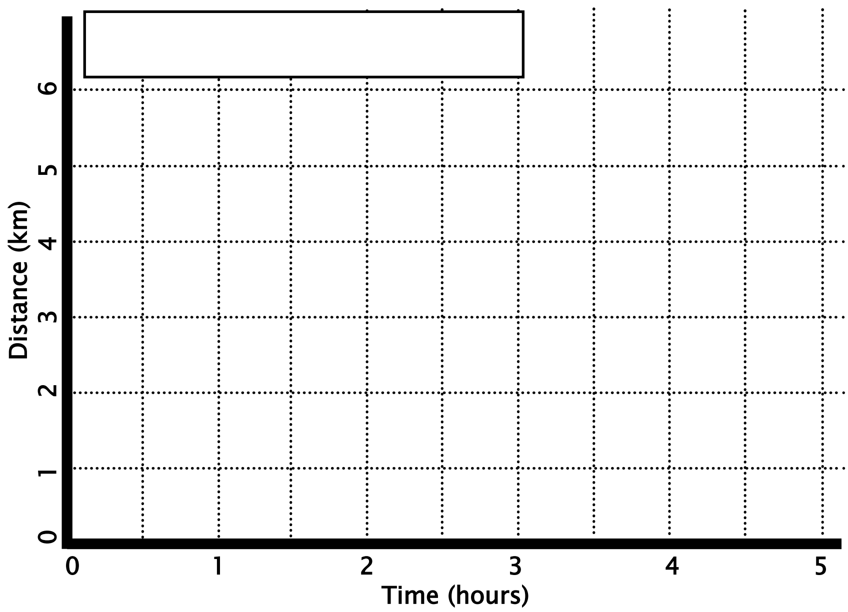
Student Name..

<u>Fred Goes Hiking</u>

Fred left base camp heading <u>east</u> and walked 4km in the first hour.

He stopped for 30 min, then walked <u>west</u> for 30min, covering 1km.

He turned east again and walked 3km in 1hr. He stopped and rested for 30min, then walked back to base camp in $1^1/_2$ hours.



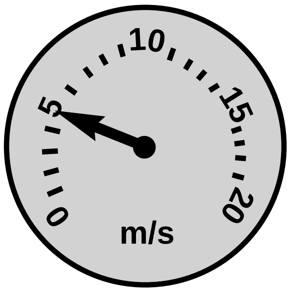
<u>Calculate Fred's speed for each part of his walk and write it along that graph section.</u>

Acceleration

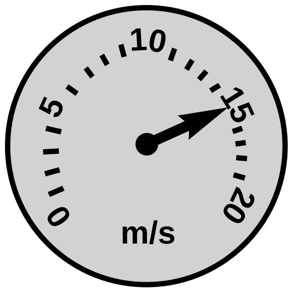
In everyday language, to "accelerate" means to speed up and go faster.
In Science, "accelerate" means any change of velocity.
So speeding up is acceleration, but slowing down is also acceleration.

Imagine a car with a "speedo" which shows its instantaneous speed in metres per second, rather than km/hr.

Speedo reading...



...and 5 sec. later.



In 5 seconds it has accelerated from an initial speed of 5 m/s to a final speed of 15 m/s. This means that the speed increased by 10 m/s, over 5 seconds.

Start	1sec	2sec	3sec	4sec	5sec
5 m/s →	7 m/s →	9 m/s →	11 m/s →	13 m/s →	15 m/s

Its rate of acceleration was an increase of speed of 2 m/s per second.

Acceleration = 2 m/s/s (or m/s^2)

Negative Acceleration

After travelling along at a speed of 15m/s (which is about 55 km/hr) the car approaches a red light, so the driver applies the brakes and comes to a complete stop in 5 seconds.

The change in speed was:

Start	1sec	2sec	3sec	4sec	5sec
15 m/s →	12 m/s →	9 m/s →	6 m/s →	3 m/s →	0 m/s

This means that during each second its speed slowed down by 3 m/s.

Its rate of acceleration was negative 3m/s per second.

Acceleration = -3 m/s^2

Acceleration means any change in velocity.

Units = metres per sec per sec (m/s^2).

Negative value means slowing down.

Calculating Acceleration

Mathematically:

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

a = acceleration, in m/s^2.

v = final speed (velocity) in m/s at the end of the acceleration.

u = initial speed (velocity) in m/s before the acceleration began.

t = time period of acceleration, in sec.

Examples
Here are the same situations described above, but calculated mathematically.

1. Car sped up from 5m/s to 15m/s in 5s.

$$a = \frac{v - u}{t} = \frac{(15 - 5)}{5} = 2\ m/s^2.$$

2. Car slowed down from 15m/s to zero in 5 seconds.

$$a = \frac{v - u}{t} = \frac{(0 - 15)}{5} = -3\ m/s^2.$$

Negative value means to slow down.

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Worksheet 3
Velocity & Acceleration

Student Name...

Fill in the blank spaces.

"Speed" refers to a)................................ something is moving. The units of speed commonly used are b)................... or .... Mathematically, speed can be calculated by dividing c)..................... by d).......................

"Average speed" is total e)..................... divided by f)................. for the entire g)...................... "Instantaneous speed" means the speed at an h)........................ of time.

The speedo of a car gives a measure of i)................................ speed. In the laboratory, inst. speed can be measured by using devices such as a j) "......................................".

Acceleration is the rate at which k)............................... changes. It is most commonly measured in units of l)............................. If the object slows down, the acceleration is m)....................

Worksheet 4
Calculating Acceleration

Student Name...

1.
An aircraft accelerating for take-off takes 20 seconds to go from stationary (u = 0) to take-off speed of 35 m/s.
What is its rate of acceleration?

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

$$= \text{....................} \ m/s^2.$$

2.
The aircraft (from Q1) lands at the same speed as it took off. (u = 35m/s)
It takes 7 seconds to slow down and stop. (v = 0)
What is its acceleration?

What is the significance of getting a negative answer?

3. When a gun is fired the bullet goes from being stationary to a velocity of 800m/s by the time it reaches the end of the barrel in a time of 0.05s.
What is its acceleration?

4. A jet fighter plane lands on an aircraft carrier at a speed of 52 m/s. To stop it quickly, its tail hook snags an "arrester wire" which brings it to a complete stop (v = 0) in 1.6s. Acceleration rate?

5. A car was travelling at 5.0 m/s. Then it accelerated to a final velocity of 30 m/s over a period of 10s. Acceleration?

Worksheet 5 (2 pages)
Practical Skills.

Analysing Ticker-Timer Data for an Accelerating Trolley

Down the centre of this page is an actual-size reproduction of a ticker-timer paper record.

This paper strip was attached to a laboratory trolley which was allowed to roll down a ramp, along a bench, and finally up a second ramp.

Most ticker-timers make a dot on the paper every 0.02s, but this one was set to beat only every 0.1 second.

Because of the small scale of this motion study, all distances will be in millimetres (mm) and speed will be in millimetres per second (mm/s).

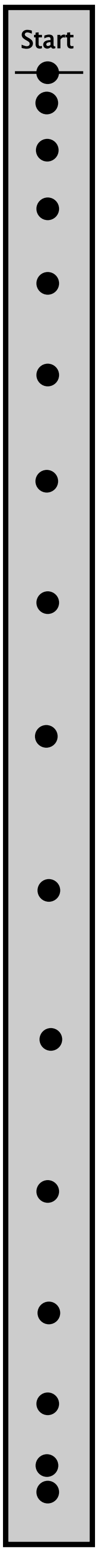
Question1
What was the total distance moved by the trolley? Measure carefully with a ruler.
(in millimetres) ....mm

Question 2
What was the total time of the motion?
(count gaps, not dots!)
.... s

Question 3
Calculate the average speed (mm/s) of the trolley for the entire motion. (show working)

(round-off answer to the nearest 1 mm/s)

Question 4
Do you think that calculating the average speed is a good way to study this motion? Why, or why not?



Student Name...

Data Table 1

Measure the distance (in mm) from the start dot to each of the others, and fill in the data table.

Total Time from start (s)	Total Distance from start (mm)
0	0
0.1	4
0.2	10
0.3	18

Data Table 2

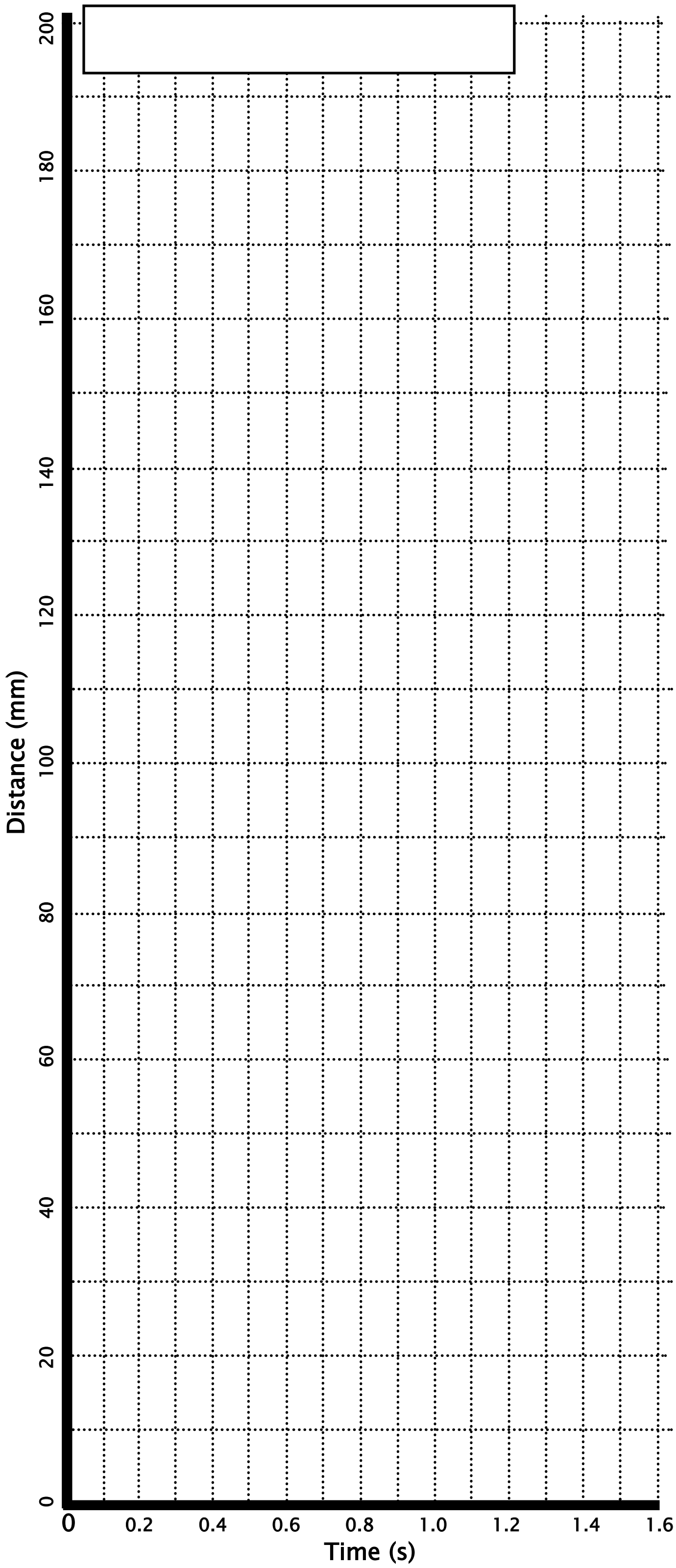
Measure the distance from each dot to the next, and record. For each distance, divide it by 0.1s to calculate the instantaneous speed at that time.

Total Time from start (s)	Distance in this 0.1s (mm)	Instant. Speed (mm/s)
0.1	4	4/0.1= 40
0.2	6	6/0.1= 60
0.3	8	8/0.1=
0.4	10	

Worksheet 5 (cont.)

Distance-Time Graph

Plot the data from Data Table 1 to construct a distance-time graph. If the points do not lie in a straight line, join them with an even curve.



To answer these questions you need to look carefully at the shape of your graph, AND the pattern of dots on the ticker-timer record AND look at the speeds shown in Table 2.

Question 5
a) Did the trolley travel at the same speed for any period of the motion? If so, when?

b) Find this time period on your graph. What shape is the graph over this period?

c) Label this part of the graph "constant speed".

Question 6
a) Was the trolley speeding up (accelerating) for any period of the motion. If so, when?

b) Find this time period on your graph. What shape is the graph over this period?

c) Label this part of the graph "+ acceleration".

Question 7
a) Was the trolley slowing down (decelerating) for any period of the motion. If so, when?

b) Find this time period on your graph. What shape is the graph over this period?

c) Label this part of the graph "– acceleration".

Question 8 Fill in the blank spaces.

When an object is travelling at constant speed a D-T graph is a)... (shape of graph). The ticker-timer tape shows dots which are b)... (describe pattern of dots during this time)

When an object is accelerating (faster) the D-T graph is c)... (shape of graph). The ticker-timer tape shows dots which are d)... (describe pattern of dots during this time)

When an object is decelerating, the D-T graph is e)... (shape of graph). The ticker-timer tape shows dots which are f)... (describe pattern of dots during this time)

Equations of Motion

Here is what you have so far in the calculations department:

Speed Equation

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

Used to: calculate speed, distance, or time.

Limitations: only works for average speed or constant speed. Cannot work with accelerations.

Acceleration Equation

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

Used to: calculate acceleration from speed change & time.

Limitations: does not include distance.

Two More Useful Equations

This is the “Acceleration Equation” turned around with a little algebra. It is often more useful in this form.

$$v = u + at$$

v = final speed (velocity), in m/s.

u = initial speed, in m/s.

a = acceleration, in m/s^2.

t = time, in seconds.

Example

A speedboat is travelling at a speed of 5.0m/s. When the throttle is opened it accelerates at $1.5m/s^2$ for 20s. What is its final speed?

Solution:

$$v = u + at$$
$$= 5.0 + (1.5 \times 20)$$
$$= 35 \text{ m/s}$$

Final speed is 35 m/s.

Distance - Acceleration Equation

$$S = ut + {}^1/_2at^2$$

S = distance travelled, in m.

u = initial speed, in m/s.

a = acceleration, in m/s^2.

t = time, in seconds.

This equation is very useful for finding the distance covered while something is accelerating.

Example

For the boat described in the example above, what distance did it cover during the acceleration?

Solution:

$$S = ut + {}^1/_2at^2$$
$$= 5.0\times20 + 0.5\times1.5\times20^2$$
$$= 100 + 300$$
$$= 400\text{m}$$

The boat travels 400m.

Worksheet 6
Equations of Motion

Student Name..

1. A Formula 1 racing car can go from a standing start to 60 m/s (that's over 200km/hr) in 12s. Find the acceleration rate. (Use a = (v-u)/t)

2. What distance would the car in Q1 cover during this acceleration? (Use $S=ut+0.5at^2$)

3. Approaching a corner at u = 60m/s, the driver of the F1 car applies the brakes to slow down. The brakes provide an acceleration of -6.0 m/s^2 (negative means deceleration) for 4.5s. What speed does it slow down to? (Use v=u+at)

4. To get into orbit, the Space Shuttle accelerates at 45m/s^2 for 8 minutes. (Convert this to seconds) What velocity does it achieve? (v=u+at)

(How many km per sec is this?)

5. What distance does the Shuttle cover during launch? ($S=ut+0.5at^2$) Convert the answer into km.

6. What rate of acceleration is needed to slow an aircraft down from a cruising speed of 300 m/s to landing speed of 60m/s in a time of 5 minutes? (5 min = ?? sec) (care: deceleration!)

7. What distance will the aircraft (Q6) cover during this deceleration?

8. A car is travelling at 5 m/s and then accelerates to a final speed of 25m/s. The rate of acceleration was 2.0m/s^2. How much time did the acceleration take? (hint: may need to change the subject of an equation by algebra.)

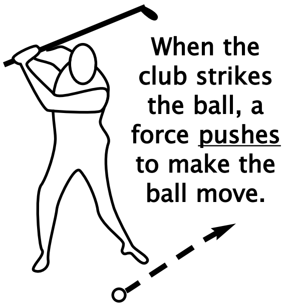
Force Causes Acceleration

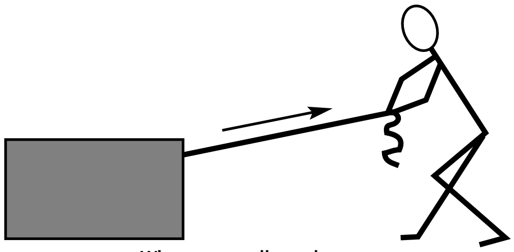
**So far in this topic we have been describing movements in terms of distance, time, speed and acceleration.
Now you will learn what causes acceleration.**

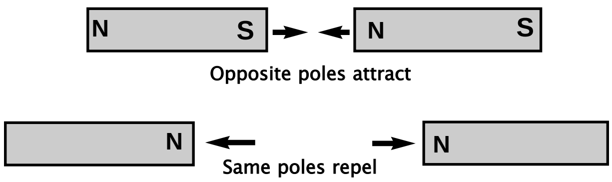
What is a Force?

A force is a push or a pull.

Forces are measured in units called newtons (N).



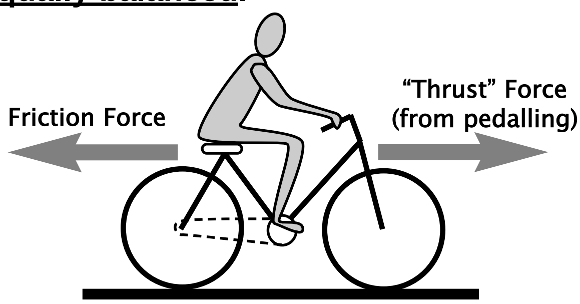




Some forces, such as gravity and magnetism, can push or pull on things without touching them.

Balanced & Unbalanced Forces

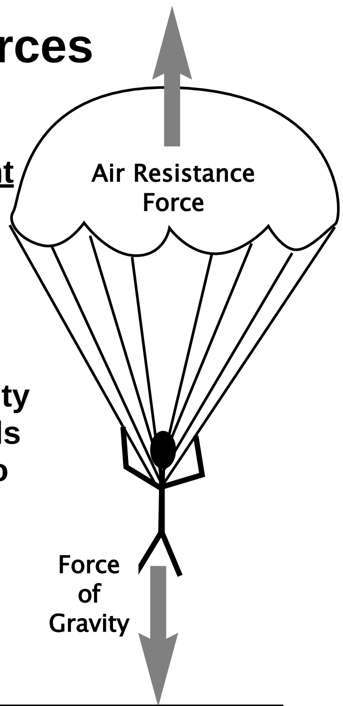
If you are riding a bike at constant speed on a level road, the forces are equally balanced.



The force pushing you forward (from you pedalling) is exactly equal to the forces of friction and air resistance pushing backwards and trying to stop you.

Falling at constant speed, the forces acting on the parachutist are equally balanced.

The force of gravity pulling downwards is exactly equal to the air resistance force pushing upwards to stop the parachute.



Whenever the forces acting on anything are exactly balanced (i.e. they are equal and opposite, and cancel out) the object will travel at a constant speed, or remain still.

When the forces are NOT balanced, acceleration occurs.

**Force causes acceleration. Acceleration can only happen when a "net force" (the total unbalanced force) acts on a mass.
The bigger the force, the greater the acceleration.
However, the bigger the mass, the less the acceleration.**

Newton's Laws of Motion

Sir Isaac Newton (English, 1642-1727) was the first to figure out the connection between unbalanced forces and accelerations

Newton's 1st Law

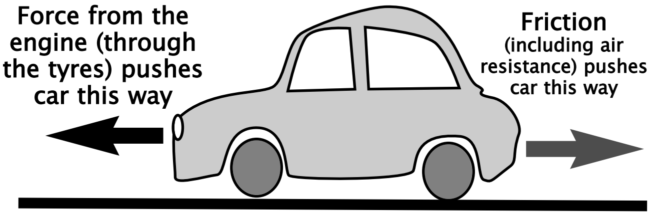
If there is no net force acting, an object will keep moving at a constant velocity in a straight line. If not moving, it will remain at rest.

Note that it doesn't mean there has to be NO forces acting, just no net force.

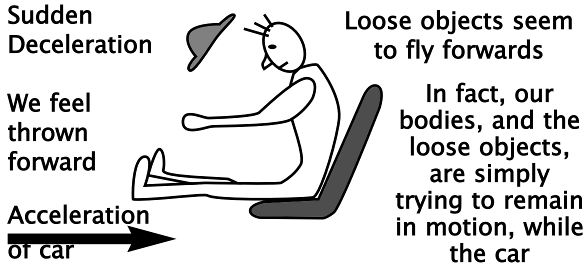
There may be many forces acting on something, but if they are balanced and all cancel out (because they push in opposite directions) then the object will keep moving at constant velocity.

This law is sometimes called the "Law of Inertia". Inertia is the tendency of things to keep moving when things around them slow down or speed up.

If the engine force (pushing the car forward) is the same strength as friction (pushing backwards) then the forces "cancel out" and the car travels at a constant speed.



INERTIA in a Sudden Stop



This is why you must wear a seatbelt!

Newton's 2nd Law

When a net force acts, it causes an acceleration in the direction of the force.

The bigger the force the greater the acceleration. The larger the mass the smaller the acceleration.

This law describes what happens when forces are unbalanced.
Mathematically:

$$F = ma \qquad \text{or} \qquad a = \frac{F}{m}$$

F = net force, in newtons (N).

m = mass of the object the force is acting on, in kilograms (kg)

a = acceleration rate, in m/s^2.

Example problems

1.
If a net force of 10N pushes on a 4.0kg trolley, what is the acceleration rate?

Solution

$a = F/m = 10/4.0$
$= 2.5\ m/s^2$.

The trolley will accelerate at $2.5\ m/s^2$.

2.
What net force is required to make a 1,000kg car accelerate at $4.0 m/s^2$?

Solution

$F = ma = 1{,}000 \times 4.0$
$= 4{,}000$ N.

A 4,000 N net force is required.

Worksheet 7
Force & Acceleration

Student Name..

1.
What net force is needed to make a car with mass 800kg accelerate at 2.5m/s^2.

F = ma = ... x ....

= .... N

2.
A bullet with a mass of 20g (=0.020 kg) is accelerated through the gun barrel at 50,000 m/s^2. What net force was pushing it?

3.
A truck with mass 5,000kg was travelling at 3.0 m/s. It then accelerated to a final speed of 25 m/s over a time of 11s.

a) What was its rate of acceleration?

b) What was the size of the net force which caused the acceleration?

4.
A bow accelerates a 50g (=??kg) arrow at a rate of 800m/s^2. What force does the bow provide?

If F = ma, then a = F/m and m = F/a

5.
A small fireworks rocket has a mass of 500g (=??kg). When fired, it produces a thrust force of 25N for 5.0s.

a) What acceleration can it produce?

b) Starting from rest (u=0), what final velocity could it reach? (v=u+at)

c) What distance can it cover while accelerating for 5.0s?

6.
A car was travelling at 20 m/s when the brakes were applied for 5.0s. This slowed the car down to a final speed of 5.0 m/s.

a) What was the acceleration rate?

b) The force acting in the brakes was measured to be -1,200N. What was the mass of the car?

c) What do you think is the meaning of the force having a negative value?

Speed & Velocity

Up until now, we have been using these words as if they mean the same thing. Now (finally) you will find out the difference.

Constant Speed, but Changing Velocity?

Turning a Corner

Imagine you are travelling in a car and you watch the "speedo" carefully as you go around a smooth corner. Your speed stays exactly the same.

That is constant speed, but it is NOT constant velocity.

The difference is direction.

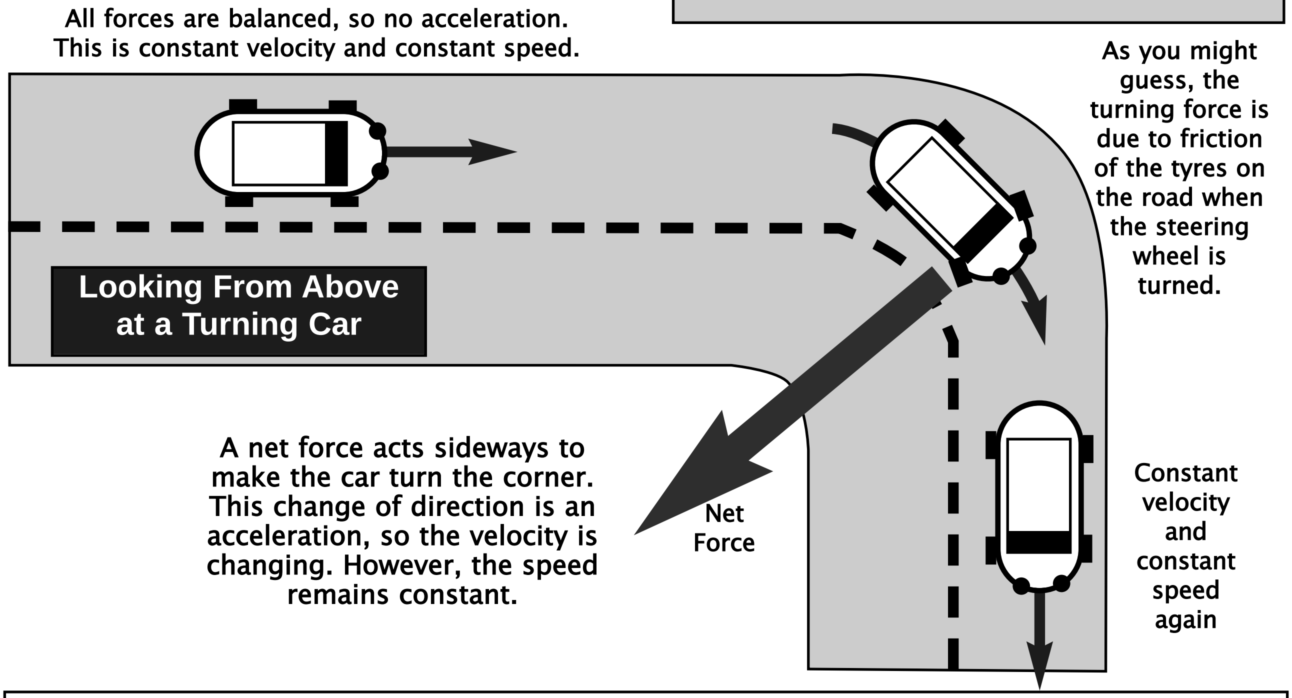
"Speed" means how fast you are going.

"Velocity" means how fast you are going in a particular direction.

To go around the corner a net force must have acted on the car. (If no net force acted, it would have continued on in a straight line... Newton's 1st Law)

A net force pulled the car sideways so it would turn the corner. It did not speed up or slow down, but it changed direction, so its velocity changed.

A change of direction counts as a change of velocity even if the speed remains the same.
Any change of direction requires a net force to act and involves acceleration.



Another Example of Inertia

While going around the corner you might see another good example of inertia, as well.

A tennis ball (or an orange) on the dashboard seems to roll sideways as the car turns the corner.

The ball is trying to obey Newton's 1st Law and keep travelling at constant velocity in a straight line. As the car turns the corner to the right, the ball rolls to the left side of the car. If the window is open it may fly out and go straight ahead at a tangent to the curve.

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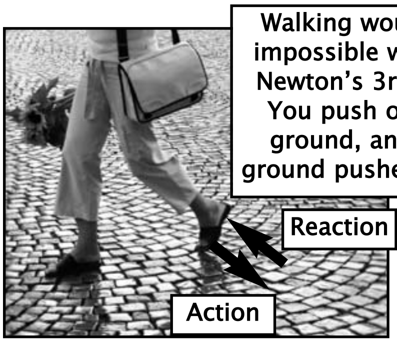
Newton's 3rd Law

Sir Isaac Newton didn't stop at just 2 laws describing the effects of forces.

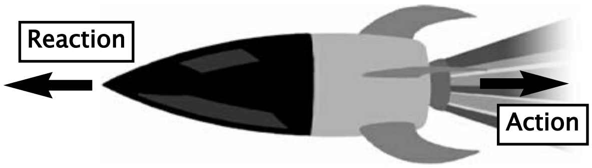
Whenever a force acts, another equal & opposite force pushes back.

Action - Reaction

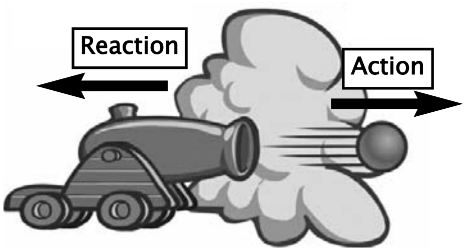
Newton's 3rd Law is best explained by example, and by considering why rockets move and guns kick back.



Walking would be impossible without Newton's 3rd Law. You push on the ground, and the ground pushes back.

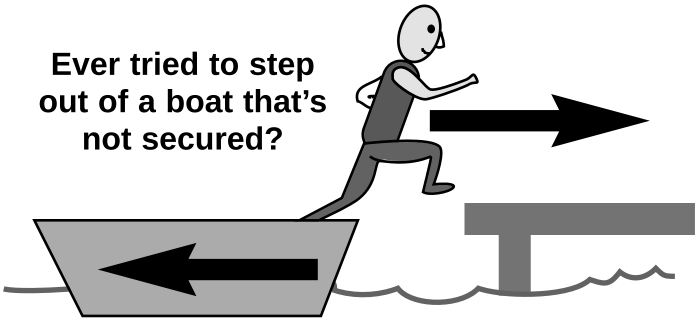


Action force blasts the exhaust gases backwards.
Reaction force thrusts the rocket forward.



When a cannon fires, there is always a "recoil" or kick-back.

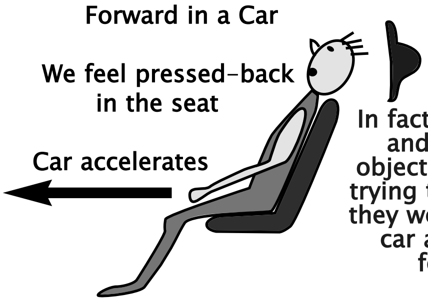
Ever tried to step out of a boat that's not secured?



Everyday Examples of Newton's Laws

1st Law: Inertia

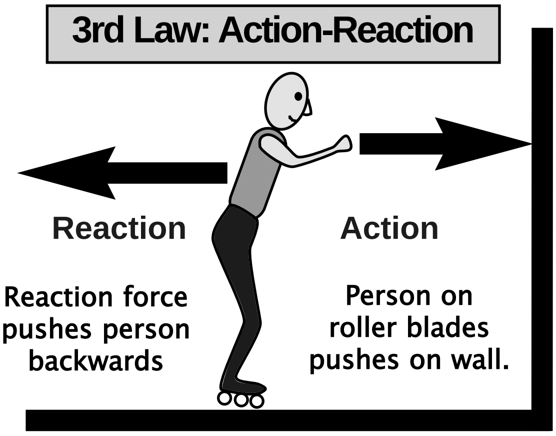
Sudden Acceleration Forward in a Car



Loose objects seem to fly backwards

In fact, our bodies, and the loose objects, are simply trying to stay where they were, while the car accelerates forward.

3rd Law: Action-Reaction

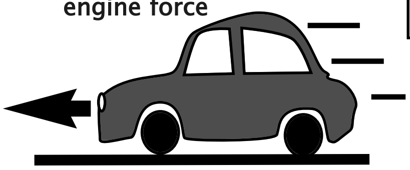


Reaction force pushes person backwards

Person on roller blades pushes on wall.

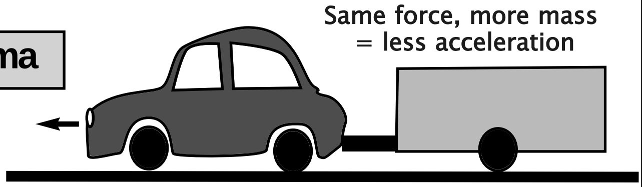
2nd Law: F = ma

Car accelerates at maximum engine force



more mass, less acceleration

Same force, more mass = less acceleration



Same car towing heavy trailer with max. engine force.

Mass, Weight & Gravity

**The force of gravity holds the planets in their orbits.
It causes things to fall down, and it is what causes things to have "weight".**

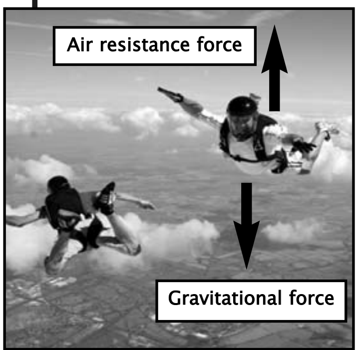
Acceleration Due to Gravity

Gravity is a force, so according to Newton's 2nd Law it can cause falling objects to accelerate.

If there was no air resistance, any object near the Earth would accelerate downwards at close to $10 m/s^2$.

We call this value "g" - the acceleration rate due to gravity.

$g \cong 10\ m/s^2$ on Earth.



In reality, there <u>is</u> air resistance, so these skydivers do not keep accelerating downwards, but reach "terminal velocity" and do not go any faster.

Calculating Weight

Newton's 2nd Law Equation is $F = ma$.

If we're talking about gravity, then "a" is the acceleration of gravity "g".

So the equation becomes $F = mg$.

This is the force due to gravity, acting on the mass... the <u>weight</u> of the object.

<u>Example Calculations</u>
What is the weight of a 65 kg person on Earth?

<u>Solution</u> $F = mg = 65 \times 10 = 650$ N.

The person weighs 650 N on Earth.

Mass and Weight

Gravity pulls on all objects because of their "<u>mass</u>". Mass is a measure of how much matter, or how much "substance", an object contains.

Mass is measured in kilograms (kg).

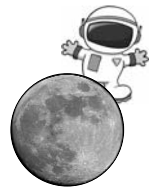
Unfortunately, in everyday life there is confusion about "mass" and "weight".

When a person says "I weigh 65 kg" they really should say "My <u>mass</u> is 65 kg... my <u>weight</u> depends on where I am".

Weight is the <u>force</u> of gravity acting on your mass. Since weight is a force it is measured in newtons (N).

The strength of this force depends on where you are within a gravitational field, so the same object can have different weights in different places.

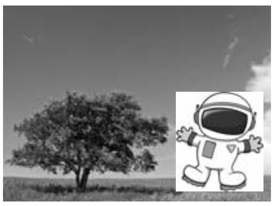
<u>Astronaut in Orbit in Space Shuttle</u>
Mass = 100 kg
Weight = zero N
(Weightless in free-fall)



<u>Astronaut on Moon</u>
Mass = 100 kg
Weight = 160 N
(Moon's gravity is much less than Earth's)

Mass is always the same.

Weight changes.



<u>Astronaut on Earth's Surface</u>
Mass = 100 kg
Weight = 1,000 N

What would a 65 kg person weigh on the Moon, where $g = 1.6 m/s^2$?
<u>Solution</u> $F = mg = 65 \times 1.6 = 104$ N.
Person weighs only 104 N on the Moon.

Worksheet 8
Newton's Laws

Student Name...

Fill in the blank spaces.

The forces acting on an object are said to be a) "..................................." if they cancel each other so that the b)............ force is zero.

If this is the case, the object will continue moving with a c)...................... .... If it is stationary, it will d)... This is Newton's e).............. Law, which is sometimes called the "Law of Inertia".

An example of inertia is the tendency of things to continue f)....................... forward when a vehicle stops. It is the reason why g).............................. and "air bags" are needed for car safety.

If the forces acting on something are h)............................ then a net force will act and cause i).................................... in the same direction as the j)......................

This is k)..................................... Law.

The bigger the force, the l)...................... the acceleration, but the bigger the mass of the object, the m)....................... the n)................................. will be.

Newton's o)................................... states that whenever a force acts, another forces pushes back. This 'reaction" force is p).................... and .... to the "action" force. This Law explains why rockets work, why guns q)................ when fired, and even why you can walk forward by r)........................... on the ground.

Worksheet 9
Mass, Weight, Gravity

Student Name...

1. Fill in the blank spaces.

"Mass" means the amount of a).............. an object contains and is measured in b)...................... Weight is a c)................. due to gravity pulling the mass towards the Earth. Weight is measured in d)..............................

Gravitational force causes objects to e)............................... downwards at a rate of almost f) .... m/s^2, if there is no g)................. resistance.

2. If there was no air resistance, what downward speed would you reach if falling under gravity for 30s? (v=u+at)

(equivalent to over 1,000 km/hr !)

3. A person has a mass of 82kg. What is their weight:
a) on Earth? ($g=10m/s^2$) (use F = mg)

b) on the Moon? ($g=1.6m/s^2$)

c) on planet Jupiter? ($g=27m/s^2$)

4. An alien weighs 1,600N on the Moon.
a) What is its mass?

b) What is its weight on Earth?

c) What is its mass on Earth?

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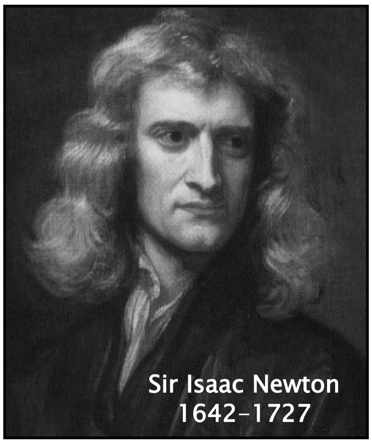
Testing Theories and Laws

The key idea of the "Scientific Method" is that we do not accept anything as "fact" unless it has been thoroughly tested by observation and experiment.

About 300 years ago, Sir Isaac Newton proposed his "Laws of Motion" and also a "Law of Gravitation" which described the force of gravity mathematically.


Sir Isaac Newton
1642-1727

His ideas were not simply accepted as correct just because he said so!

Careful experiments have been carried out by thousands of scientists to test his ideas.

In the case of gravitation, careful observation of the orbiting movements of the planets were the "test". If his idea was right it would have to fit perfectly with the observations... and it did!

The many experiments and observations of forces and accelerations, orbiting satellites, etc. have confirmed that Newton's Laws are correct.

If the evidence had shown that his "Laws" didn't work, they would have been rejected long ago.

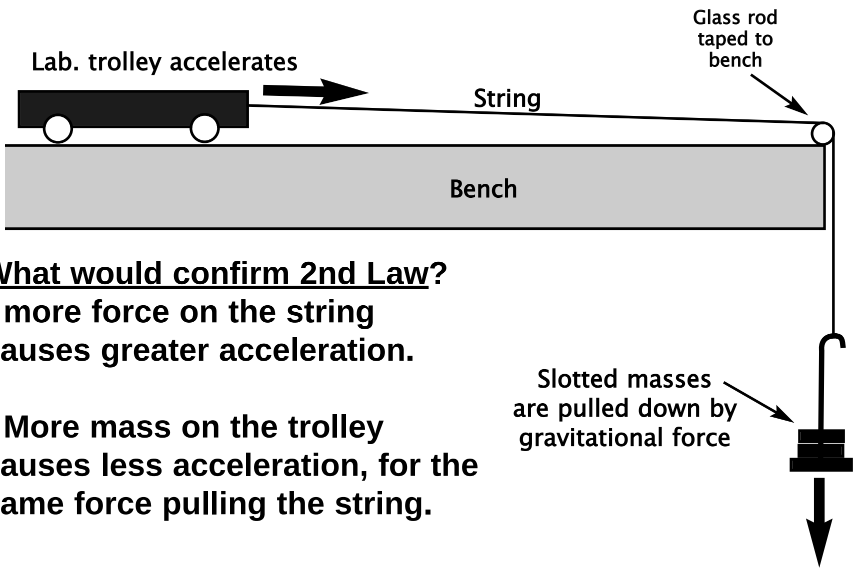
Even though we believe Newton's Laws to be correct, there is still the possibility that new evidence will prove them wrong.
A good scientist always keeps an open mind.

In fact, we now know that these laws are only approximations which work well in the ordinary world. At extreme high speeds, or down at the atomic scale, Newton's Laws do NOT work properly.

Science has developed other "theories" to explain things that Newton's Laws cannot cope with. For example, Einstein's "Theory of Relativity" has been tested again and again by experiment and observation. So far, we believe it works!

Testing Newton's 2nd Law

You might test the F = ma law in the laboratory as suggested below.



What would confirm 2nd Law?
- **more force on the string causes greater acceleration.**
- **More mass on the trolley causes less acceleration, for the same force pulling the string.**

You can experiment by:

- **Adding more hanging masses. This increases the gravitational force pulling on the string.**
  How does this change the acceleration?
- **Adding a large mass to the trolley, but leave the same amount of mass hanging on the string.**
  How does this change the acceleration?

Topic Test
Forces & Motion

Student Name.. Score = /

Useful Equations		
v = S/t	a = (v−u)/t	F = ma

Answer all questions in the spaces provided.

1. (5 marks)
Match each description to an item from the list. To answer, write the letter (A,B,C, etc) of the list item beside the description.

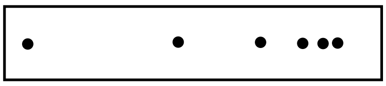
Description	matches with	**List Item**
a) A change of velocity.		....
b) The tendency of things to keep moving when a car stops.		....
c) What forces cause to happen.		....
d) Unit of weight.		....
e) A force due to 3rd Law		....

List Items Not all will be used. Some may be used more than once.

A. newton	D. inertia
B. acceleration	E. reaction
C. speed	F. kilogram

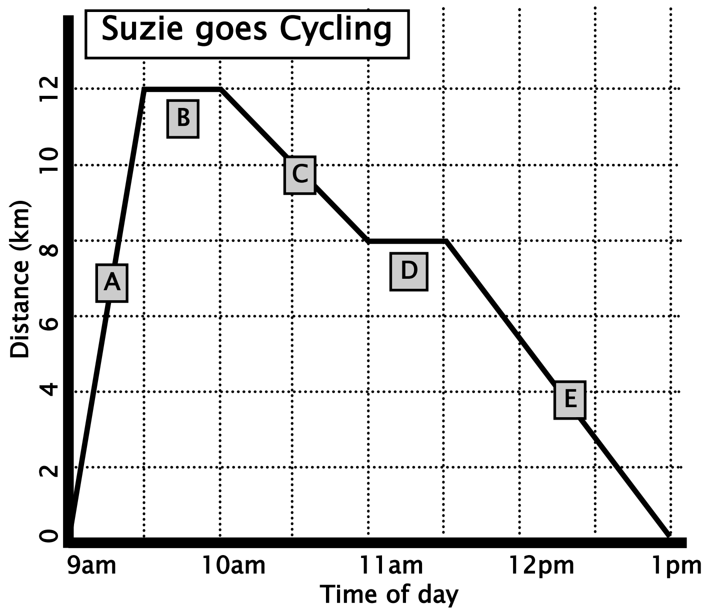
2. (1 marks)
Here is part of a "ticker-tape" record of the motion of a trolley.
Describe what the trolley was doing.

start this end



3. (3 marks)
What force is needed to accelerate a 900kg car at 3.0m/s^2?

4. (7 marks)



a) Calculate Suzie's speed for the first half-hour. Show working.

b) What was she doing in graph section D?

c) Describe what she was doing in section E.

d) How far did Suzie travel altogether?

e) Calculate her average speed for the entire journey. (show working)

5. (4 marks)
a) Why is it scientifically incorrect for someone to say "my weight is 55 kg".

b) What is this person's weight?
($g = 10\ m/s^2$) Show working.

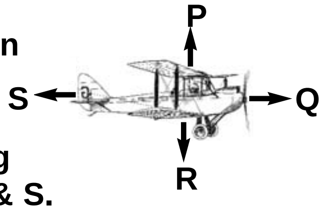
6. (3 marks)
Which of Newton's Laws are involved in each of these situations?

a) When the brakes were applied a truck slowed down and stopped.
....

b) When the cannon fired, it jumped backwards.
....

c) In a sudden stop, a book on the car seat slid forward onto the floor.
....

7. (5 marks)
The diagram shows an aircraft in flight.



Four forces are acting on it, labelled P,Q, R & S.

a) Which pairs of forces must be equal for the aircraft to fly at a constant velocity and height?

Pair 1 = ... and ....

Pair 2 = ... and ....

b) Which 2 forces would have to be increased for the plane to fly faster and higher?
.... and ....

c) A passenger jumps from the plane to parachute down. As he jumps, the pilot notices that the plane climbs to a new height, even though none of the controls were moved. Explain why the plane climbed.
Refer to 2 of the forces in the diagram.

Your teacher will tell you whether or not to attempt this question.

8. (6 marks)
A bicycle and its rider (total mass 80kg) were travelling at an initial speed of 5.0 m/s on a level road. Then, by pedalling harder, the rider applied an net force of 120 N for 6.0s.

a) Use F=ma to find the acceleration of the bike.

b) Use v=u+at to find the final speed of the bike.

c) Use $S = ut + 0.5at^2$ to find how far the bike travelled during the acceleration.

Total marks without Q8 = 28

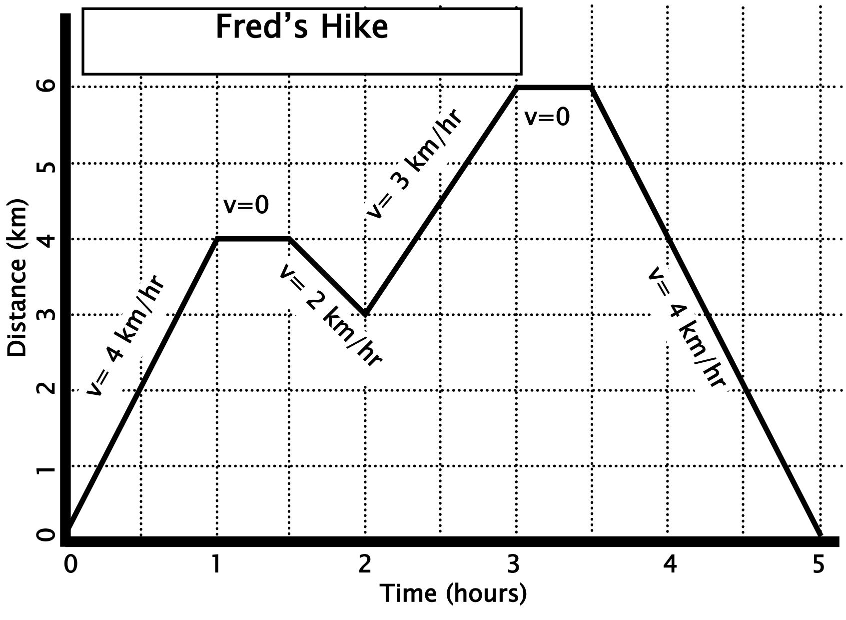
Total marks with Q8 = 34

Answer Section

Worksheet 1

1.
v = S/t = 120/1.5 = 80 km/hr
2.
v = S/t = 200/25 = 8.0 m/s
3.
v = S/t = 4,000/5 = 800 km/hr
4.
v = S/t = 50/0.08 = 625 m/s
5.
v = S/t = 440/8 = 55 km/hr
6.
S = vxt = 80 x 3.5 = 280 km
7.
S = vxt = 120 x 0.2 = 24 m
8.
t = S/v = 42/15 = 2.8 hr
9.
S = vxt = 330 x 8 = 2,640 m = 2.64 km
10.
t = S/v = 3,000/7.5 = 400 s (almost 7 min.)

Worksheet 2



Worksheet 3

a) how fast
b) m/s or km/hr
c) distance
d) time
e) distance
f) time
g) journey
h) instant
i) instantaneous
j) "ticker-timer"
k) speed/velocity
l) m/s^2
m) negative

Worksheet 4

1.
a = (v-u)/t = (35-0)/20 = 1.75 m/s^2.
2.
a = (v-u)/t = (0-35)/7 = -5.0 m/s^2.
Negative accel. means slowing down.
3.
a = (v-u)/t = (800-0)/0.05 = 16,000 m/s^2.
4.
a = (v-u)/t = (0-52)/1.6 = -32.5 m/s^2.
5.
a = (v-u)/t = (30-5)/10 = 2.5 m/s^2.

Worksheet 5 - see next page

Worksheet 6

1. a=(v-u)/t = (60-0)/12 = 5.0 m/s^2.

2. $S=ut+\frac{1}{2}at^2$ = 0 + 0.5 x 5 x 12^2
= 360 m.

3. v=u+at = 60 + (-6.0x4.5)
= 60 - 27 = 33 m/s.

4. 8 min = 480s
v=u+at = 0 + 45 x 480 = 21,600 m/s
= 21.6 km/s

5. $S=ut+\frac{1}{2}at^2$ = 0 + 0.5 x 45 x 480^2
= 5,184,000 m
= 5,184 km

6. 5 min = 300 s.
a=(v-u)/t = (60-300)/300 = 0.80 m/s^2.

7. $S=ut+\frac{1}{2}at^2$
= 300x300 + 0.5x(-1.80)x300^2
= 90,000 - 81,000
= 9,000 m (9 km)

8. v=u+at, so t = (v-u)/a
= (25-5)/2.0
= 10 s.

Worksheet 5

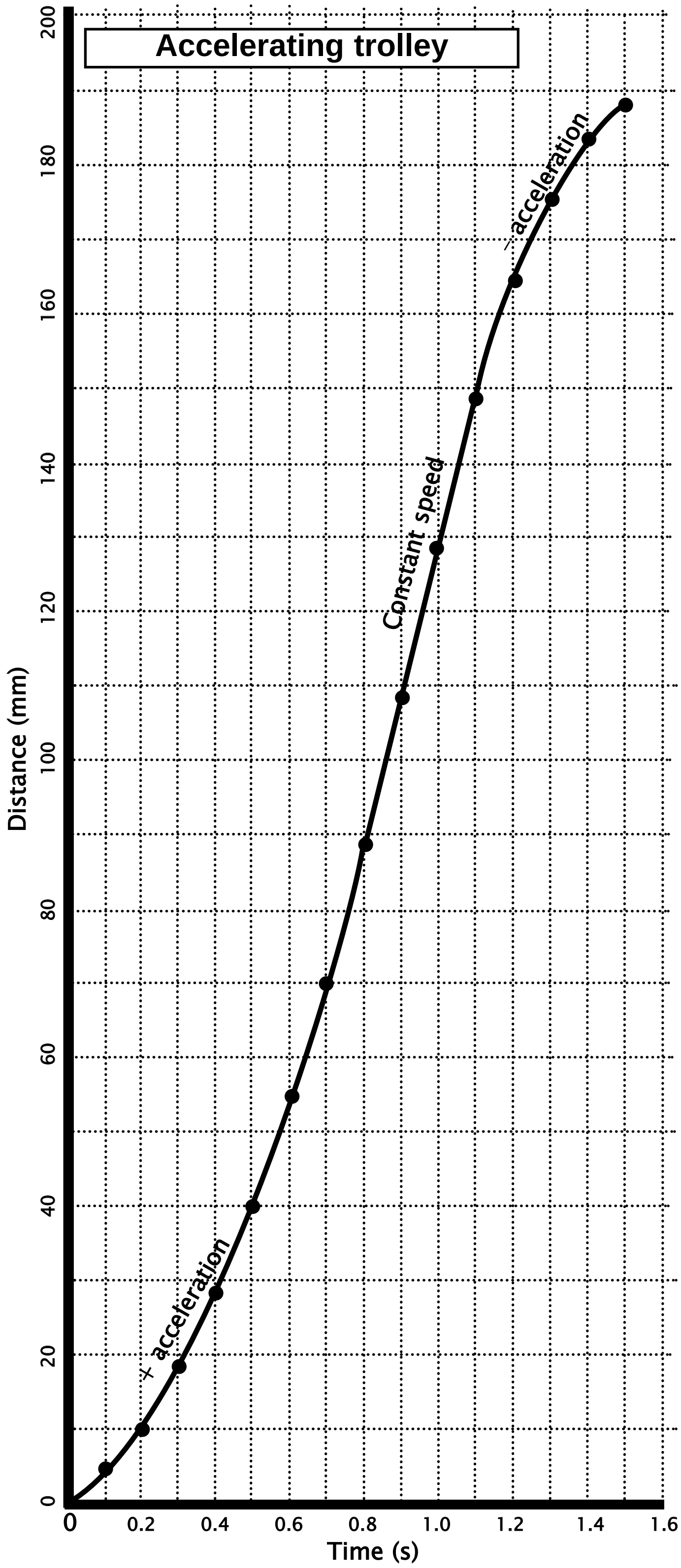
Q1. 188mm Q2. 1.5 s
Q3. v = S/t = 188/1.5 = 125 mm/s
Q4. No, because it sped up and slowed down, so the average doesn't tell you much about the motion at all.

Data Table 1

Total Time from start (s)	Total Distance from start (mm)
0	0
0.1	4
0.2	10
0.3	18
0.4	28
0.5	40
0.6	54
0.7	70
0.8	88
0.9	108
1.0	128
1.1	148
1.2	164
1.3	176
1.4	184
1.5	188

Data Table 2

Total Time from start (s)	Distance in this 0.1s (mm)	Instant. Speed (mm/s)
0.1	4	4/0.1= 40
0.2	6	6/0.1= 60
0.3	8	80
0.4	10	100
0.5	12	120
0.6	14	140
0.7	16	160
0.8	18	180
0.9	20	200
1.0	20	200
1.1	20	200
1.2	16	160
1.3	12	120
1.4	8	80
1.5	4	40



Q5. a) Yes, between 0.9-1.1s same speed.
b) straight line c) on graph

Q6. a) Yes from start to 0.9s.
b) upward curve c) on graph

Worksheet 5 (cont.)

Q7.
a) Yes, from 1.2s to the end.
b) downward curve c) on graph

Q8.
a) straight line b) evenly spaced
c) upward curve d) spreading apart
e) downward curve f) getting closer

Worksheet 7

1. F= ma = 800 x 2.5 = 2,000 N.

2. F= ma = 0.020 x 50,000
= 1,000 N.

3. a) a=(v-u)/t = (25-3)/11 = 2.0 m/s^2.
b) F=ma = 5,000 x 2.0 = 10,000 N.

4. F= ma = 0.050 x 800 = 40 N.

5. a) a=F/m = 25/0.5 = 12.5 m/s^2.
b) v=u+at = 0 + 12.5 x 5.0 = 62.5 m/s.
c) $S=ut+{}^1/_2at^2$ = 0 + 0.5 x 12.5 $x5^2$
= 156 m.

6. a) a=(v-u)/t = (5.0-20)/5.0 = -3.0 m/s^2.
b) F=ma, so m = F/a = -1,200/-3.0
= 400 kg.
c) Negative force means it is pushing against the motion, so it slows the car down.

Worksheet 8

a) balanced b) net
c) constant velocity
d) remain at rest e) 1st
f) moving g) seatbelts
h) unbalanced i)acceleration
j) force k) Newton's 2nd
l) bigger m) less
n) acceleration o) 3rd Law
p) equal & opposite
q) recoil r) pushing back

Worksheet 9

1.
a) matter b) kg
c) force d) newtons (N)
e) accelerate f) 10
g) air
2. v=u+at = 0 + 10 x 30 = 300 m/s.
3. a) F =mg = 82 x 10 = 820 N.
b) F =mg = 82 x 1.6 = 131 N.
c) F =mg = 82 x 27 = 2,214 N.
4. a) F=mg, so m= F/g = 1,600/1.6
= 1,000 kg.
b) F =mg = 1,000 x 10 = 10,000 N.
c) 1,000 kg (always stays the same)

Topic Test

1.
a) B b) D c) B
d) A e) E
2.
Slowing down, decelerating.
3.
F =ma = 900 x 3.0 = 2,700 N.
4.
a) v = S/t = 12/0.5 = 24 km/hr.
b) stopped
c) Moving back to starting point.
d) 12 km each way, so 24 km.
e) v=S/t = 24/4 = 6.0 km/hr.
5.
a) Weight is a force so its units should be newtons, not kg.
b) F = mg = 55 x 10 = 550 N.
6.
a) 2nd b) 3rd c) 1st
7.
a) S&Q and P&R
b) P and Q
c) When the passenger jumps, the weight of the plane decreases, so force R is less. Force P is still the same, so it lifts the plane up.
8.
a) F=ma, so a = F/m = 120/80 = 1.5 m/s^2.
b) v=u+at= 5.0 + 1.5 x 6.0 = 14 m/s.
c) $S=ut+{}^1/_2at^2$ = 5.0x6.0 + 0.5 x 1.5 x 6.0^2
= 30 + 27
= 57 m.