Gleniffer High School

Level 4

Unit 2

Summary Notes

Name:______________________

S3 Physics - Unit Two - Summary Notes
Gas Laws and the Kinetic Model

Density is defined as the **mass per unit volume**. This relationship can be written as the following equation: -

density = mass / volume

where,

density is measured in kilograms per cubic metre (kgm^{-3})
mass is measured in kilograms (kg)
volume is measured in cubic metres (m^3)

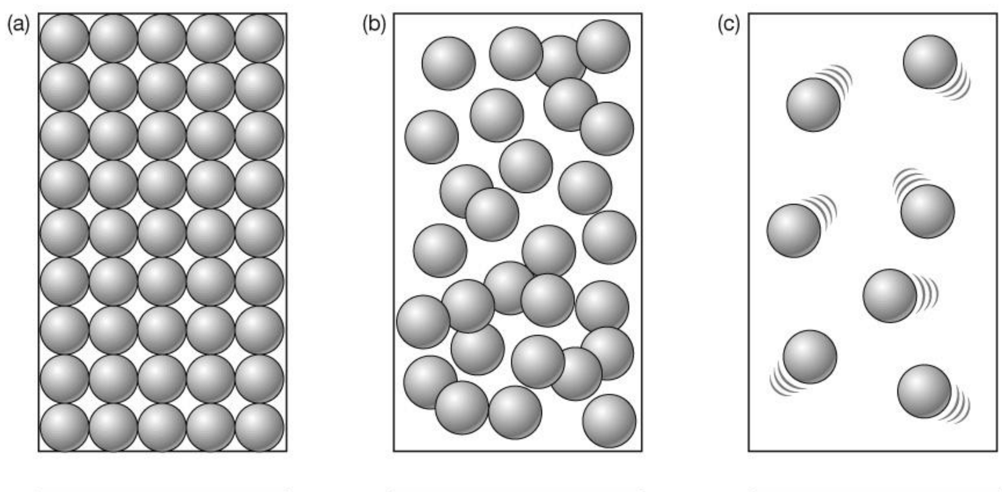
Example
A brass block of mass 4200kg, has a volume of $0.5m^3$. What is the density of the block?

density = ? mass = 4200N volume = $0.5m^{-3}$

density = mass / volume
density = 4200 / 0.5
density = $8400kgm^{-3}$

The following diagrams show the arrangements for particles in

a) solids
b) liquids
c) gases



These diagrams help to explain why the density of gases is always much smaller (about 1000times less) than the density of solids and liquids.

Material	State of Matter	Density (in kgm^{-3})
aluminium	solid	2800
wood	solid	750
oil	liquid	900
water	liquid	1000
oxygen	gas	1.2
carbon dioxide	gas	1.8

Aluminium will sink in water because it is more dense than water. Wood will float in water because it is less dense than water.

S3 Physics - Unit Two - Summary Notes

Pressure is defined as the **force per unit area**. This relationship can be written as the following equation:-

$$p = F / A$$

where,

p = pressure measured in Nm^{-2}
F = force measured in N
A = area of contact measured in m^2

Example

A box exerts a downwards force of 120 N. If the area of contact with the surface is $3m^2$, what pressure does the block put on the surface?

$p = ?$ $F = 120N$ $A = 3m^2$

$p = F / A$
$p = 120 / 3$
$p = 40Nm^{-2}$

Kinetic Theory of Gases

The kinetic theory of gases uses a model to explain how they behave. This model states that:-

- Gases are made up of lots of **very small particles**
- Gas particles are **very far apart**
- Gas particles move in a **random fashion**
- Gas particles move at **very high speeds**
- When gas particles **collide** with any object they **do not lose** any **kinetic energy**

The kinetic theory of gases will no longer be true when the temperature reaches **-273^0C**. At this temperature the particles have no kinetic energy and will be unable to move. This temperature is called **absolute zero** or **zero Kelvin (OK)**

The kinetic theory allows the gas properties of **pressure, volume and temperature** to be related to each other by a set of rules known as the **Gas Laws**. For all three laws it can be assumed that the gas has a fixed mass.

Boyle's Law

When the volume of a container of gas is decreased, the pressure exerted by the gas in the container will increase. Assuming the temperature of the gas does not change.

Pressure Law

When the temperature of a gas in a container is increased, the pressure exerted by the gas on the container will also increase. Assuming the volume of the container does not change.

Charles' Law

When the temperature of a gas is increased, the volume taken up by the gas will also increase. Assuming the pressure exerted by the gas does not change.

Example

Q. A driver checks his tyre pressure before and after a long journey. Assuming the volume of the tyres does not change, will the pressure reading be higher before or after the journey. Explain your answer.

A. After. The tyres will have a higher temperature, which will cause the air inside them to have more kinetic energy and this will allow the gas to exert more pressure on the tyre.

Speed and Acceleration

Average Speed

The **average speed** of a moving object can be found by measuring the **distance** it travels and the **time** it takes to travel that distance. Average speeds are usually measured over large distances or long times. **Metre-sticks** or **trundle wheels** would normally be used to measure the distance in an average speed experiment. The time would normally be measured using a hand held **stopwatch**.

The following equation is used to calculate average speed:-

average speed = distance / time

where,

average speed is measured in metres per second (ms^{-1})
distance is measured in metres (m)
time is measured in seconds (s)

Example
A marble takes 4seconds to travel 50cm across a desk. What is the average speed of the marble?

average speed = ?   distance = 50cm = 0.5m   time = 4.0s

average speed = distance / time
average speed = 0.5 / 4.0
average speed = $0.125ms^{-1}$

When much larger distances or longer times are used it is often necessary to use a different set of units for average speed calculations. These are shown below:-

Average speed is measured in kilometres per hour (kmh^{-1})
Distance is measured in kilometres (km)
Time is measured in hours (h)

Example
A cyclist travels 7000m in 30minutes. What is her average speed?

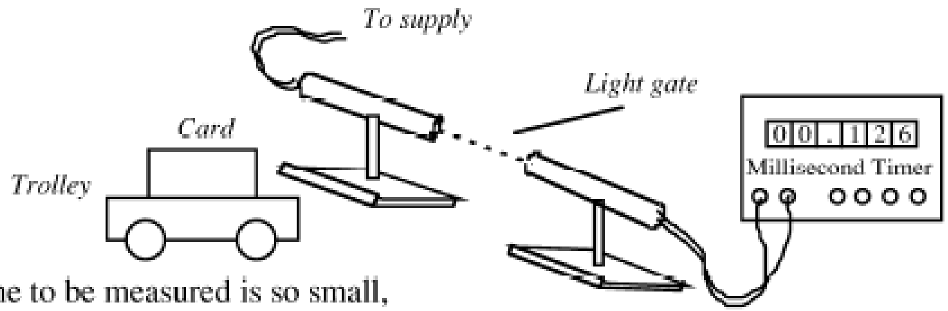
average speed = ?   distance = 7000m = 7km   time = 30minutes = 0.5h

average speed = distance / time
average speed = 7.0 / 0.5
average speed = $14kmh^{-1}$

Instantaneous Speed

Your speed at any particular point during a journey is called the instantaneous speed - the speed at an instant. Measuring this speed is the same as measuring the average speed but the time interval must be very small.

Measuring Instantaneous Speed



Because the time to be measured is so small, there is a problem with reaction time (the time taken by a person to start and stop a timer). To measure the speed of a moving trolley, it is better to use a light gate because there is no reaction time. The trolley is fitted with a card. The timer measures the time the card cuts off the beam of light. It starts when the card cuts the light gate beam and it stops again when the beam is remade. The instantaneous speed is calculated using the length of card as the distance and the timer reading as the time.

metres per second (m/s) *metres (m)* *seconds (s)*

$$\boxed{\text{Instantaneous speed} = \frac{\text{length of card}}{\text{time on timer}}}$$

Example

A trolley is fitted with a card 0.10 m in length. The trolley is set in motion and the card cuts a light gate. The time on the timer is 0.025 seconds. Calculate the speed of the trolley when it passes the light gate.

$$\textit{Instantaneous speed} = \frac{\textit{length of card}}{\textit{time on timer}}$$

$$= \frac{0.10}{0.025}$$

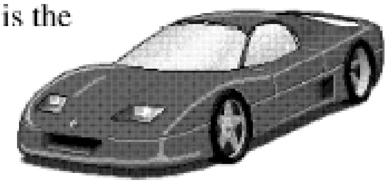
$$= 4\,\mathrm{ms^{-1}}$$

Acceleration

Acceleration is the change of speed of an object in one second. If an object is getting faster, it is accelerating - the speed of the object is increasing. If an object is getting slower, it is decelerating - the speed of the object is decreasing.

Car performance

Car manufacturers often state a value for their car's acceleration to indicate its performance. The usual performance figure quoted is the time in seconds it takes for the car to increase its speed from rest to 60 mph. The smaller the time, the higher the acceleration and the higher the performance.



A high performance car might be quoted as: 0-60 mph in 6.0 s

The table below shows performance figures for some makes of car.

Make of Car	Increase in Speed	Time for increase
Mini	0 —> 60 mph	10.5 seconds
Volvo	0 —> 60 mph	9.6 seconds
Ford	0 > 60 mph	8.1 seconds
Jaguar	0 —> 60 mph	6.1 seconds

<u>Example</u>

Which car has the greatest acceleration? Explain your answer.

<u>Answer</u>

The car with the greatest acceleration is the Jaguar because it has the shortest time to make the same increase in speed as all the others.

Acceleration can be calculated using the following equation:-

acceleration = change in speed / time taken for change

This equation shows that the unit for acceleration will be the unit of speed (ms^{-1}) divided by the unit for time (s). This means the unit for acceleration is written as ms^{-2}. This unit is a short way of writing metres per second per second.

<u>Example</u>

A car accelerates from rest to a speed of $8ms^{-1}$. If this takes 3.2seconds, what is the acceleration of the car?

acceleration = ? change in speed = 8 – 0 = $8ms^{-1}$ time = 3.2s

acceleration = change in speed / time taken for change
acceleration = 8 / 3.2
acceleration = $2.5ms^{-2}$

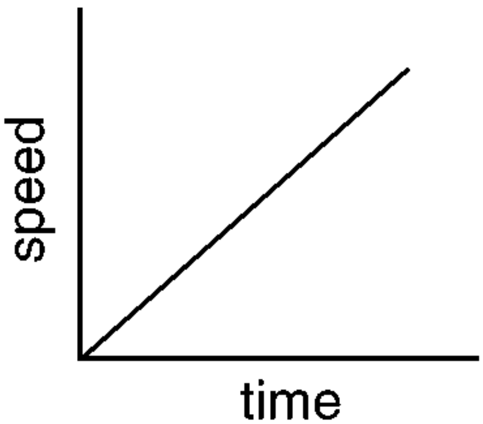
S3 Physics - Unit Two - Summary Notes

Speed-time Graphs

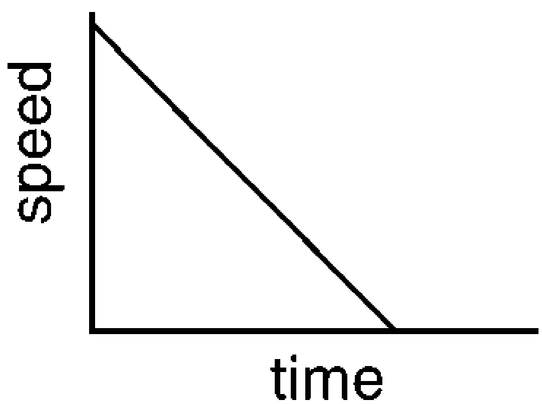
A speed-time graph is a useful way to describe the movement of an object. The shape of the graph shows whether the object is…

- accelerating/speeding up
- decelerating/slowing down
- moving with a constant (steady) speed

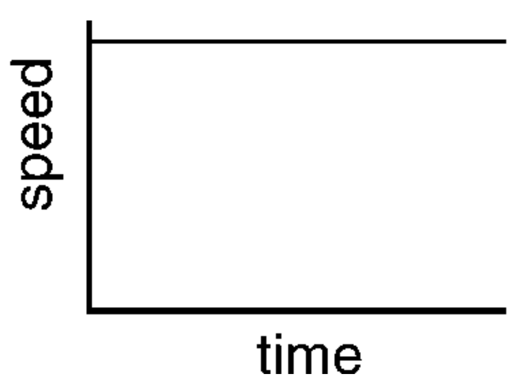
Speed-time graph for acceleration.



Speed-time graph for deceleration



Speed-time graph for constant speed



S3 Physics - Unit Two - Summary Notes
Newton's Laws

Forces

Effects of forces

Forces can only be detected by their effects.

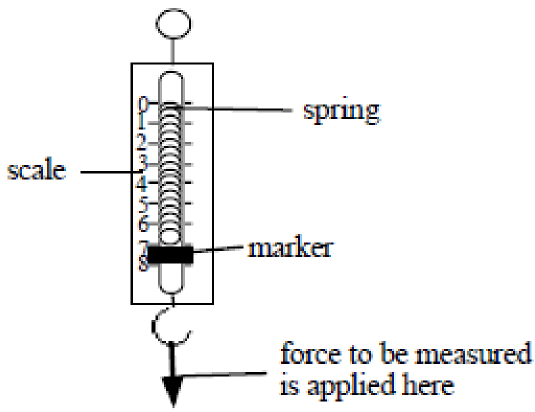
They can change:

- the shape of an object (stretch it, squeeze it etc)
- the speed of an object
- the direction of movement of an object

Measurement of Forces

Forces are measured in units called **Newtons (N).**

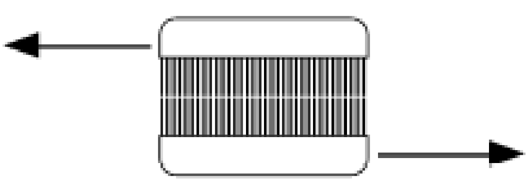
Forces can be measured with a newton balance. This instrument depends on the effect of a force on the shape (length) of a spring.



A newton balance has a spring inside. The force to be measured is applied to the hook which is attached to the spring. The force causes the spring to stretch. The greater the force, the greater the stretch of the spring and the further the marker moves across the scale.

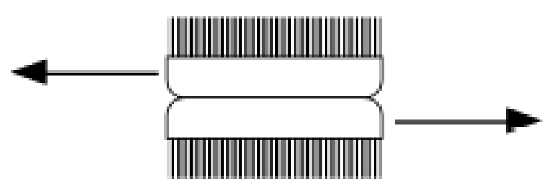
Friction

Friction causes a force that opposes the motion of a body. The force of friction can stop a moving object or slow it down. The force of friction can also keep objects from starting to move. Friction is caused by the contact of two surfaces. If objects do not slide across each other easily, the force of friction between the surfaces of two objects is large. If the objects slide easily, the force of friction is small.



High Friction

Sliding rough surfaces is like sliding the bristles of two brushes - it is difficult.



Low Friction

Sliding smooth surfaces is like sliding the backs of two brushes - it is easy.

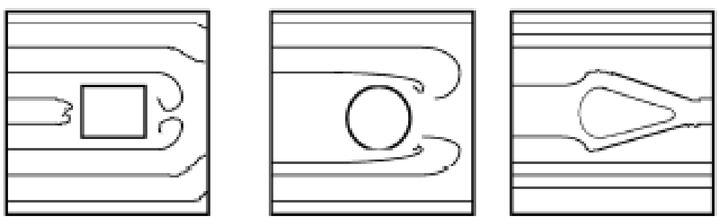
Changing Friction

The force of friction can be increased by making the surfaces rougher or by pressing the surfaces harder together.

The force of friction can be reduced by making the surfaces smoother or lifting the surfaces away from each other. Lubrication for example, uses oil which lifts two surfaces apart and reduces the force of friction. Air can also be used to lift surfaces apart e.g. in the hovercraft.

Streamlining

When an object moves through the air, the air rubs against the object causing friction; this air friction is called air resistance. Streamlining is when you change the shape of the object to reduce the air resistance.



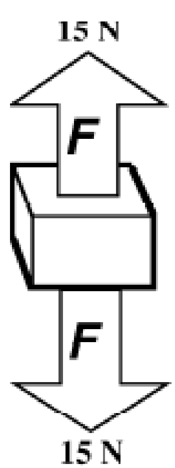
The lines in wind tunnel tests show the pattern of air flow. The smoother the air flow, the less the air resistance. The shape with the least air resistance is the teardrop shape - this is the most streamlined.

Cars and Streamlining

Wind tunnels are used to improve the streamlining of cars. The shape of a car can be made like a teardrop or like an aeroplane wing to reduce air resistance. Sometimes a spoiler is fitted at the back to improve the air flow making it more streamlined. Another way to reduce air resistance is to make the car closer to the ground.

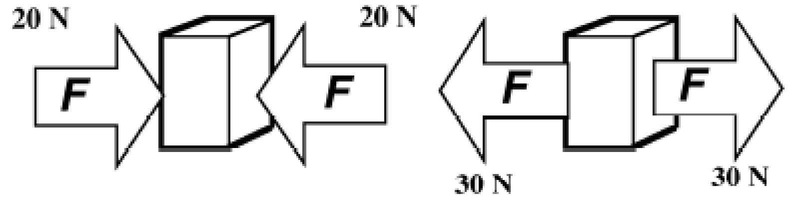
Balanced Forces

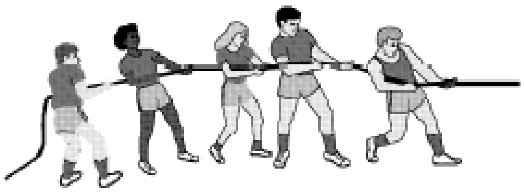
When two forces are the same size as each other *and* act on the same object but in opposite directions, they balance each other. The forces are called **balanced forces**.



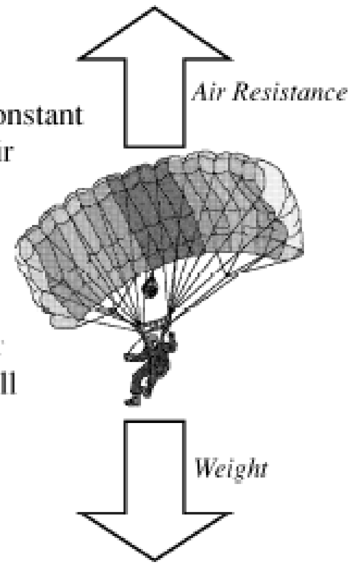
S3 Physics - Unit Two - Summary Notes

More Balanced Forces



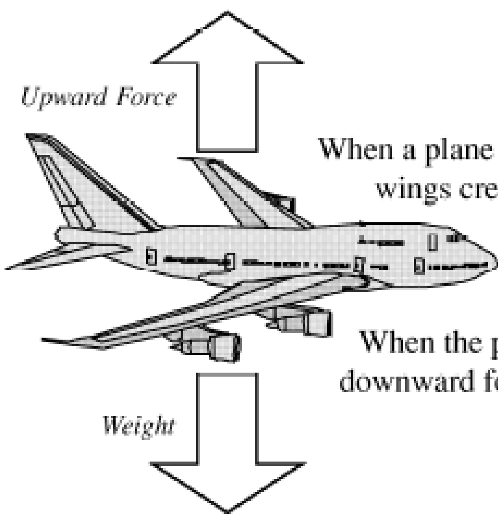


When two tug-of-war teams are pulling against each other but neither is making any progress, the forces applied by each team must be balanced.



Before skydivers open their parachute they fall with a constant speed called their terminal velocity. This is because their weight is balanced by the air resistance on their body.

When they open their parachute they still fall at a constant speed but much slower than before because the air resistance is greater with the parachute open. The air resistance is still equal to the weight so the forces are still balanced.



When a plane is travelling forwards, the air rushing over the wings creates an upward force. When the plane is flying level, this upward force balances the weight of the plane.

When the plane is taking off and landing, the upward and downward forces are not balanced.

Newton worked out the effects that balanced forces could have on an object and used this to write his **First Law of Motion**…

…**a stationary object will remain at rest or a moving object will remain with a constant speed unless an unbalanced force acts on the object**.

Newton also worked out the effects that unbalanced forces could have on an object. This allowed him to write his **Second Law of Motion** which is usually stated as an equation.

$$\text{Unbalanced force} = \text{mass} \times \text{acceleration}$$
$$F = m \times a$$

where,

F is the unbalanced force measured in Newtons(N)
m is the mass measured in kilograms(kg)
a is the acceleration measured in metres per second per second(ms^{-2})

Example

A car of mass 1000kg has an unbalanced force of 1600N acting on it. What is its acceleration?

$F = 1600N \quad m = 1000kg \quad a = ?$

$$F = m \times a$$
$$1600 = 1000 \times a$$
$$a = 1600 / 1000$$
$$a = 1.6ms^{-2}$$

Weight

Mass measures how much matter there is in an object. Mass is measured in **kilograms**. The mass of an object stays the same at all places.

Weight is a force. The weight of an object always acts downwards. Weight is measured in **Newtons**. The weight of an object can change.

Weight to mass ratio is usually called gravity. Gravity is the shortened version of gravitational field strength. **Gravity is measured in Newtons per kilogram (Nkg^{-1})**. Gravity can vary but is quoted as 9.8Newtons per kilogram ($9.8Nkg^{-1}$) on planet Earth.

$$\text{Weight} = \text{mass} \times \text{gravity}$$
$$W = m \times g$$

where,

W is weight measured in Newtons(N)
m is mass measured in kilograms(kg)
g is measured in Newtons per kilogram(Nkg^{-1})

Example

A pupil has a mass of 60kg. What is their weight on planet Earth?

$W = ? \quad m = 60kg \quad g = 9.8Nkg^{-1}$

$$W = m \times g$$
$$W = 60 \times 9.8$$
$$W = 588N$$

S3 Physics - Unit Two - Summary Notes
Space History

Early history
The naked eye is used and observations were carried out to predict the future on Earth.
Ancient Greece
Planets were noted to behave differently from stars; observations still based on the Earth being at the centre of the Universe.
Ptolemy (2nd Century AD)
Accurate prediction about the speed and movement of the Sun, the moon and known planets are made; observations still based on the Earth being at the centre of the Universe.
Copernicus (1540AD)
He proposes the theory that the Sun is the centre of the known Universe.

From this point in history telescopes keep getting better and more accurate observations get made. The following table gives some up to date space definitions.

Term	Definition
Planet	A large object (like Earth) moving in an orbit round a star (like the Sun)
Star	A very large, hot luminous object in space.
Galaxy	A system of billions of stars with gas and dust held together by gravitational attraction.
Universe	A collection of galaxies.
Light Year	The distance light travels in one year.
Satellite	A small object which orbits a larger object (like the moon orbits the Earth)
Exoplanet	A planet that is outside our Solar System.

As well as satellites and telescopes, space is also observed using space shuttles and landing probes on other planets. However, when objects like space shuttles return to Earth, their **kinetic energy is changed to heat energy** due to the friction created by our atmosphere. This means they must be protected by special heat resistant tiles or they will “burn up” in the atmosphere.

Free Fall and weightlessness

An object falling “freely” towards the surface of the Earth is said to be in “free fall”.
All objects accelerate towards the Earth with an acceleration of 9.8 ms^{-2} (assuming no air resistance).
An object in “free fall” inside a box would fall at the same rate as the box and would appear to be “weightless”.
Astronauts in orbit around the Earth are in a constant state of “free fall”. The spaceship, everything which is inside it, including the astronauts, are all accelerating towards the Earth due to the gravitational field strength.
This is known as “apparent weightlessness”.

Satellites and dish aerials.

World wide communication over a long distance is difficult because of the curvature of the Earth. A satellite can be used to send signals for very long distances. The higher a satellite is above the Earth, the longer is its **period** (the time it takes to make one revolution round the Earth).
A **geostationary** satellite stays above the same point on the Earth's surface - the satellite takes 24 hours to make one revolution, the same length of time as the Earth. Signals are sent from a **ground** station to the satellite, which amplifies the signal and sends it back to a different ground station. Three geostationary satellites, positioned evenly round the equator, can relay signals right round the world.

Telescopes

Since stars do not only emit visible light, astronomers use different kinds of telescope.

Radio
Radio telescopes detect noise from radio wavelengths in space. It turns out that objects in space give off radio noise. These telescopes are able to listen to all this noise and process it into information for researchers to study. A radio telescope can produce a picture from an object it is listening to from the noise is picks up from that object.

X-Ray
X-ray telescopes are used to study mainly the Sun, stars and supernovas. X-ray telescopes work better at very high altitudes on the Earth's surface, like on top of a very tall mountain where the atmosphere is thinner. They work even better in space. This is because the Earth's atmosphere interferes with the x-ray signals they receive.

Gamma Ray
Gamma ray telescopes are best used at high altitudes like the x-ray telescopes. This is also because gamma ray signals are disrupted and become weaker when they enter the Earth's atmosphere. Gamma ray telescopes detect bursts of gamma rays. They help astronomers confirm events in outer space like supernovas, pulsars and black holes.

Reflector
The Hubble Space Telescope (HST) is a reflecting telescope and is currently the largest space telescope there is. It is 43 feet long (13.1 meters) and weighs 24,250 pounds (11,000kg). Its reflector is 94.8 inches in diameter (240cm). The Hubble Space Telescope was launched into space on April 24, 1990, from the Space Shuttle Discovery. It is still operational. It has had some work performed on it from time to time, such as installing new state-of-the-art cameras. This wonderful telescope has brought a wealth of information to researchers here on Earth. It has taken numerous spectacular pictures of far away galaxies, nebulae, a green space blob, beautiful dying stars (one that looks like a butterfly), and amazing infrared and ultraviolet pictures that show an incredible amount of detail. These pictures have allowed researchers to greatly expand our knowledge of the universe.

Optical Telescopes
An optical telescope gathers and focuses light mainly from the visible part of the electromagnetic spectrum in order to directly view a magnified image for producing a photograph or collecting data via electronic image sensors.
The light gathering power of a telescope and its ability to resolve minute detail is directly related to the diameter of the objective lens. The larger the objective lens then a brighter image is obtained and it can resolve finer detail.

DATA SHEET

Speed of light in materials

Material	Speed in $m\,s^{-1}$
Air	$3{\cdot}0 \times 10^8$
Carbon dioxide	$3{\cdot}0 \times 10^8$
Diamond	$1{\cdot}2 \times 10^8$
Glass	$2{\cdot}0 \times 10^8$
Glycerol	$2{\cdot}1 \times 10^8$
Water	$2{\cdot}3 \times 10^8$

Gravitational field strengths

	Gravitational field strength on the surface in $N\,kg^{-1}$
Earth	9·8
Jupiter	23
Mars	3·7
Mercury	3·7
Moon	1·6
Neptune	11
Saturn	9·0
Sun	270
Uranus	8·7
Venus	8·9

Specific latent heat of fusion of materials

Material	*Specific latent heat of fusion* in $J\,kg^{-1}$
Alcohol	$0{\cdot}99 \times 10^5$
Aluminium	$3{\cdot}95 \times 10^5$
Carbon Dioxide	$1{\cdot}80 \times 10^5$
Copper	$2{\cdot}05 \times 10^5$
Iron	$2{\cdot}67 \times 10^5$
Lead	$0{\cdot}25 \times 10^5$
Water	$3{\cdot}34 \times 10^5$

Specific latent heat of vaporisation of materials

Material	*Specific latent heat of vaporisation* in $J\,kg^{-1}$
Alcohol	$11{\cdot}2 \times 10^5$
Carbon Dioxide	$3{\cdot}77 \times 10^5$
Glycerol	$8{\cdot}30 \times 10^5$
Turpentine	$2{\cdot}90 \times 10^5$
Water	$22{\cdot}6 \times 10^5$

Speed of sound in materials

Material	Speed in $m\,s^{-1}$
Aluminium	5200
Air	340
Bone	4100
Carbon dioxide	270
Glycerol	1900
Muscle	1600
Steel	5200
Tissue	1500
Water	1500

Specific heat capacity of materials

Material	*Specific heat capacity* in $J\,kg^{-1}\,°C^{-1}$
Alcohol	2350
Aluminium	902
Copper	386
Glass	500
Ice	2100
Iron	480
Lead	128
Oil	2130
Water	4180

Melting and boiling points of materials

Material	*Melting point* in °C	*Boiling point* in °C
Alcohol	−98	65
Aluminium	660	2470
Copper	1077	2567
Glycerol	18	290
Lead	328	1737
Iron	1537	2737

Radiation weighting factors

Type of radiation	*Radiation weighting factor*
alpha	20
beta	1
fast neutrons	10
gamma	1
slow neutrons	3

Prefix	Symbol	Factor
tera	T	1000000000000 = 10^{12}
giga	G	1000000000 = 10^{9}
mega	M	1000000 = 10^{6}
kilo	k	1000 = 10^{3}
hecto	h	100 = 10^{2}
		1 = 10^{0}
deci	d	0.1 = 10^{-1}
centi	c	0.01 = 10^{-2}
milli	m	0.001 = 10^{-3}
micro	µ	0.000001 = 10^{-6}
nano	n	0.000000001 = 10^{-9}
pico	p	0.000000000001 = 10^{-12}

Scientific Notation

Scientific Notation or **standard form** is a way of expressing a number in terms of power of ten. In other words, it's expressed in the form

$$a \times 10^n$$

where a is a real number that satisfies $1 \leq |a| < 10$ and n is an integer. a is called the *significand* and n is called the *exponent*.

Please note that the absolute value of a must be at least 1 and less than 10, hence 0.34×10^2 and -11.23×10^4 are not in standard form.

Examples of converting numbers to scientific notation

- 1234 becomes 1.234×10^3
- -0.000023 becomes -2.3×10^{-5}
- 50000000 becomes 5×10^7

Rounding

Some decimal numbers go on for ever! To simplify their use, we decide on a cut off point and "round" them up or down.
If we want to round 2.734216 to two decimal places, we look at the number in the third place after the decimal, in this case, 4. If the number is 0, 1, 2, 3 or 4, we leave the last figure before the cut off as it is. If the number is 5, 6, 7, 8 or 9 we "round up" the last figure before the cut off by one. 2.734216 therefore becomes 2.73 when rounded to 2 decimal places.

If we are rounding to 2 decimal places, we leave 2 numbers to the right of the decimal.
If we are rounding to 2 significant figures, we leave two numbers, whether they are decimals or not.

$Q = It$

$V = IR$

$R_{total} = R_1 + R_2 + R_3$ etc

$\frac{1}{R_{total}} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3}$ etc

$P = E/t$

$P = IV$

$P = I^2 R$

$P = V^2/R$

$\% \text{ efficiency} = \frac{\text{useful } E_o}{E_i} \times 100\%$

$\% \text{ efficiency} = \frac{\text{useful } P_o}{P_i} \times 100\%$

$E_h = Cm\Delta T$

$P = F/A$

$\frac{P_1 V_1}{T_1} = \frac{P_2 V_2}{T_2}$

$v = d/t$

$v = f\lambda$

$H = Dw_r$

$D = E/m$

$\bar{v}$ = total displacement / total time

v = displacement / time

$v = u + at$

$F = ma$

$E_w = Fd$

$W = mg$

$E_h = mL_v$