Section 1 - Signals From Space

The Universe

The **universe** consists of many galaxies separated by empty space.

A **galaxy** is a large cluster of stars (e.g. the Milky Way).

A **star** is a large ball of matter that is undergoing nuclear fusion and emitting light. The sun is a star.

The sun and many other stars have a solar system. A **solar system** consists of a central star orbited by planets.

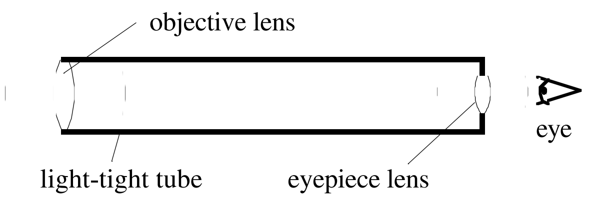
A **planet** is a large ball of matter that orbits a star (e.g. Earth or Jupiter). Planets do not emit light themselves.

Many planets have moons. A **moon** is a lump of matter that orbits a planet (e.g. the Moon orbits the Earth or Deimos and Phobos orbit Mars)

Refracting Telescopes

Refracting telescopes use lenses to obtain images of distant objects.

A refracting telescope consists of an objective lens, an eyepiece lens and a light-tight tube:



The **objective lens** produces an image which is then magnified by the **eyepiece lens**. The **light-tight tube** cuts out light from other sources.

The larger the diameter of the objective lens the more light it can collect and therefore the brighter the image .

The Light-year

Since distances in space are so enormous it is useful to think about how long it takes light to reach us from an object. For example:

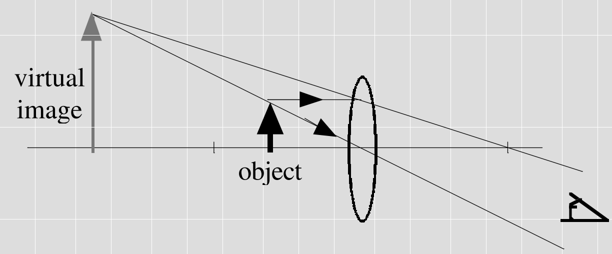
Object	Time taken for light to reach Earth
Sun	8 minutes
nearest star (Proxima Centauri)	4.3 years
edge of galaxy	100,000 years

A useful measurement of distances in space is the light-year. A **light-year** is the distance travelled by light in one year

Magnifying Lenses

Convex lenses can be used to obtain magnified images of an object (e.g. a magnifying glass or the eyepiece lens of a telescope.

In order to magnify the object must be placed between the lens and it's focus.



In this position the rays of light from the object through the lens do not meet. However when viewed with the human eye they appear to come from a point on the same side of the lens as the object. This image is known as a **virtual image**. The virtual image is larger than the object and is the same way up.

Colour and Wavelength

Different colours of light correspond to different wavelengths.

Red light has a longer wavelength than **green** light which in turn has a longer wavelength than **blue** light.

The Electromagnetic Spectrum

Light is only one of a range of radiations all of which travel at the speed of light (3×10^{8} ms^{-1}).

This family of waves is known as the **electromagnetic spectrum**. Different waves in the electromagnetic spectrum have different wavelengths.

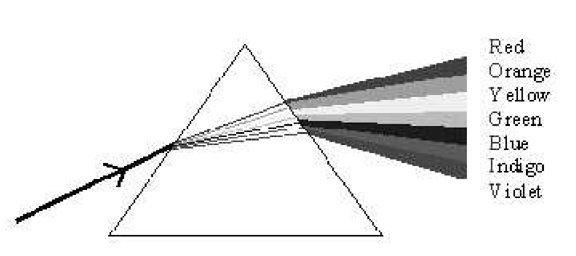
increasing wavelength ↓		increasing frequency ↑
	Gamma rays	
	X-rays	
	Ultraviolet	
	Visible light	
	Infrared	
	Microwaves	
	TV	
	Radio	

Radio Telescopes

Different types of telescopes are required to detect different types of electromagnetic radiation. In addition to optical telescopes, which detect visible light, **radio telescopes** are often used to detect radio signals from space.

Spectra

White light is made up of a range of colours. These colours can be separated by splitting white light with a **prism** to obtain a **spectrum**.



A complete (continuous) spectrum is made up of the following colours: Red., Orange , Yellow, Green, Blue, Indigo and Violet (ROYGBIV).

A **line spectrum** consists of a complete (continuous) spectrum with certain colours missing which appear as black line in the spectrum.

Every element produces a unique line spectrum. Studying line spectra allows the elements present in a light source (e.g. a star) to be identified (this can allow the type, distance, age or speed of a star to be identified)

Detectors of Radiation

Energy is given out by objects in space (e.g. stars or galaxies) over the whole range of the electromagnetic spectrum. To fully understand the universe we must collect information at all these wavelengths. Different kinds of telescope are therefore required to detect these radiations.

Radiation	Detector
Gamma rays	Geiger-Muller tube
X-rays	Photographic film
Ultraviolet	Fluorescent paint
Visible light	Photographic film
Infrared	Blackened thermometer
Microwaves	Diode probe
TV	Aerial
Radio	Aerial

Section 2 - Space Travel

Newton's Third Law

A rocket is pushed forward because a 'propellant' is pushed back.

This is an example of the principle that if A pushes B then B pushes A back. For example when a foot pushes a ball the ball pushes back on the foot.

This principle is known as **Newton's Third Law of Motion**. It is usually stated as: *"If A exerts a force on B then B exerts an equal but opposite force on A"* .

In such a situation the forces of A on B and B on A are known as a **Newton pair**. Newton pairs always act on different objects and should not be confused with balanced forces which act on the same object. For example the downward force on the air by a hovercraft and the upward force on the hovercraft by the air are a Newton pair but the weight and the lift on the hovercraft by the air are balanced forces.

Weight and Mass

The **weight** of an object is the force on it due to the gravitational pull of gravity at that point. Since it is a force weight is measured in newtons (not kilograms!)

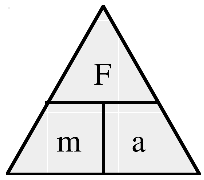
The weight of an object on different planets (or moons) is different from it's weight on Earth.

The **mass** of an object is the amount of matter that makes up the object and is measured in kilograms. The mass of an object remains the same no matter where the object is in the universe

Thrust, Mass and Acceleration

The thrust exerted by a rocket can cause an unbalanced force on the rocket causing it to accelerate. Calculations can be performed using the following equation:

$$\underbrace{\text{unbalanced force}}_{\text{N}} = \overbrace{\text{mass}}^{\text{kg}} \text{ x } \underbrace{\text{acceleration}}_{\text{m/s/s}}$$



$F = ma$

$m = \dfrac{F}{a}$

$a = \dfrac{F}{m}$

If more than one force acts on an object it is necessary to work out the unbalanced force before using the above equation.

Interplanetary Flight

During interplanetary flight there is no need for the engines to be kept on. Since space is a vacuum there is no friction acting on the space vehicle. With no unbalanced forces acting on the vehicle it will continue to move at a steady speed (Newton's First Law of Motion).

Gravitational Field Strength

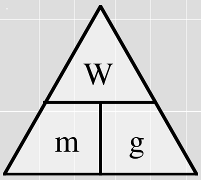
The **gravitational field strength**, **g**, of a planet is the *weight per unit mass of an object* on that planet. Gravitational field strength therefore has units of N/kg. For example on Earth g = 10 N/kg, whereas on Mars g =3.8 N/kg.

Weight, Mass and g

kg

weight = mass x gravitational field strength

N N/kg



$W = mg$

$m = \frac{W}{g}$

$g = \frac{W}{m}$

Note that gravitational field strength is numerically equal to the acceleration due to gravity.

Inertia

The **inertia** of an object is a measure of how hard it is to change the motion of an object. The inertia of an object varies with it's mass.

Freefall

When an object is in freefall it appears to be weightless. For example the astronauts inside a spacecraft appear to be weightless because both the astronauts and the spacecraft are falling towards the Earth at the same rate.

Satellite Motion

Satellite motion is an extension of projectile motion.

A satellite is continually accelerating towards the Earth just like any other projectile. However the satellite is moving so fast that the Earth curves away from it as quickly as it falls. This means that the satellite never reaches the Earth but continues to move in orbit.

Gravitational Acceleration

The force of gravity (weight) near the Earth's surface gives all objects the same acceleration (if the effects of air resistance are negligible).

Explanation:

The only force acting on the object is weight.

$W = mg$

Therefore unbalanced force, $F = mg$

Substituting this into $F = ma$ (Newton II)

gives $mg = ma$

so $g = a$

Weight and Distance

The weight of an object decreases as it's distance from the Earth increases. This is because the gravitational field strength decreases with distance.

Projectile Motion

When an object is projected in a gravitational field (e.g. when a ball is thrown on Earth) it will follow a curved path. This is known as **projectile motion**.

This is because the only force on the object is the force of gravity (weight) acting vertically downwards. This results in a *constant downward acceleration*. Whereas there are no horizontal forces so the object continues to move with a *constant horizontal speed.*

The horizontal and vertical motion of a projectile can be treated independently.

Calculations can be done using:

$d = vt$ for it's horizontal motion (constant horizontal speed)

$a = \frac{v-u}{t}$ for it's vertical motion (constant downward acceleration of 10 ms^{-2})

Spacecraft Re-entry

When a spacecraft re-enters the Earth's atmosphere it experiences friction with the atmosphere. This results in kinetic energy being changed into heat. For this reason spacecraft have to be covered with heat shielding to prevent them from burning up on re-entry.

Calculations can be performed relating to satellite re-entry using the principle of conservation of energy and the following equations:

$E_k = \frac{1}{2}mv^2$	kinetic energy
$E_w = Fd$	work done by friction (equal to loss in kinetic energy)
$E_H = cm\Delta T$	temperature rise of the spacecrafts's shielding (equal to work done by friction.)