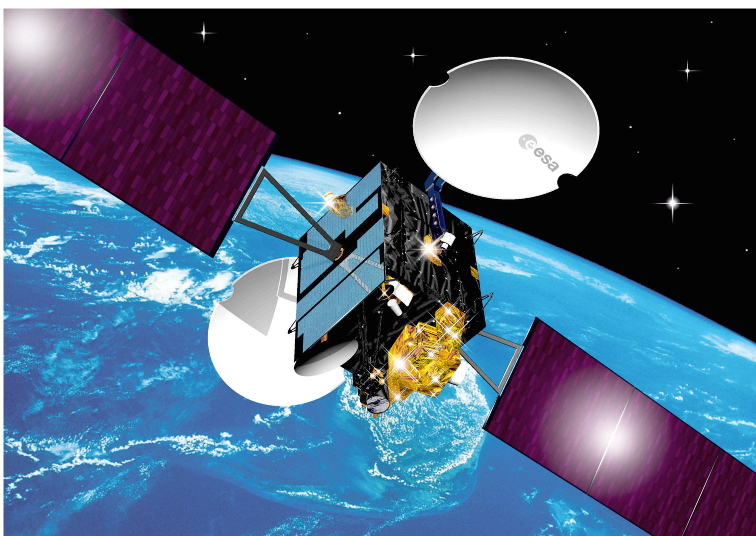
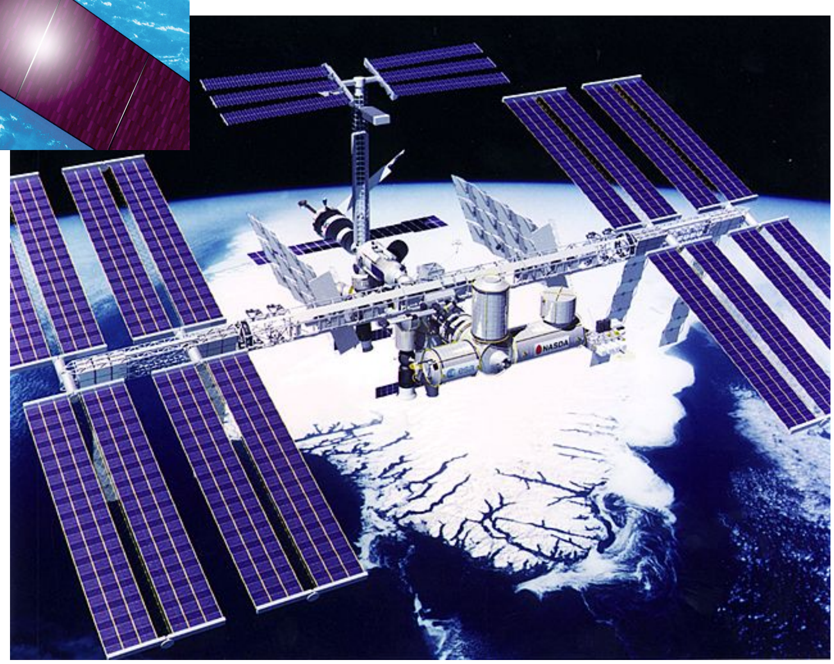
National 5 Physics

Dynamics and Space





Throughout the Course, appropriate attention should be given to units, prefixes and scientific notation.

Common prefixes

tera	T	10^{12}	x 1,000,000,000,000
giga	G	10^{9}	x 1,000,000,000
mega	M	10^{6}	x 1,000,000
kilo	k	10^{3}	x 1,000
centi	c	10^{-2}	/ 100
milli	m	10^{-3}	/ 1,000
micro	μ	10^{-6}	/ 1,000,000
nano	n	10^{-9}	/ 1,000,000,000
pico	p	10^{-12}	/ 1,000,000,000,000

In this section the prefixes you will use most often are milli and kilo. It is essential that you use these correctly in calculations.

Example 1

In Physics, the standard unit for force is the **Newton (N)** and therefore if force is given in kiloNewtons (kN) it must be converted to Newtons.

An object experiences a force of 15 kN. How many Newton is this?

15 kN = 15 kiloNewtons = 15 x 10^{3} N = 15 x 1000 = 15 000 Newtons

Example 2

In Physics, the standard unit for mass is the **kilogram (kg)** and therefore if mass is given in grams (g) it must be converted to kilograms.

A ball bearing has a mass of 3.5 g. What is the mass of the ball in kg?

3.5 g = 3.5 grams = 3.5 x 10^{-3} kg = 3.5 / 1 000 = 0.0035 kg.

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Contents

1. **Projectile Motion**
    1.1. Explanation of projectile motion Effect of electric field on a charge.
    1.2. Calculations of projectile motion from a horizontal launch using appropriate relationships and graphs.
    1.3. Explanation of satellite orbits in terms of projectile motion.

$$Horizontal\ range = area\ under\ v_H - t\ graph$$

$$Vertical\ range = area\ under\ v_v - t\ graph$$

$$v_H = \frac{s}{t}$$

$$v_v = u + at$$

Projectile Motion

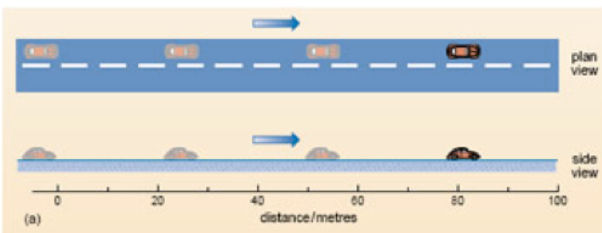
A **projectile** is an object that is only being acted upon by the downward force of gravity. In this course will be study objects being dropped **vertically** and objects being fired **horizontally**. A projectile has two **separate** motions at right angles to each other. Each motion is **independent** of the other. A projectile will have a **constant horizontal velocity** and a **constant vertical acceleration**, this results in a curved path of motion.

A projectile can be viewed as having two discrete components of motion:

HORIZONTAL

A constant horizontal velocity.

eg v = 20 m/s at all times

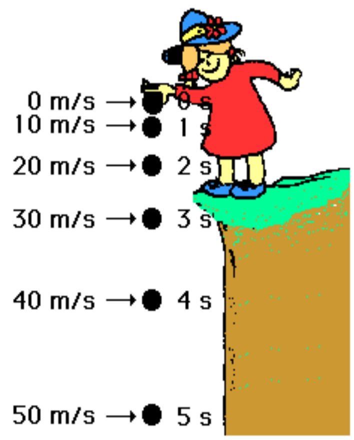


Time

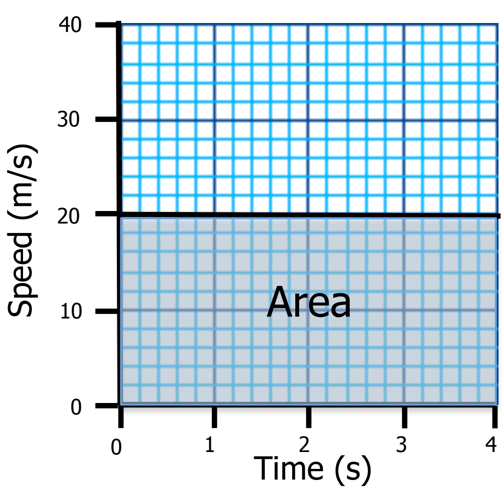
VERTICAL

A constant vertical acceleration

$a = 10\ m/s^2$ at all times

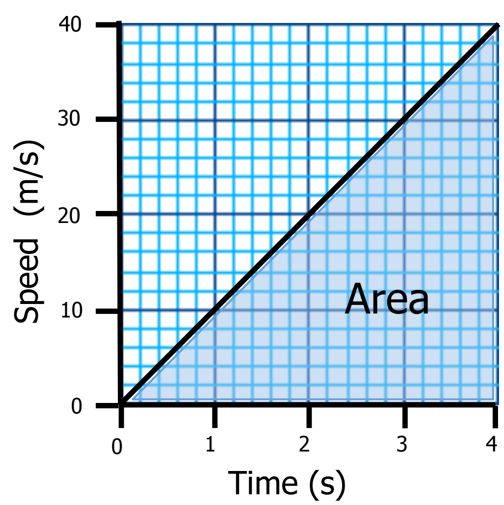


The horizontal range can be found by plotting a velocity – time graph of the motion.



Distance = Area under graph
= b x h
= 4 x 20
= 80 m

The vertical range can be found by plotting a velocity – time graph of the motion.



Distance = Area under graph
= ½ x b x h
= 0.5 x 4 x 40
= 80 m

Horizontal

The **horizontal** motion is at a **constant velocity** since there are no unbalanced forces acting horizontally (air resistance can be ignored).

$$v_H = \frac{s}{t}$$

Symbol	Name	Unit	Unit Symbol
s	Displacement	metre	m
v_H	Horizontal velocity	metres per second	ms^{-1}
t	Time	second	s

Horizontal distance travelled = horizontal velocity x time in the air. ($s = v_H \times t$)

Vertical

The **vertical** motion is one of **constant acceleration** due to gravity. ($a = 10\ ms^{-2}$).

$$v = u + at$$

Symbol	Name	Unit	Unit Symbol
u	Initial Speed	metre	m
v	Final speed	metres per second	ms^{-1}
a	Acceleration	metres per second per second	ms^{-2}
t	Time	second	s

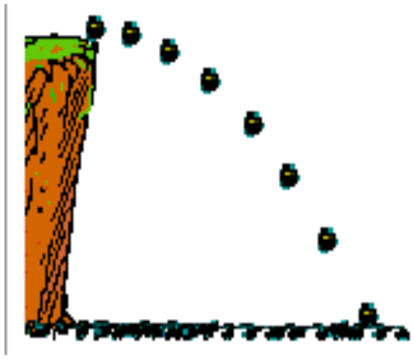
The **vertical** motion is one of **constant acceleration** due to gravity, equal to a_g.

For projectiles which are projected **horizontally, the initial vertical velocity is zero.**

For vertical calculations, use $a = (v-u)/t$, where **$u = 0$** and **$a = g = 10\ ms^{-2}$.**

Worked Example

A ball is kicked horizontally at 5 ms^{-1} from a cliff top as shown below. It takes 2 seconds to reach the ground.



a. What horizontal distance did it travel in the 2 seconds?

S_H = ?

v_H = 5 ms^{-1}

t = 2 s

$S_H = v_H \times t$

$S_H = 5 \times 2$

$S_H = 10$ m

b. What was its vertical speed just before it hit the ground ?

u_v = 0 m/s

v_H = ?

t = 2 s

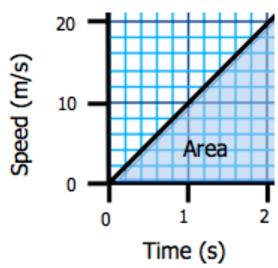
a = 10 ms^{-2}

a = (v-u)/t

10 = v/2

v_v = 20 ms^{-1}

c. What was the vertical height of the hill? (use a speed time graph)

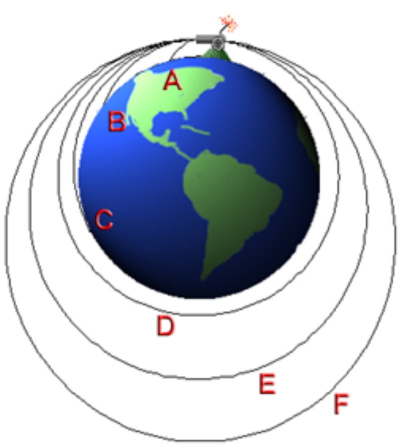


distance = area

= 0.5 x 2 x 20

= 20 m

Projectiles at a height - Satellites



http://astro.unl.edu/naap/atmosphere/graphics/OrbitingCannonBalls.

When considering gravity, Isaac Newton conducted a thought experiment. He reasoned that if an object was fired from a high enough height, with enough horizontal velocity, it would fall back towards earth at the same rate as the Earth curved away from the object.

Newton was trying to explain that the **moon's orbit** was just an example of projectile motion.

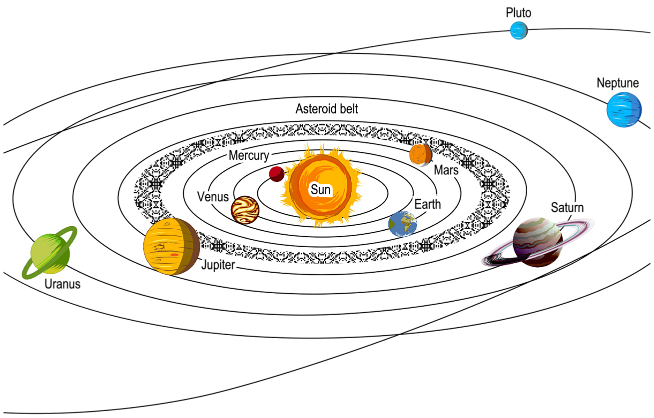
This same principle used for communications satellites **Geostationary orbits.**

Problems with Newton's Experiment.

1. Newton did not allow for air resistance.
2. To stay in orbit, Newton calculated that a ball would have to be fired from 150 km above the Earth's surface (this would take it out of the Earth's atmosphere thus reducing the air resistance problem). However 300 years ago there was no conceivable way of getting anything that high up!

Natural Satellites

Planets are satellites of the star they orbit and moons are satellites of the planet they orbit.



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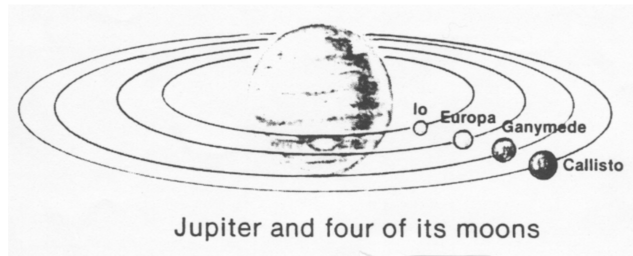


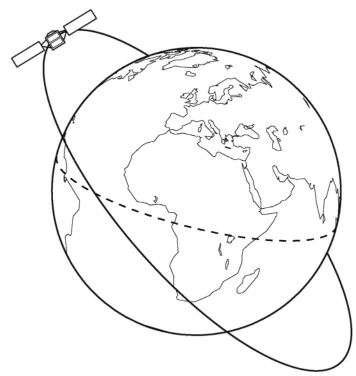
http://www.is.wayne.edu/mnissani/a&s/Jupiter.gif

Artificial Satellites

The first artificial satellite (Sputnik 1) was launched by the Soviet Union on 4 October 1957. Many 1000's of satellites have been launched since then and there are currently approximately 3 500 in use (plus many thousands of bits of "space junk") orbiting the Earth.

The largest man made satellite is the International Space Station.

These satellites help make our lives safer, more convenient, provide entertainment and supply vast quantities of climate and meteorological data.



There are two types of artificial satellite orbit:-

Geostationary

A geostationary satellite remains above the same point of the earth's surface. It has a period of rotation of 24 hours. They maintain an orbit height of approximately 36,000 km above the surface of the Earth.

Polar Orbiting

These satellites have a low altitude and orbit around both the North and South Pole regions of Earth. These satellites are good for collecting climate data as information can be obtained at regular intervals throughout the day but not very appropriate for telecommunications as communication cannot be maintained for 24 hours a day from the same point on the earth's surface.

Space Exploration

2. **Space Exploration**
   - 2.1. Evidence to support current understanding of the universe from telescopes and space exploration.
   - 2.2. Impact of space exploration on our understanding of planet Earth, including use of satellites.
   - 2.3. The potential benefits of space exploration including associated technologies and the impact on everyday life.
   - 2.4. Risks and benefits associated with space exploration, including challenges of re-entry to a planet's atmosphere.

$$E_h = Cm\Delta T$$

$$E_h = mL_v$$

Our Universe

Planets | Stars | Solar Systems | Galaxies

According to current estimates, the universe is approximately 13.8 billion (13.8×10^9) years old and consists of approximately 100 billion galaxies, each containing approximately 100 – 1000 million stars!!

How do we know this? Why are the numbers so approximate? How has the world benefitted from Space Exploration? Why are we still exploring Space?

Our understanding of the immediate and distant universe comes mainly from two activities, **space exploration** and **looking up**.

Space Exploration

We have launched satellites, sent Man to the Moon and probes beyond the furthest planet in our solar system, built a Space Station that is visible from the ground, landed a "rover" on Mars; and launched the Hubble Space telescope, which has arguably produced the greatest pictures ever taken.

Although no manned missions to the Moon are currently planned, there are still thousands of people employed researching and developing the next generation of satellites, space station modules, probes, space telescopes and many other devices to aid our understanding of the universe.

Looking Up

All of our understanding of stars and galaxies comes from using telescopes to look up at the sky. Some of these telescopes are in space (The Hubble Telescope) but most are in ground-based arrays. These arrays consist of tens or hundreds of curved reflector telescopes that can scan the sky to observe not just visible light but radiation from all parts of the visible spectrum.

http://icc.ub.edu/images/vla2.jpg

Understanding our planet

Weather Forecasting

Over 200 weather satellites carry equipment that allow real time detection of visible, infrared and microwave radiation. Weather satellites are either "Geostationary" or "polar orbiting". The Geostationary satellites are used to photograph cloud cover, these images are then animated and used in weather forecasts on TV. The earth turns underneath the Polar orbiting satellites allowing full global data collection. Often these satellites are "sun-synchronous", allowing data measurements to be recorded twice a day at the same point on the Earth's surface at the same time each day.

Three polar-orbiting satellites working together can observe the entire planet every six hours. This allows a closer look at the Earth, producing images and measurements with a high resolution. These satellites are however always on the move and therefore do not allow continuous observation of a particular geographical area. Temperature, wind speed and direction, chemical content of the atmosphere, water vapour, cloud cover, precipitation, storms, and tropical cyclones can all be observed.

Environmental Monitoring

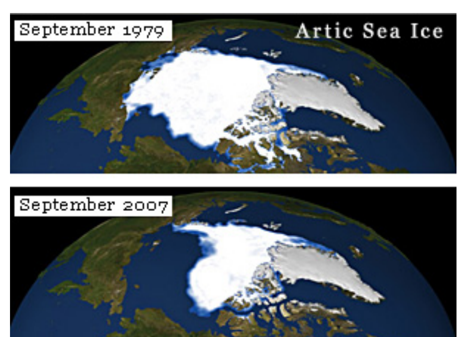
Satellites are ideal for observing the global environment, as they are capable of revealing and monitoring remote environments, hidden features, and even events that the human eye cannot detect. They provide reliable data 24 hours a day, seven days a week. Satellites can also monitor how winds disperse smoke from wildfires or ash from volcanic eruptions. Information on land surface temperature, winds, vegetation cover, bodies of water, human settlements, soil moisture, depth and extent of snow and ice can all be recorded.

Detail of the Oceans

Sea surface temperature, sea level height, ocean currents, and ocean winds are all monitored. It is also possible to monitor accidents, such as large oil spills, and periodic changes in the sea that affect global weather patterns, such as El Niño in the Pacific Ocean.

Climate Monitoring

Satellites are ideal for monitoring climate change because they can monitor the concentration of greenhouse gases in the atmosphere, such as aerosols, water vapor, carbon monoxide (CO), carbon-dioxide (CO2) and methane.



http://serc.carleton.edu/images/eyesinthesky2/week3/arctic_sea_ice_september_1263888610.jpg

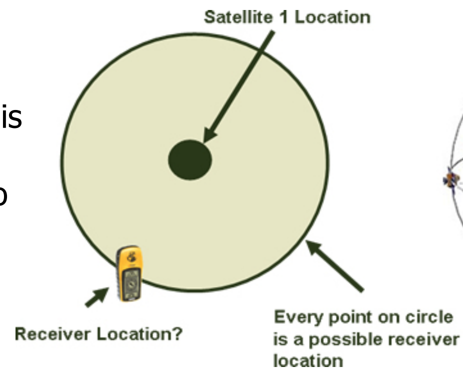
Satellite Imaging/Sensing

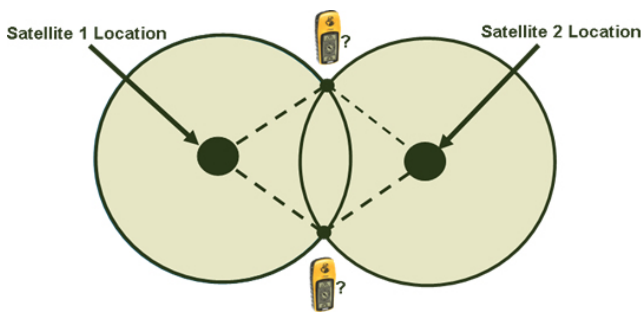
The IKONOS satellite has been used to obtain detailed imagery of military sites and nuclear facilities across the world. Coastal management, ground quality, irrigation, and many more applications can be found here http://www.satimagingcorp.com/services.html.

GPS

The GPS system uses 24 geostationary satellites transmitting microwaves to allow accurate determination of the position of an object. This includes a time stamp signal so by comparing multiple distance measurements, an object's velocity can be calculated.

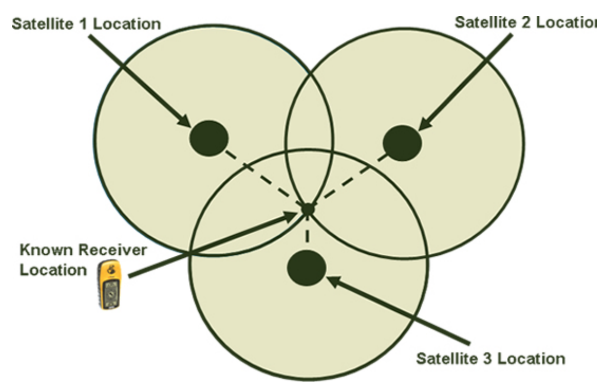
A GPS receiver finds its position by measuring the distance between itself and three or more GPS satellites (called trilateration). A microwave signal is sent out from one satellite to the GPS receiver, the receiver measures how long it took for the signal to reach it. The signal travels at a known speed, the receiver then uses the length of travel time for the signal to calculate a circular range of possible locations.





Using the signal from a second satellite, possible locations of the receiver on the ground are narrowed to the two points where the circles intersect as shown.

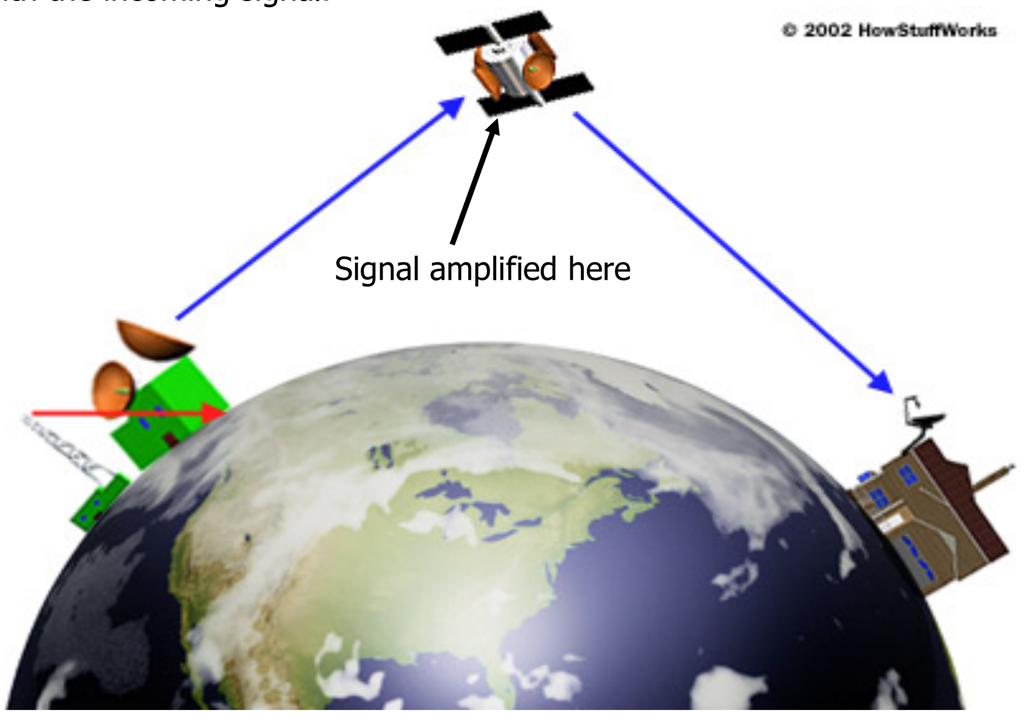
When a third satellite locates the receiver, an approximate location can be determined. Most GPS receivers give a location to within 100 metres using three satellites, but additional satellites will increase this accuracy. If four or more satellites are in range, the receiver can determine the user's position and elevation.



http://ibis.colostate.edu/DH.php?WC=/WS/CitSci/Tutorials_Wisconsin/Tutorial2_Static.html

Satellite Communications – Curved Reflectors In Action

Satellite dishes are designed to receive microwave signals from satellites. A satellite will have several receiving and several transmitting curved reflectors. Signals are **not** "bounced" off satellites. They are taken in (received), amplified and then retransmitted on a different frequency to avoid interference with the incoming signal.



Satellite Receiving Dish

The dish connected to a house is a curved reflector with a receiver placed at the focus of the curved dish. This dish reflects the signal transmitted from the orbiting satellite to the receiver located at the focus of the dish.

Radio Telescopes

Radio astronomy is the study of celestial objects that emit radio waves. Astronomical phenomena that are invisible to the eye can be observed. Phenomena such as the Cosmic Microwave Background Radiation, which is the remnant signal of the birth of our Universe, the "Dark Ages" before the onset of the first stars and even the earliest generation of galaxies are observable using radio waves. Radio waves penetrate dust, so regions of space that cannot be seen in visible light can be investigated. Using radio telescopes astronomers analyse and explore the black holes that live at the hearts of most galaxies. These telescopes are huge curved reflectors designed to capture many radio waves. These are arranged in Very Large Arrays of many individual telescopes to allow improved resolution of data capture.

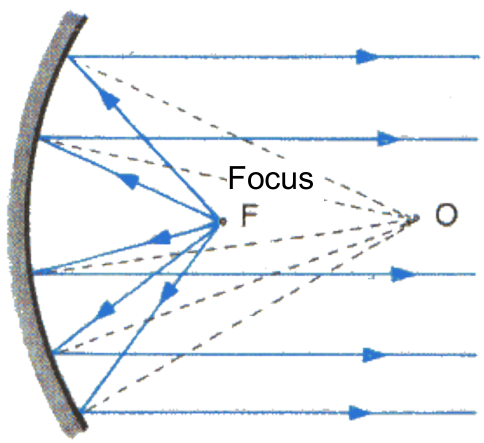
http://www.vla.nrao.edu/images/tightcenter.small.jpg

Curved Reflectors – In Detail

These can be used in transmitters and receivers of waves, e.g. sound, infrared, visible light, microwaves, TV signals and satellite communication.

The curved reflectors have a special parabolic shape that makes any waves that strike it reflect to the same point. This point is called the focus.

Transmitters



In a transmitter the transmitting device is placed at the focus of the parabolic reflector. The waves are emitted from the transmitter and are reflected off the curved reflector.

The special shape means that all the reflected waves come out in parallel straight lines. This makes it very good for sending the waves in a particular direction.

Outgoing waves are reflected out in a parallel beam

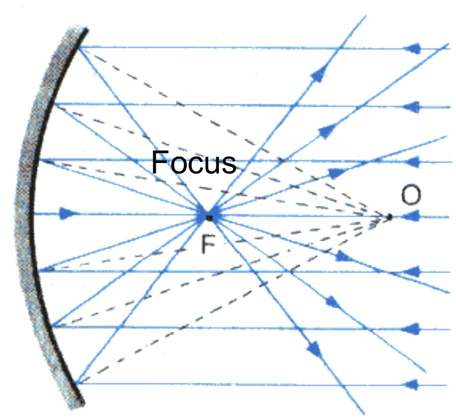
This is what happens in searchlights, torches and in microwave transmitters sending messages up to satellites.

Receivers

In a receiver the receiving device, such as an aerial, is placed at the focus of the parabolic reflector. The waves that strike the curved reflected are all reflected to the focus.

This makes the signal at the focus much stronger.
The curved "dish" can **gather more energy** from the wave and focus it onto the receiver.

Incoming waves are reflected to the focus.



Images from http://library.thinkquest.org/22915/reflection.html

Curved reflectors are used in satellite receivers, radio telescopes, solar cookers and in many other applications.

Technological Benefits of Space exploration

Many technological advances have been made in the pursuit of space travel. Some as a result of a requirement for new technology/materials, others due to a need to improve existing devices. These advances can then be applied to everyday life. Examples include in the fields of health and medicine, transportation, public safety, consumer goods, environmental and agricultural resources, computer technology and industrial productivity.

Technology	Use
Teflon-coated fiberglass	Developed for spacesuits now used worldwide as permanent roofing material in stadiums.
Liquid cooled spacesuits	Now used in portable cooling systems.
Lightweight breathing apparatus	Technology now employed by firefighters across the world
Stronger/safer school bus chassis	As a result of NASA technology from the space shuttle.
Robotic surgery	Originally developed for servicing spacecraft, robotics is now widely used in surgery and manufacturing.
Adaptation of the design of the fuel pump from the space shuttle.	Led to the LVAD - a device for maintaining the human heart's blood pumping capability during transplanting or while waiting for a donor organ.
Atomic Oxygen can gradually destroy materials used in satellites and spacecraft.	NASA developed a testing system to bombard items with atomic Oxygen, it was discovered that in a controlled manner this oxygen can clean microscopic dust from objects without damaging them. This technique is now used in non-contact ancient art restoration.
Multispectral imaging methods	Developed for investigating the surface of Mars. This is now used to analyse burnt objects to reveal writing that is not visible to the human eye.
Others include :- Developing power output of LEDs, infrared ear thermometers, Improvements in Artificial limbs, Invisible braces, scratch resistant lenses, development of the "Dustbuster" handheld vacuum cleaner, high performance silicon crystal solar cells, freeze drying, temper foam mattresses and many more.	

Technology is advancing rapidly, the sensors in satellite recording systems are significantly better than the equivalent technology available on the high street, however over time the research undertaken to produce the best equipment for a satellite can then be used to improve everyday items such as digital recording equipment.

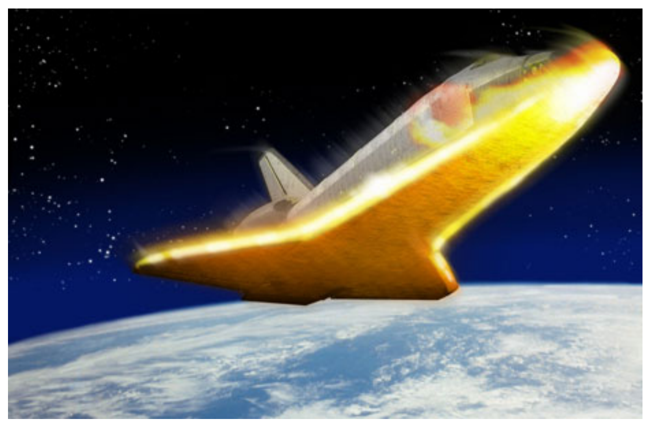
Risks of Space exploration

Space travel is not easy and there are many problems that can occur. Three astronauts were killed on the Apollo 1 mission when a space craft caught fire during testing. The first inflight disaster was the 1986 Challlenger disaster. A failure in the rings holding the solid rocket boosters allowed hot gases to escape leading to the break up of the external fuel tank. This caused the entire space craft to tilt towards the air stream and subsequently break up killing the crew of 7. The most recent U.S. disaster was the 2003 Columbia disaster. Due to a piece of insulation breaking off and damaging the leading edge of one of its wings the Columbia broke up in the atmosphere during re-entry.

Re-entry In Detail

As an aircraft moves through the air, the air molecules near the aircraft are disturbed and move around the aircraft. Exactly how the air re-acts to the aircraft depends upon the ratio of the speed of the aircraft to the speed of sound through the air.

As a spacecraft **re-enters** the earth's atmosphere, it is traveling very much faster than the speed of sound. The aircraft is said to be **hypersonic**. Typical low earth orbit re-entry speeds are near 7 820 ms^{-1} (approximately Mach 25).



The chief characteristic of re-entry aerodynamics is that the temperature of the air flow is so great that the chemical bonds of the diatomic molecules of the air are broken. The molecules break apart producing an electrically charged plasma around the aircraft. During re-entry the aircraft is actually an un-powered glider. The heat energy is so great (temperatures can reach 1650 ^oC) during re-entry that a special **thermal protection system** is used to keep the spacecraft intact.

On the Shuttle, special silicon tiles are placed on the aluminum skin to insulate the interior. On the leading edge of the wings, carbon-carbon composite material is used to withstand the heat. The high forces and high heat dictate that the Shuttle has short, blunt wings. The Shuttle flies at a high angle of attack during re-entry to generate drag to dissipate speed.

The Soyuz, Shenzhou, and all of the early Apollo, Gemini, and Mercury spacecraft used a thermal protection system that is different to the Space Shuttle. Each of these older spacecraft use an **ablative, or "burning"**, heat shield. This heat shield is made of special ceramic materials and is designed to slowly burn away as it encounters the high temperature. Large amounts of energy are required to change phase from solid to liquid (and then to gas) therefore reducing the energy that can reach the skin of the spacecraft therefore protecting the astronauts from the heat of re-entry.

When you supply heat energy to a material two separate effects can take place.

The kinetic energy of the material's molecules increases and therefore the temperature of the material increases.

OR

The bonds between the molecules in the material change and the material changes state from solid to liquid [melting] or from liquid to a gas [vapourising].

The **space shuttle** missions used the first method and the **Apollo space** missions used the second effect for cooling.

Change of Temperature and Specific Heat Capacity

The same mass of different materials will heat up at different rates. The temperature rise will depend on the amount of energy supplied, the mass of the material and what the material is.
The temperature rise, ΔT, will be proportional to the amount of energy, E, and inversely proportional to the mass, m.

$$\Delta T \propto \frac{E_h}{m}$$

A constant of proportionality is required. This gives

$$E_h = mc\Delta T$$

Symbol	Name	Unit	Unit Symbol
E_h	Heat Energy	Joule	J
m	Mass	Kilogram	kg
c	Specific Heat Capacity	Joules per kilogram degrees Celsius	J/kg^0C
T	Temperature	Degrees Celsius	^0C

The constant, **c**, is called the **specific heat capacity**. This formula should be used whenever a material changes its temperature.

Definition

The **specific heat capacity** of a substance is the **amount of heat energy** required to **change the temperature** of **1 kg** of a substance by **1 ^oC**.

Why does the inside of space shuttle not get really hot?

The **same** mass of **different** materials needs **different** quantities of heat energy to change their temperature by one degree Celsius. A material with a **large** specific heat capacity will require **a lot of energy** to increase its **temperature** and will be able to store a lot of heat energy. The temperature of a material with a small specific heat capacity will rise more quickly and it will only be able to store a little heat energy.

The space shuttle is covered with specially designed heat tiles. These have a very high specific heat capacity, allowing the absorption of large amounts of energy with relatively little heat rise. In addition they have a very low density maintaining a low mass for the shuttle to reduce the required launch fuel.

Worked example - calculating specific heat capacity

A space shuttle tile of mass 5 kg is heated by using 6.28×10^6 J of energy. The temperature rises by 2000^{o}C, calculate the specific heat capacity of the tile.

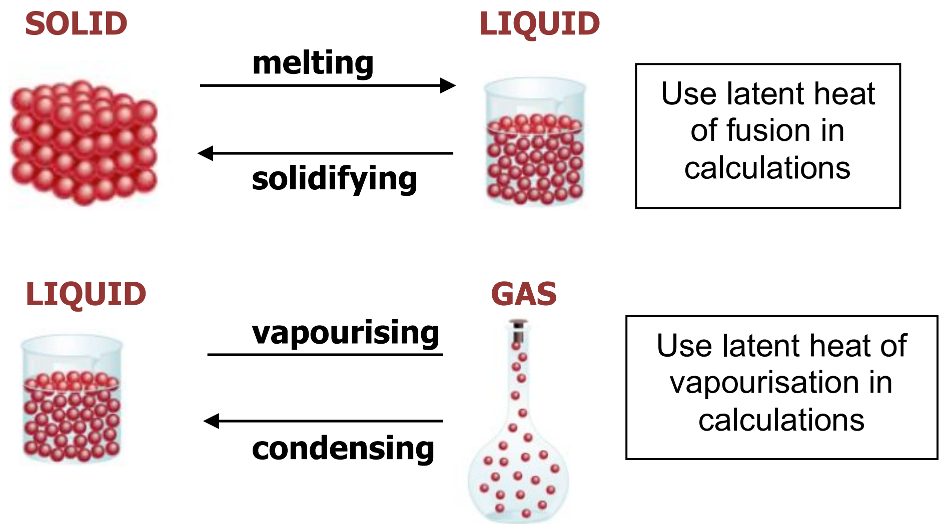
Solution

$E_h = 6\ 280\ 000$
$m = 5$
$\Delta T = 2000$

Equation $E_h = mc\Delta T$
Substitute $6\ 280\ 000 = 5 \times c \times 2000$
Rearrange $c = 6\ 280\ 000/10\ 000$
Answer $c = 628\ \text{Jkg}^{-1}\,^{o}\text{C}^{-1}$

Change of State and Latent Heats

A substance can undergo two changes of state.



http://science.taskermilward.org.uk/Mod1/Mod3/mod3img/Solid%20Liq%20Gas%20Parts.jpg

When a solid melts it requires extra energy to free the molecules into the liquid state. This extra energy involves **no change in temperature**.

When a liquid boils or vapourises it requires extra energy to free the molecules into the gaseous state.

When the change of state goes the other way energy is released with **no change in temperature**. When a gas condenses it gives off heat energy and when a liquid freezes it is also giving off heat energy.

The fact that a substance can gain or lose heat when it changes state, without a change in temperature is why this heat is called "latent". The word means hidden. The heat is used to rearrange the way the molecules are bound together without affecting their average kinetic energy, which is a measure of their temperature.

LATENT HEATOF **FUSION** (l_f) = the energy required to **melt or freeze** one kilogram of a substance with no change in temperature.

LATENT HEAT OF **VAPOURISATION** (l_v) = the energy required to **boil or condense** one kilogram of a substance with no change in temperature.

The specific latent heat of a substance is the energy involved in changing the state of 1 kg of the substance without any temperature change. Specific latent heat of a substance is calculated using the formula:

$$E_h = ml$$

Symbol	Name	Unit	Unit Symbol
E_h	Heat Energy	Joule	J
m	Mass	Kilogram	kg
l	Specific Latent Heat	Joules per kilogram	J/kg

The specific latent heat of **fusion** is the heat energy required to change 1 kg of a solid to liquid without change in temperature.

The specific latent heat of **vapourisation** is the heat energy required to change 1 kg of liquid to vapour without temperature change.

Units
The unit for specific latent heat is the joule per kilogram, J/kg.

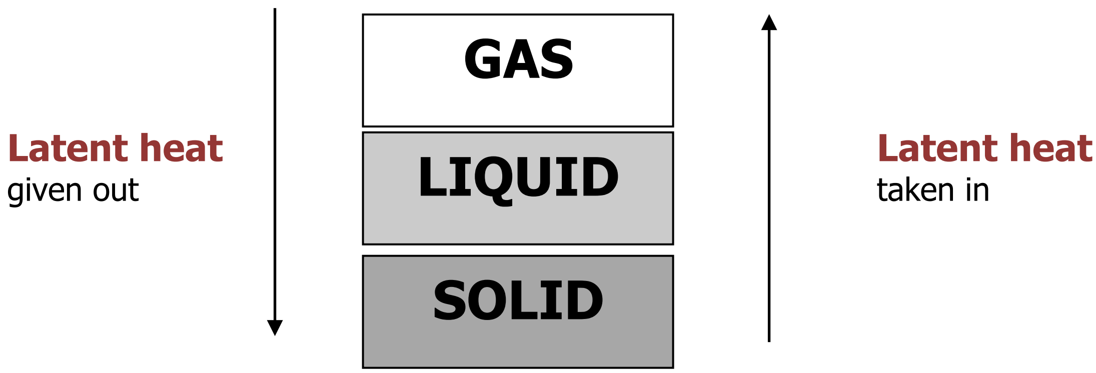
Worked Example
A mass of 2.5 kg of ammonia at its boiling point is vaporised when 6500 J of heat is supplied to it. Calculate the specific latent heat of vapourisation of ammonia.

Solution

E_h = 6 500	**E**quation	E_h = ml
m = 2.5	**S**ubstitute	6 500 = 2.5 x l
l = ?	**R**earrange	l = 6 500/2.5
	Answer	l = 2600 Jkg^{-1}

Latent Heat - Summary

When a substance changes its temperature it either gains or loses heat energy. When a substance changes its state it either gains or loses heat energy with no change in temperature.



If a question involves a substance changing temperature then use the equation $E_h = mc\Delta T$

If a question involves a substance changing its state then use the equation $E_h = ml$.

If a question involves a substance changing its temperature and a change in state then use both the equations and add the energies together.

Question involves ΔT	**Use $E_h = cm\Delta T$**
Question involves a change in state	**Use $E_h = ml$**
Question involves ΔT and a change in state	**Use $E_h = cm\Delta T$ and $E_h = ml$ and add them**

Worked Example

How much energy is required to melt 300 g of ice that is initially at -20 ºC?

Specific heat capacity of ice is 2100 Jkg^{-1}ºC^{-1}

Latent heat of fusion of ice is 3.34×10^5 Jkg^{-1}

Solution - Stage one – Heating from -20°C to 0°C

E_h = ?	**E**quation	$E_h = mc\Delta T$
m = 300 g = 0.3 kg	**S**ubstitute	$E_h = 0.3 \times 2\,100 \times 20$
ΔT = 20	**R**earrange	
c = 2 100	**A**nswer	E_h = 12 600 J

Solution - Stage two – Melting 300 g of ice

E_h = ?	**E**quation	$E_h = ml$
m = 0.3 kg	**S**ubstitute	$E_h = 0.3 \times 3.34 \times 10^5$
$l = 3.34 \times 10^5$	**R**earrange	
	Answer	E_h = 102 000 J

Therefore total energy required = 12 600 + 102 000 = 114 600J

Principle of Conservation of Energy

The total amount of energy remains constant during energy transfers. **Energy cannot be created or destroyed but simply transformed to one of its many forms.** The following example demonstrates this principle when it involves materials changing temperature or state.

Worked Example

A piece of brass of mass 2 kg is dropped onto a hard surface without rebounding resulting in a temperature rise of 1 ^{o}C. Calculate the speed with which the brass hits the surface.

Solution

$m = 2$

$\Delta T = 1^{o}C$

$c = 390\ Jkg^{-1}{}^{o}C^{-1}$

$E_h = ?$

$v = ?$

Conservation of energy gives

$$E_h = mc\Delta T = E_K = \frac{1}{2}mv^2$$

$$c\Delta T = \frac{1}{2}v^2$$

$$390 \times 1 = 0.5\ v^2$$

$$v^2 = 780$$

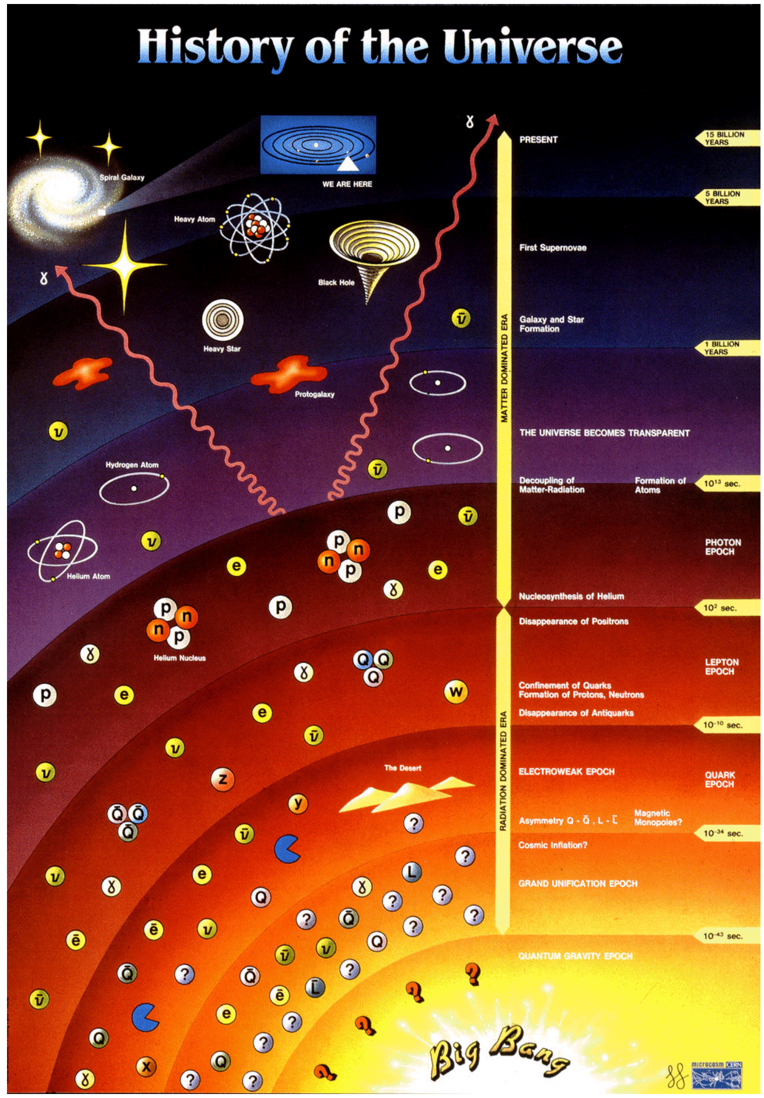
$$v = 27.9\ ms^{-1}$$

Cosmology

3. **Cosmology**
    3.1. Use of the term ‘light year’ and conversion between light years and metres.
    3.2. Observable universe — description, origin and age of universe.
    3.3. The use of different parts of the electromagnetic spectrum in obtaining information about astronomical objects.
    3.4. Identification of continuous and line spectra.
    3.5. Use of spectral data for known elements, to identify the elements present in stars.

The Universe

Scientific evidence indicates that we live in a finite but ever expanding universe. The universe started at a certain point in time and at that time all the matter, energy and space in the universe was squeezed into an infinitesimally small volume. Something caused a sudden and dramatic expansion, the story of this expansion has become known as the Big Bang Theory. It is just a model to describe what happened at the beginning but it was not an actual explosion. (The phrase "Big Bang" was introduced by accident when English astronomer Fred Hoyle used it as an insulting description of the theory he disagreed with). The Big Bang Theory is currently considered by many scientists as the most likely scenario for the birth of universe. The finer details of the early universe will continue to be revised as our understanding increases in years to come. Current best estimates are that the universe began 13.8 billion years ago.



http://eliotche.com/wp-content/uploads/2009/09/history-of-the-universe.gif

What is the universe?

http://images.sciencedaily.com/2010/04/100413202858-large.jpg

The universe contains planets, which orbit stars (Solar systems). These stars exist in massive collections called galaxies. Galaxies exist in clusters (groups of galaxies) and these clusters exist in super clusters which are evenly dispersed across the whole of the universe.

http://www.le.ac.uk/ph/faulkes/web/images/galaxies.jpg

How Big is the Universe?

The Universe is massive, so big it is pretty much impossible to really imagine how big it is! It is estimated that the universe is at least 9.2 x 10^{26} metres wide. This number is too large to really comprehend, indeed all distances in the universe are huge. The Earth is approximately 150 million kilometres away from the Sun and approximately 39.9 x 10^{12} km away from Proxima Centauri (the nearest star to our Solar system). These numbers are just too big so astronomers use a longer standard unit of distance – **The Light Year**.

The light year is a measure of distance and is the distance that light travels in one year.

How many metres are in a light year?

d = ?
v = 3 x 10^8 m/s
t = 1 year = 365 x 24 x 60 x 60
= 31 536 000 s

d = s x t
d = 3 x 10^8 x 31 536 000
= 9.46 x 10^{15} m

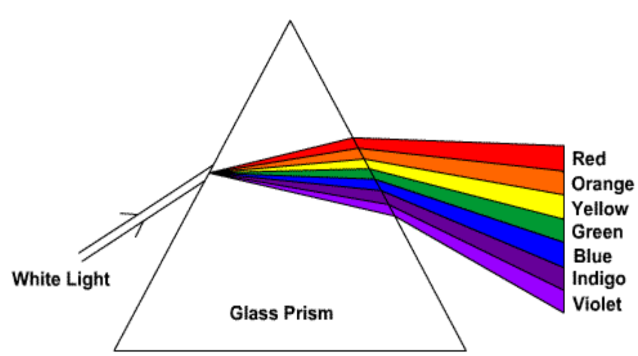
*There are **9.46 x 10^{15} m** in a light year. You must be able to convert distances in light years into metres.*

How Do Scientists Know the Composition of the Universe?

The simple answer is by looking! Looking with our eyes we can see (on a very clear night) approximately 2000 stars in the night sky at any one time. However, using telescopes we can capture more light and so we can see stars that are not visible to the naked eye. This is when the fun really begins.

Most stars look white to the naked eye (some look blue or red) however much like when watching TV or using an energy efficient bulb our brain is being tricked. Red, blue and green light shone together look white. When white light is shone through a prism, a continuous spectrum is visible.

http://www.winsornewton.com/assets/hints_tips/Colour%20Mixing/add_colour.jpg



http://annandiluz.files.wordpress.com/2012/08/light_dispersion1.gif

Looking at this spectrum in details reveals all the visible colours as shown below. White light produces a **continuous spectrum** displaying all visible colours.

http://highered.mcgraw-hill.com/sites/dl/free/0072415932/9304/spectrumc.gif

All atoms give off **light** when **heated**, although sometimes this light is not visible to the human eye. (eg Infra red and UV). A **prism** can be used to split the light from the atoms to form a **spectrum**. Each element produces a distinctive and unique **line spectrum**. The coloured lines (or Spectral Lines) are a kind of "fingerprint" or "barcode" for the atoms. This technique is known as **spectroscopy**. A Spectroscope is a device that allows detailed spectra to be captured. Example spectra are given below.

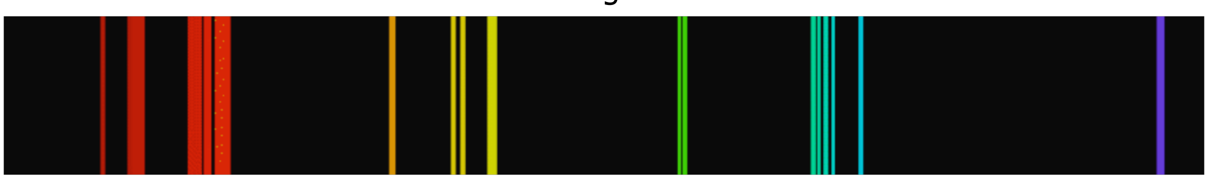
Hydrogen

Red Violet

Helium

Red Violet

Nitrogen



Red http://chemistry.bd.psu.edu/jircitano/periodic4.html Violet

As can be seen above, each atom has its own colour spectrum.

A gas can also absorb energy, the emission and absorption lines appear in the same position but for an absorption spectra we see dark lines as shown below. It is the absorption lines that are used to identify gases within stars. Shown below is the absorption spectra for hydrogen.

Using the Rest of the Electromagnetic Spectrum to Investigate the Universe.

Observations of light from other parts of the e.m. spectrum have allowed a greater understanding of the origin, composition and history of the Universe.

Range of em spectrum	Information gained
Gamma rays & x rays	Extremely high energy particles, cosmic explosions, high speed collisions can be detected. Material moving at extremely high speeds emit these rays. Some emanate from supernovae remnants.
Ultra-violet	Very young massive stars, some very old stars, bright nebulae, white dwarfs stars, active galaxies and quasars shine brightly in the ultraviolet region.
Visible	Chemical composition of the stars, particles at the outer edges of nebula
Infra Red	Infrared observations are used to peer into star-forming regions and into the central areas of our galaxy. Cool stars and cold interstellar cloud are detected.
Radio Waves	The study of the radio universe brought us the first detection of the radiation left over from the Big Bang. Radio waves also bring us information about supernovae, quasars, pulsars, regions of gas between the stars, and interstellar molecules.

Useful links
http://www.atlasoftheuniverse.com/index.html

http://www.universetoday.com/13507/what-is-the-biggest-star-in-the-universe/

http://www.launc.tased.edu.au/online/sciences/physics/linespec.html

http://www.mhhe.com/physsci/chemistry/essentialchemistry/flash/linesp16.swf

Example Spectra - http://www.colorado.edu/physics/2000/quantumzone/index.html

Tutorial Problems on Projectiles

1. A stone thrown horizontally from a cliff lands 24 m out from the cliff after 3 s. Find:
   a) the horizontal speed of the stone
   b) the vertical speed at impact.

2. A ball is thrown horizontally from a high window at 6 m/s and reaches the ground after 2 s. Calculate:
   a) the horizontal distance travelled
   b) the vertical speed at impact.

3. An aircraft flying horizontally at 150 m/s, drops a bomb which hits the target after 8 s. Find:
   a) the distance travelled horizontally by the bomb
   b) the vertical speed of the bomb at impact
   c) the distance travelled horizontally by the aircraft as the bomb fell
   d) the position of the aircraft relative to the bomb at impact.

4. A ball is projected horizontally at 15 m/s from the top of a vertical cliff. It reaches the ground 5 s later. For the period between projection until it hits the ground, draw graphs with numerical values on the scales of the ball's:
   a) horizontal velocity against time
   b) vertical velocity against time
   c) From the graphs calculate the horizontal and vertical distances travelled.

5. In the experimental set-up shown below, the arrow is lined up towards the target. As it is fired, the arrow breaks the circuit supplying the electromagnet, and the target falls downwards from A to B.

   a) Explain why the arrow will hit the target.
   b) Suggest one set of circumstances when the arrow would fail to hit the target.
   It is assumed that the arrow is always lined up correctly.

Tutorial Problems on Space Exploration and Specific Heat

1. What is a satellite?

2. What is a geostationary orbit?

3. Explain the difference between an natural satellite and an artificial satellite.

4. What is a Galaxy?

5. What is a Star?

6. A large telescope array uses many curved reflecting dishes to receive signals from space.

7. What parts of the em spectrum are detected using large telescope arrays?

8. Show by means of a diagram how the em rays are received.

9. Explain, using a diagram how a curved reflector is used to transmit satellite TV images from a geostationary satellite to Britain.

10. How can a curved reflector be used to create a "solar cooker"?

11. There have been many technological advances due to space exploration, including infrared ear thermometers, scratch resistant lenses, high performance solar cells, freeze drying, robotic surgery etc. Pick any two technologies and research why they were developed for space and explain how they are benefiting the human race.

12. A satellite orbiting the Earth transmits radio signals to a receiver. The signals take a time of 150 ms to reach the receiver. What is the distance between the satellite and the receiver?

13. Explain what causes items of "space junk" to burn up on entry into the Earth's atmosphere.

14. Copy and complete the following sentence by selecting the correct words. Compared to infrared radiation, X-rays have a *longer/shorter* wavelength which means they have a *higher/lower* frequency.

15. The specific heat capacity of concrete is 800 J/kg0C. How much additional heat is stored in a storage heater containing 50 kg of concrete if the temperature is increased by 100^0C?

16. 1.344 MJ of heat energy is used to heat water from 20 0C to 100 0C. Calculate the mass.

17. 9600 J of heat energy is supplied to 1 kg of methylated spirit in a polystyrene cup. Calculate the rise in temperature produced.

18. When 2.0 x 104 J of heat is supplied to 4 kg of paraffin at 10 0C in a container the temperature increases to 14 0C.

a) Calculate the specific heat capacity of the paraffin.

b) Explain why the result in part a) is different from the theoretical value of 2200 J/kg0C.

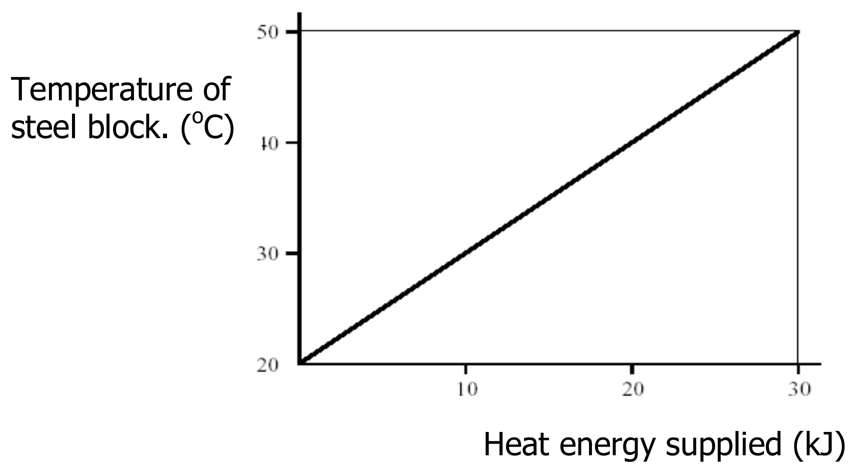
19. If a kettle containing 2 kg of water cools from 40 0C to 25 0C, calculate the heat given out.

20. The temperature of a 0.8 kg metal block is raised from 27 0C to 77 0C when 4200 J of energy is supplied. Find the specific heat capacity of the metal.

21. 10000 J of energy raises the temperature of 1 kg of liquid by 2 0C. How much energy will be required to raise the temperature of 4 kg of the liquid by 1 0C?

22. The tip of the soldering iron is made of copper with a mass of 30 g. Calculate how much heat energy is required to heat up the tip of a soldering iron by 400 0C.

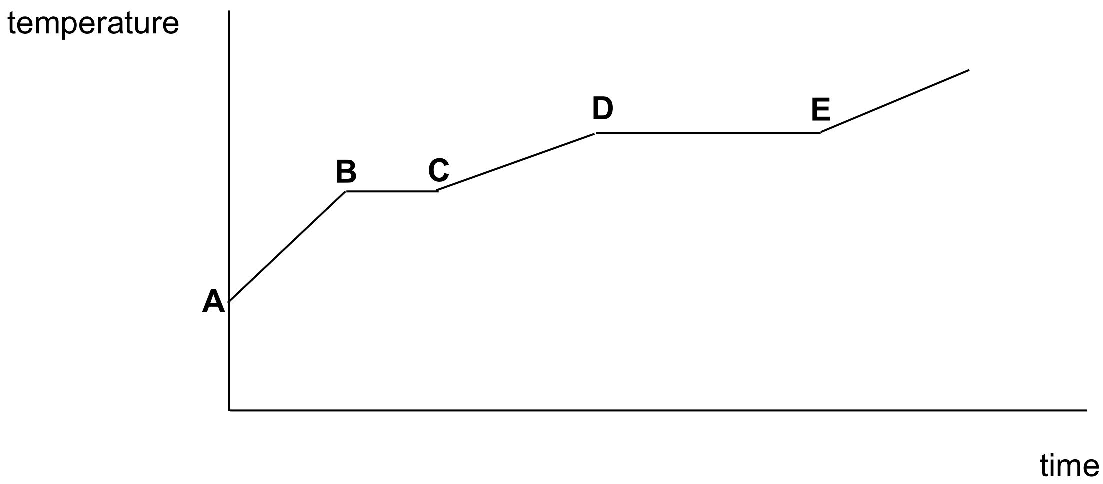
23. The graph below represents how the temperature of a 2 kg steel block changes as heat energy is supplied. From the graph calculate the specific heat capacity of the steel.



Tutorial Problems for Latent Heat

specific heat capacity of water is 4180 $Jkg^{-1}{}^{o}C^{-1}$
latent heat of fusion of ice is 3.34×10^5 Jkg^{-1}
latent heat of vapourisation of water is 2.26×10^6 Jkg^{-1}

1. Look at the graph below, which provides information on the temperature of a substance as it is being heated at a steady rate.



a) What is happening at the following parts of the graph? AB has been done for you.

AB A solid is increasing its temperature.

BC

CD

DE

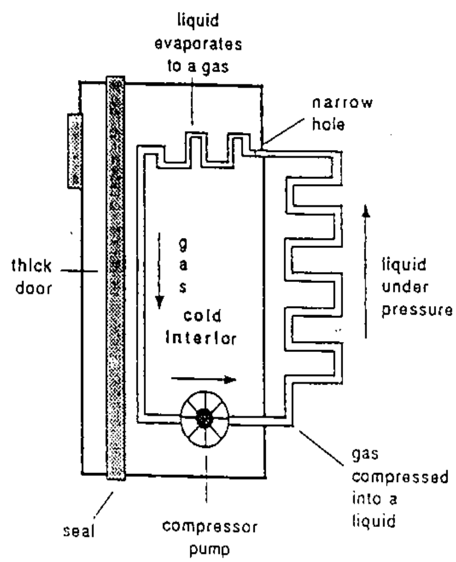
b) Does the solid or liquid state have the bigger specific heat capacity? Explain why.
c) Which latent heat is bigger? Explain why.

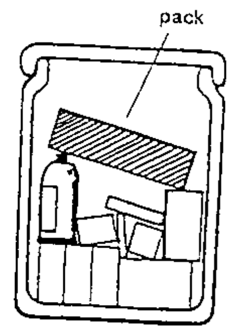
2. A steam burn is much worse than a burn from boiling water.
Do the following calculations to prove this.

a) Calculate the energy given out from 0.1 g of boiling water as it cools to 30 ^{o}C (skin temperature.)
b) Calculate the energy given out from 0.1 g of steam as it condenses to water at 100 ^{o}C.
c) What is the total energy release by 0.1 g of steam if it condenses and cools to 30 ^{o}C on your skin.
d) Explain why steam scalds are worse than scalds from water at the same temperature.

3. It is possible to produce an extremely cold drink in the dessert by filling a clay jar with water and then splashing the outside of the jar with more water several times. Explain why this cools the water inside the jar.
4. Explain how a fridge manages to transfer heat from inside the fridge to outside the fridge by changing the state of a refrigerant fluid called Freon.

See website http://www.ior.org.uk/science/fridge1/fridgediag.htm





5. a) Explain how freezer packs keep a cool box cold.

   b) Explain why the freezer pack should be placed on top of the food.

6. Explain why sports players often get a "freeze" spray put onto a muscular injury.

7. Calculate the amount of heat energy required to melt 0.3 kg of ice at 0 ^{0}C.

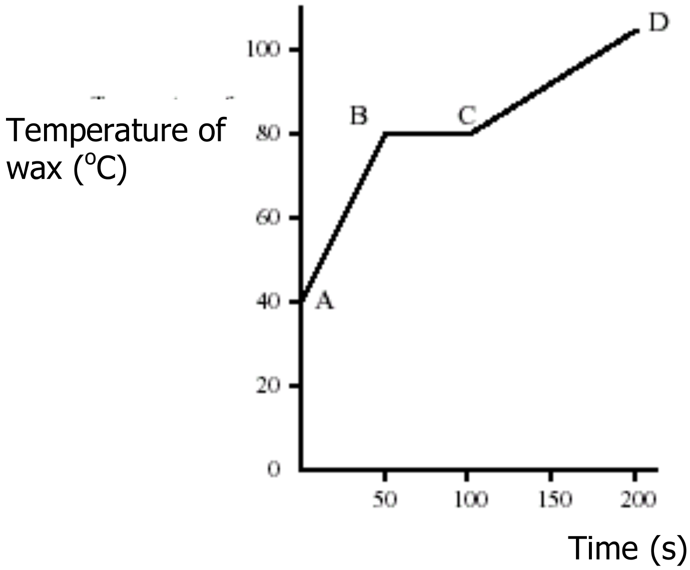
8. Calculate the specific latent heat of fusion of naphthalene given that 6 x 10^5 J of heat are given out when 4.0 kg of naphthalene at its melting point changes to a solid.

9. Calculate what mass of water can be changed to steam if 10.6 kJ of heat energy is supplied to the water at 100 ^{0}C.

10. Ammonia is vaporised in order to freeze an ice rink.
    a) Find out how much heat it would take to vaporise 1 g of ammonia.

    b) Assuming this heat is taken from water at 0 ^{0}C, find the mass of water frozen for every gram of ammonia vaporised.
    (Specific latent heat of vapourisation of ammonia = 1.34 x 10^6 J/kg)

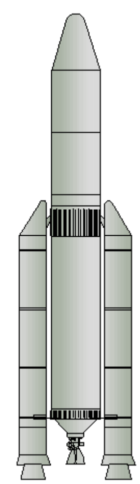
11. The graph below shows how the temperature of a 2 kg lump of solid wax varies with time when heated.



a) Explain what is happening to the wax in the regions AB, BC and CD.

b) If a 200 W heater was used to heat the wax, calculate the specific latent heat of fusion of the solid wax.

Tutorial Problems for Space Exploration and Energy



1. A multistage rocket jettisons its third stage fuel tank when it is empty. The fuel tank is made of aluminium and has a mass of 4 000 kg. (specific heat capacity of aluminium is 900 J/kg°C)

   a) Calculate the kinetic energy lost by the fuel tank as it slows down from 5 000 m/s to 1 000 m/s during its journey through the atmosphere.

   b) How much heat energy is produced?

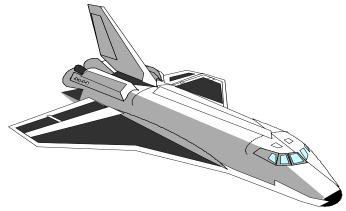
   c) Calculate the rise in temperature of the fuel tank.

2. The space shuttle Columbia re-entered the Earth's atmosphere at a speed of 8 000 m/s and was slowed down by friction to a speed of 200 m/s. The shuttle has a mass of 2 x10^6 kg.

   a) How much kinetic energy did the shuttle lose?

   b) How much heat energy was produced during this process?

3. A space shuttle of mass 2 x 10^6 kg was travelling with a speed of 9 000 m/s as it entered the Earth's atmosphere. The speed of the shuttle dropped to 100 m/s at touch down, at which point the brakes were applied, bringing the shuttle to rest.0



a) Explain why the speed of the shuttle decreased from 9 000 m/s to 100 m/s before the brakes were applied.

b) How much kinetic energy did the shuttle lose before the brakes were applied?

c) How much heat energy was created as the shuttle speed dropped from 9000 m/s to 100 m/s?

d) The shuttle was covered with special heat-resistant tiles. Why was this necessary?

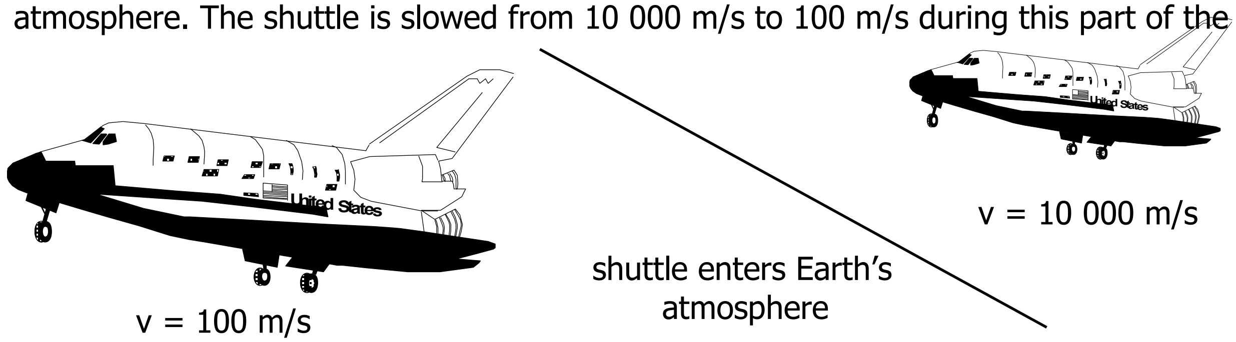
e) The specific heat capacity of the heat-resistant material used in the tiles is 35 700 J/kg^{0}C. The temperature of the tiles should increase by no more than 1 300 ^{0}C during re-entry.

What mass of tiles would be required to absorb all of the heat energy produced?

Explain why in practice the mass of the tiles was less than calculated in part (*e*).

How much work was done by the brakes to bring the shuttle to rest?

4. The nose section of the shuttle is covered with 250 kg of heat resistant tiles which experience a rise in temperature of 1 400 ^{o}C during the shuttle's journey back through the Earth's atmosphere. The shuttle is slowed from 10 000 m/s to 100 m/s during this part of the journey .



a) How much kinetic energy does the nose of the shuttle lose?

b) How much heat energy is produced at the nose during re-entry?

c) Calculate the specific heat capacity of the material used to make the nose tiles.

Tutorial Problems on Cosmology

1. What is a light year?

2. How many metres are in a light year?

3. Light from the Sun takes 8 minutes to reach earth.
   a) How many years is eight minutes?
   b) How far away is the sun (in metres)?

4. The star "Sirius" is 8.146×10^{16} m from Earth. How far is this in light years?

5. The dwarf planet Pluto is approximately 5.9×10^{12} m away from Earth, how many light years is this?

6. The nearest Galaxy to Earth is approximately 2.2×10^{6} light years away form Earth, how far is this in metres?

7. To the nearest billion years, how old is the universe?

8. State what is meant by the term solar system.

9. What is a planet?

10. What is a galaxy?

11. Radio waves emitted by galaxies are detected and used to provide images of the galaxies.
    a) How does the wavelength of the radio waves compare with the wavelength of light?
    b) Why are different kinds of telescope used to detect signals form space?

12. Read the following:-
    "Halley's Comet is famous because it is visible to the naked eye, orbiting from beyond the planet Neptune and returning to the solar system on average once every 76 years.
    Halley's Comet last visited the inner solar system in 1986. It will return again in 2061.
    Comets are made of ice mixed with frozen methane; substances very similar to those found on a moon called Miranda.
    Comets can only survive very far away from the Sun. Most comets reside in the Oort Cloud which contains many billions of comets. The Oort Cloud reaches a quarter of the distance from the Sun to the next nearest star called Proxima Centauri.
    The Oort Cloud is easily affected by the gravitational pull of the Milky Way galaxy which causes comets to move into new orbits that carry them closer to the Sun."

    Use information given in the passage to answer the following questions.
    a) State the name of one object that orbits a planet.
    b) State the name of one object that generates light.
    c) State the name of the object furthest away from the Earth.
    d) State the name of one object that orbits the Sun.

Answers to numerical problems

Projectiles

1. a) 8 m/s b) 30 m/s
2. a) 12 m b) 20 m/s
3. a) 1200 m b) 80 m/s c) 1200 m d) aircraft is above bomb
4. a) - b) - c) Horizontal – 75 m Vertical – 125m
5. a) - b) -

Space Exploration and Heat

1.
2.
3.
4.
5.
6.
7.
8.
9.
10.
11.
12.
13.
14.
15. 4 000 000 J
16. 4.019 kg
17. 3.8 °C
18. a) 1 250 J/kg°C
19. 125 400 J
20. 105 J/kg°C
21. 20 000 J
22. 4 800 J
23. 500 J/kg°C

Latent Heat Problems

1.
2. a) 29.3 J b) 226 J c) 255 J
3.
4.
5.
6.
7. 100 000 J
8. 150 000 J/kg
9. 4.69×10^{-3} kg
10. a) 1 340 J b) 0.004 kg
11. 5 000 J/kg

Space Exploration and Energy

1. (a) 4.8×10^{10} J
   (b) 4.8×10^{10} J
   (c) 13 333 ^{o}C
2. (a) 6.4×10^{13}J
   (b) 6.4×10^{13}J
3. (b) 8.1×10^{13} J
   (c) 8.1×10^{13} J
   (e) 1.75×10^{6} kg
   (g) 1×10^{10} J
4. (a) 1.25×10^{10} J
   (b) 1.25×10^{10} J
   (c) 35 714 J/kg^{o}C

Cosmology

1.
2. 9.46×10^{15} m
3. a) 1.52×10^{-5} b) 1.44×10^{11}
4. 8.61 ly
5. 0.00062 ly
6. 2.08×10^{21}
7. 14