Carter Observatory Education Team

Activity booklet Level 4

This booklet contains:

- Teacher's notes for Level 4
- Level 4 assessment points
- Classroom activities
- Curriculum links

Classroom Activities:

Use these flexible activities to develop students awareness of abstract scientific concepts.

- Survival on the Moon
- Solar System Scale Model
- How Can We Navigate by the Sky?
- Seeing Clearly with Binoculars
- How to take Astronomical Measurements
- How do we Measure the Brightness of Stars and Planets?

Curriculum Links:

Use these ideas to link this science topic with Literacy, Mathematics and Craft sessions.

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Notes for Teachers

Level 4 includes Exploring the Solar System, Telescopes and Hunting for Asteroids. These cover more about how seasons happen and if this could happen on other objects in space, features and affects of the Sun and builds on the knowledge of our galaxy and beyond as well as how to find asteroids.

Our Solar System

The Solar System is made up of the Sun and its planetary system of eight planets, their moons, and other non-stellar objects like comets and asteroids. It formed approximately 4.6 billion years ago from the gravitational collapse of a massive molecular cloud. Most of the System's mass is in the Sun, with the rest of the remaining mass mostly contained within Jupiter. The four smaller inner planets, Mercury, Venus, Earth and Mars, are also called terrestrial planets; are primarily made of metal and rock. The four outer planets, called the gas giants, are significantly more massive than the terrestrials. The two largest, Jupiter and Saturn, are made mainly of hydrogen and helium. The two outermost planets, Uranus and Neptune, are made largely of substances with relatively high melting points called *ices*, such as water, ammonia and methane, and are often referred to separately as 'ice giants'. All planets have almost circular orbits that lie within a nearly flat disc called the ecliptic plane.

The Solar System also contains a number of areas occupied by many smaller objects. The asteroid belt, which lies between Mars and Jupiter, contains objects comprised of rock and metal. Beyond Neptune's orbit lies the Kuiper Belt and a scattered disc, which includes trans-Neptunian objects made mostly of ices. Within these areas are objects that are large enough to have been rounded by their own gravity. Such objects are referred to as dwarf planets. Identified dwarf planets include Pluto, Ceres, Eris, Haumea, and Makemake. Many of the planets and dwarf planets are orbited by natural satellites, usually termed 'moon' after Earth's Moon. Each of the outer planets is encircled by planetary rings of dust and ice and other small objects.

The solar wind, a stream of plasma from the Sun, generates a bubble in the interstellar medium known as the heliosphere, which extends out to the edge of the scattered disc. The Oort Cloud, which is believed to be the source for long-period comets, may also exist at a distance approximately a thousand times further than the heliosphere. The heliopause is the point at which pressure from the solar wind is equal to the opposing pressure of interstellar wind. The Solar System is located within one of the outer arms of the Milky Way Galaxy called the Orion Arm.

Our Galaxy - The Milky Way

This name comes from its appearance as a dim 'milky' glowing band bending across the night sky. This cloudy haze is produced by stars so far away that the naked eye cannot distinguish them. The Milky Way appears like a band because it is a disc-shaped structure being viewed from inside. That this faint band of light is made up of stars was proven in 1610 when Galileo Galilei used his telescope to resolve it into individual stars. In the 1920s, observations by astronomer Edwin Hubble showed that the Milky Way is just one of many galaxies.

The Milky Way is a barred spiral galaxy 100,000–120,000 light-years in diameter containing 100–400 billion stars. It is thought to contain at least as many planets. The very centre is marked by an intense radio source named Sagittarius A which is believed to be a supermassive black hole. The stars and gas of the the Galaxy rotate around the centre at approximately the same speed, which contradicts the laws of Keplerian dynamics. This indicates that much of the mass of the Milky Way does not emit or absorb electromagnetic radiation; this is known as dark matter. The rotational period is about 200 million years at the position of the Sun. The Galaxy as a whole is moving at a velocity of approximately 600 km per second. The oldest known star in the Galaxy is about 13.2 billion years old, nearly as old as the Universe. The Milky Way is surrounded by several smaller satellite galaxies, and is part of the Local Group of galaxies, which forms part of the Virgo Supercluster.

Black Holes

A black hole is an area of space from which gravity prevents anything escaping including light. Einstein's theory of general relativity predicts that a compact mass will deform space to form a black hole. The mathematically defined surface around a black hole is called the event horizon, this marks the point of no return. The hole is labelled 'black' because it absorbs all the light that hits the horizon and reflects nothing.

Black holes form when very massive stars collapse at the end of their life cycle. After a black hole has formed it can continue to expand by absorbing mass from its surroundings. Supermassive black holes form by absorbing other stars and merging with other black holes. It generally accepted that supermassive black holes exist in the centre of most large galaxies.

The presence of a black hole can be found through its interaction with other matter and with electromagnetic radiation such as light. Matter falling into a black hole can form an accretion disk heated by friction, forming some of the brightest objects in the universe. If there are other stars orbiting a black hole, their orbit can be used to determine its mass and location. Astronomers have identified numerous stellar black hole candidates and established that the core of our Milky Way Galaxy contains a supermassive black hole of approximately 4.3 million solar masses.

Life of a Star

Stellar evolution is the process by which a star undergoes a sequence of changes during its lifetime. Depending on the mass of the star, this lifetime ranges from only a few million years for the most massive to trillions of years for the least massive. All stars are born from nebulae or molecular clouds, which are collapsing clouds of gas and dust. Over the course of millions of years, these protostars settle down into a state of nuclear fusion, becoming what is known as a main-sequence star.

Nuclear fusion powers a star for most of its life. Initially the energy is generated by the fusion of hydrogen atoms to helium atoms at the core of the main-sequence star. Later, as most of the atoms at the core become helium, stars like the Sun begin to fuse hydrogen along a spherical shell surrounding the core. This process causes the star to gradually grow in size, passing through the subgiant stage until it reaches the red giant phase. Stars with at least half the mass of the Sun can also begin to generate energy through the fusion of helium at their core. More massive stars can fuse heavier elements along a series of concentric shells. Once a star like the Sun has exhausted its nuclear fuel, its core collapses into a dense white dwarf and the outer layers are expelled as a planetary nebula. Large stars can explode in supernova as their inert iron cores collapse into an extremely dense neutron star or black hole. The Universe is not old enough for any of the small(est) red dwarfs to reach the end of their lives. Models suggest they will slowly become brighter and hotter before running out of hydrogen fuel and becoming low-mass white dwarfs.

The Universe

The Universe is commonly defined as the totality of existence, including planets, stars, galaxies, the contents of intergalactic space, and all matter and energy. The Universe is thought to be approximately 13.8 billion years old.

The farthest distance that it is possible for humans to see is called the observable universe, about 93 billion light years in diameter. Scientific observation of the Universe has led to suggestions of its earlier stages. These observations suggest that the Universe has been governed by the same physical laws and constants throughout most of its existence and history. Observations have shown that the Universe appears to be expanding at an accelerating rate.

According to the generally accepted scientific model of the Universe, known as the Big Bang, the Universe expanded from an extremely hot, dense phase called the Planck Epoch, in which all the matter and energy of the observable universe was concentrated. Since then, the Universe has been expanding to its present form, possibly with a brief period (less than 10^{-32} seconds) of cosmic inflation. Recent observations indicate that this expansion is accelerating because of dark energy, and that most of the matter in the Universe may be in a form which cannot be detected by present instruments, called dark matter. It is thought 95% mass of the Universe comes from this dark matter.

There are many competing theories about the ultimate fate of the Universe. Physicists remain unsure about what, if anything, was before the Big Bang. There are various multiverse hypotheses, in which physicists have suggested that the Universe might be one among many universes that likewise exist.

Assessment Points for Teachers

Assessment Points: The Planets

Students should be able to draw and label the 8 planets, the 5 dwarf planets, the Sun and at least one moon per planet. They may not have drawn them to scale or size. The correct order is:

The Sun - Mercury - Venus - Earth - Mars - Jupiter - Saturn - Uranus - Neptune
The dwarf planets are: Pluto, Ceres, Eris, Makemake and Haumea

Largest Moon of each Planet: Mercury and Venus do have moons. **Earth** has the one moon, Luna.
Mars has two moons called Phobos and Diemos.
Jupiter has the largest satellite in the Solar system called Ganymede. The four Galilean moons of Jupiter are Io, Callisto, Ganymede and Europa.
Saturn has 62 moons, the most famous is Titan, which is the second largest moon in the Solar System.
Uranus moons are named after Shakespearean characters and there are 27. The largest one is Titania.
Neptune has 14 moons, the most famous is Triton.

A planet: needs three things to be classified as a planet.

1. It must have enough gravity to pull itself into a ball and become spherical
2. It needs to orbit a star
3. It needs to have cleared its orbit of any other objects around the star

A planet can be rock, gas or even ice! A **dwarf planet** has not cleared its orbit of objects but is spherical and orbits a star.

Your students may also add an asteroid belt between Mars and Jupiter, or the Kuiper Belt after Neptune. The Oort Cloud is the boundary of our Solar System and is where most of the comets in our Solar System are thought to come from. Moons can also be added, one for the Earth, two for Mars, 67 for Jupiter, 62 for Saturn, 27 for Uranus, 14 for Neptune. Pluto may also be added as a dwarf planet. Pluto has 5 moons, one of these moons called Charon is almost as big as Pluto.

Mercury, Venus, Earth and Mars are known as the **inner or rocky planets**, Jupiter, Saturn, Uranus and Neptune are known as the **outer and gas planets.**

Students may also add rings. Jupiter, Saturn, Uranus and Neptune all have rings but Saturn has the most obvious ones. Saturn has nine main rings which are made of icy rocks.

The Solar System: the collection of eight planets and their moons in orbit around the sun, together with smaller bodies in the form of asteroids, meteoroids, and comets.

The Galaxy: a system of millions or billions of stars, together with gas and dust, held together by gravitational attraction.

The Universe: all existing matter and space considered as a whole - the cosmos. The Universe is believed to be at least 10 billion light years in diameter and contains a vast number of galaxies. It has been expanding since its creation in the Big Bang about 13.8 billion years ago.

Students may also draw our galaxy, the Milky Way. It is generally accepted that our galaxy is spiral shaped and flat with many spiral arms. The Solar System is found in the Orion Arm. Students should be able to label the different spiral arms, and the location of the largest black hole. They should be able to label roughly where the Solar System lies.

Assessment Points for Teachers

Can students explain scientific words like 'binary star', 'light year', 'constellation', 'eclipse' and 'satellite' in context?

Binary Star: These stars make up approximately 40% of the stars we see in our sky. A binary star is a star system made up of two stars orbiting a common centre of mass. The brighter star of the pair is known as the 'primary star' whilst the other is known as the 'companion star'. Our nearest binary star system is Alpha Centauri, one of the stars known as the Pointer Stars, which point to the Southern Cross.

A Light Year (l.y.): A light year is how far light travels in one Earth year, approximately 10 million million km! Light travels at 300,000km per second. Our nearest star (after our Sun) is Proxima Centauri, which orbits the binary star Alpha Centauri a and Alpha Centauri b. It lies 4.3 light years. away from us. So this means the light we see from this star left 4.3 years ago.

Constellation: A constellation is a set of stars that form a pattern or shape, like a dot to dot picture. Every culture has their own set of constellations but the scientific community uses the **88- which have become recognised by all.** The most familiar ones would be Orion, Scorpius, Crux and the Signs of the Zodiac. Students should be able to recognise these constellations and know the main star, object or structure in each.

Orion: Three belt stars, Rigel/Puanga, Betelgeuse, the asterism 'the pot', M42 nebula
Crux: Acrux, Gacrux, The Jewel Box
Aries: Hamal
Taurus: The Hyades Cluster, Matariki/Seven Sisters/Pleiades, Aldebaran
Gemini: Castor, Pollux
Cancer: The Beehive Cluster
Leo: Regulus and many Messier galaxies
Virgo: Spica
Libra: Alpha Librae
Scorpius: Antares, Messier 6 (Butterfly Cluster) and Messier 7 (Ptolemy Cluster)
Sagittarius: The asterism the 'teapot', located at the galactic centre of the galaxy
Capricornus: Messier 30
Aquarius: Exo planets Gliese 876, Gliese 849 and Gliese 849b
Pisces: The Vernal Equinox is currently situated in Pisces

Eclipse: An **eclipse** is an astronomical event that occurs when an astronomical object is temporarily obscured, either by passing into the shadow of another body or by having another body pass between it and the viewer.

Satellite: there are two different kinds of satellites, artificial and natural. Artificial satellites are objects which has been placed into **orbit** by human endeavour. The Moon is known as our natural satellite, as it orbits the Earth. The International Space Station and Sputnik are classed as artificial satellites. Satellites are used for a large number of purposes, including uses in civilian and military communication, research and weather predictions.

Assessment Points for Teachers

Can students explain a solar cycle and how it affects the Earth?

The Sun, like all stars, produces energy at the core through nuclear fusion. In this process energy is released through heat and light and is eventually lost from the Sun's surface. This energy (heat and light) is what lights our days, warms our planet, drives our weather and allows life on Earth to exist.

Sunspots have been observed for hundreds of years and have given us interesting insights into the Sun's activity and its long term cycles. Sunspots are cooler regions on the Sun's surface. They appear as dark areas as they are about 2000°C cooler than the normal surface temperature, which is approximately 5500°C. These can range in size from a few thousand to tens of thousands of kms wide.

The Sun is moving towards its current peak of sunspots over the year 2013-2014 after which there will be a gradual decline in the number of sunspots. With the large number of sunspots visible, now is a good time to follow the changing number, position and shape of sunspots on our nearest star.

The increased solar activity around the time of solar maximum sees solar radiation increased by about 0.1% (1.3 watts per square metre). This is a time when solar storms and aurora are particularly prevalent .

Extended solar minima may lead to cold periods and 'mini-ice ages'. The 'Maunder Minimum' dates was a period associated with very cold winters. Period of extended sunspot activity may be linked to increase temperatures and plant growth. Your students could investigate why this is different to the effect of 'global warming' or 'climate change'.

Key Questions:

- What is the name of the nearest star to Earth?
- What is the second nearest star to Earth?
- How long does it take a light to travel from the Sun to Earth?
- How fast does light travel?
- Do all stars have planets? Explain your answer.
- Investigate the five different coloured stars in the Universe. What are they and why?
- Where do stars come from and what happens to them when they die?
- Explain **Habitable Zone** or **Goldilocks Zone** is and why it is important.

Survival on the Moon

The year is 2050. Your spaceship is on route to an unmanned storage depot on the near side of the Moon. It is daytime on the part of the Moon you are travelling over. There are four astronauts on board and your mission is to deliver supplies, including a lunar rover, to the depot and construct a lunar habitation module for a construction crew to live in whilst they construct a bigger base.

About 300km from the depot a meteor hits the space craft and you have to make an emergency landing. The spacecraft is no longer functional and the propulsion system is wrecked.

Fortunately the lunar rover, with its pressurised cabin is undamaged along with 14 other items. There is not enough room for the astronauts and all the undamaged supplies. The Rover will be able to take you to the depot, but the journey will take 24 hours. A rescue craft will meet you at the depot in 48 hours.

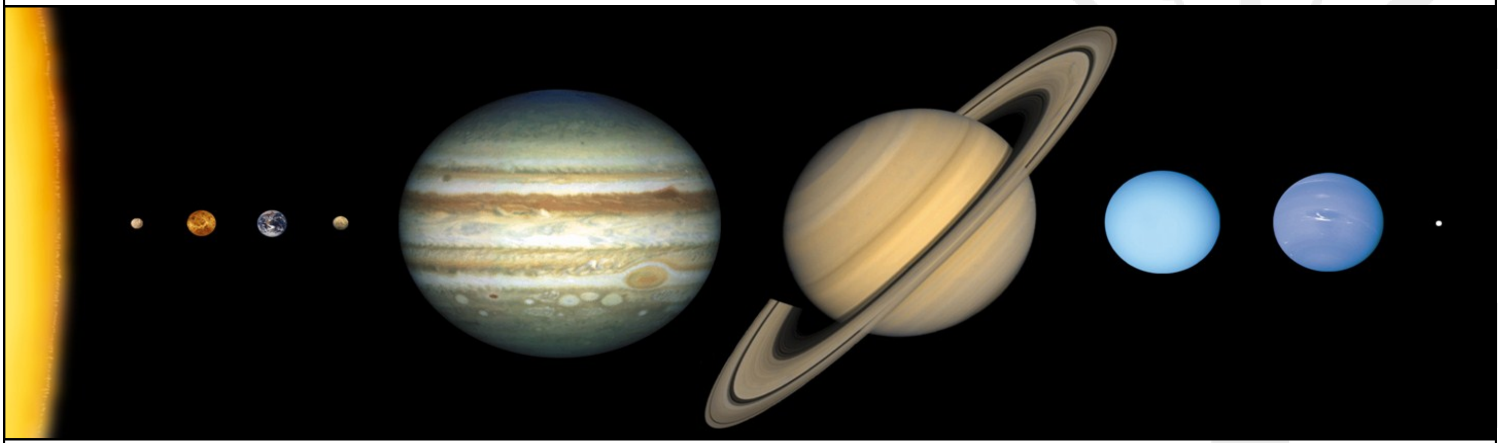
Your team must decide what the most critical supplies to take are and what you will leave behind.

Below is the list of items. List them in order of importance to be taken with you in the lunar rover.

Box of computer parts	Battery powered lunar navigation computer
Food concentrate	Box of spare clothes
50 litres of water	Solar powered heating unit
First aid kit	15 meters nylon rope
2 oxygen recyclers	4 space suits
Signal flares	Two heavy duty batteries
Box of multi-purpose tools	Solar powered radio transmitter/receiver

Make a list of items that you would/would not take and explain why.

Solar System scale model



The Solar System is often portrayed as a line of planets, closely packed to each other. But this picture is misleading! There is a lot of space in space!

Astronomical distances are measured in kilometres and in Astronomical Units (AU). 1 AU is 149,600,000km and is the same distance between the Sun and the Earth.

A light year measures further distances. Light, travelling at 300,000 km/s takes only 8.3 minutes to travel from the Sun to the Earth. Our nearest star after our Sun is 4.3 light years away. 1 l.y. is approximately 10 million million km.

If we scale 1AU to a metre, the Sun could be represented by a ball bearing or 1cm width.

Use the table below to create your Solar System scale model, with a little more accuracy than the diagram above! Create your own Solar System in your classroom, or school corridor!

	Scaled Distance from the Sun	Light Travel Time	Scale model diameter
Mercury	38.7cm	3.2 minutes	0.035mm
Venus	72.3cm	6 minutes	0.087mm
Earth	1m	8.3 minutes	0.092mm
Mars	1.52m	12.6 minutes	0.049mm
Jupiter	5.2m	43.2 minutes	1.026mm
Saturn	9.54m	1hr 19 minutes	0.862mm
Uranus	19.18m	2hrs 11 minutes	0.360mm
Neptune	30.06m	4hrs 11 minutes	0.355mm
Pluto	39.44m	5hrs 31 minutes	0.016mm
Our Moon	1m	8.3 minutes	0.025mm

Go onto your playground and create a moving Solar System with these distances, how long are each planet's orbits/years?

How Can We Navigate by the Sky?

There are many useful stars that sailors would use to help them cross vast oceans. They would recognise the location of where certain stars and constellations would set and rise along the horizon. They would also consider the type of weather and the season they were travelling in, look at particular wildlife species and when they would gather, and the direction, speed and the size of waves.

Investigate the roles of these stars and constellations.

- **Crux and Achernar**
- **Rising of Matariki**
- **Rising and setting of Antares**
- **Rising and setting of Orion's Belt stars**

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Seeing Clearly with Binoculars

A Skills Training Sheet

Binoculars are wonderful instruments to use for star gazing. This skills sheet explains how to set your binoculars up ready to use!

Important: Never look at the Sun through binoculars!

Perform two checks before observing with binoculars:

1. **Are the lenses clean? Skin oils will smudge the lens so keep your fingers off the lens. Use a clean glasses cloth to wipe lenses if necessary.**
2. **Are the binoculars set up for your eyesight? When properly adjusted, you should be able to see objects clearly through binoculars.**

How to adjust your binoculars:

1. **Put the sling around your neck.**
2. **Take off the lens covers and put them in the binocular case for safe keeping.**
3. **Bend the binoculars so they fit comfortably over your nose. You should be able to see objects ahead of you in a circle (0) not like in the movies (00).**
4. **Close your RIGHT eye. Now, use the centre wheel to focus on an object.**
5. **Close your LEFT eye. Turn the wheel on the right lens until you can see the same object CLEARLY.**

With BOTH eyes open, look at the same object. Use the centre wheel to very finely adjust the binoculars so that you can see the object very, very clearly.

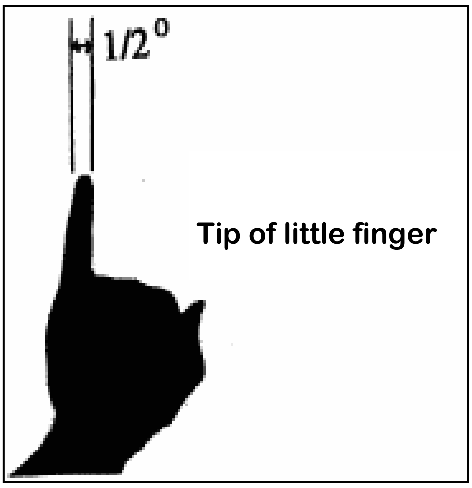
Remember that as you move binoculars from place to place, the distances will change from one object to another. You will need to adjust your binoculars by turning the centre wheel.

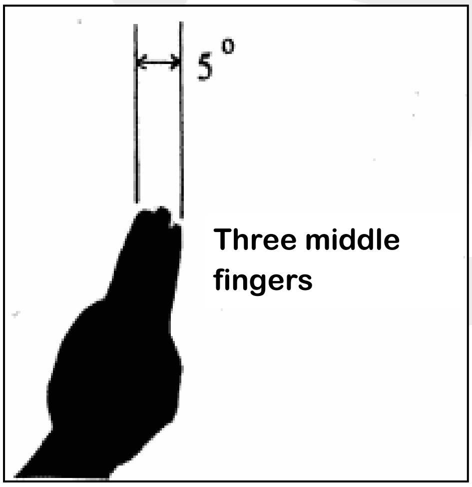
If objects are not clear go back to Step 4.

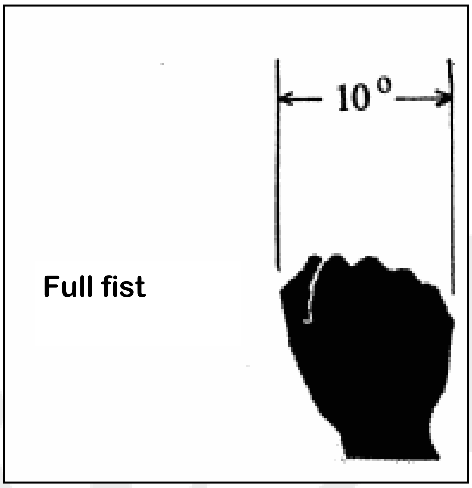
How to Take Astronomical Measurements

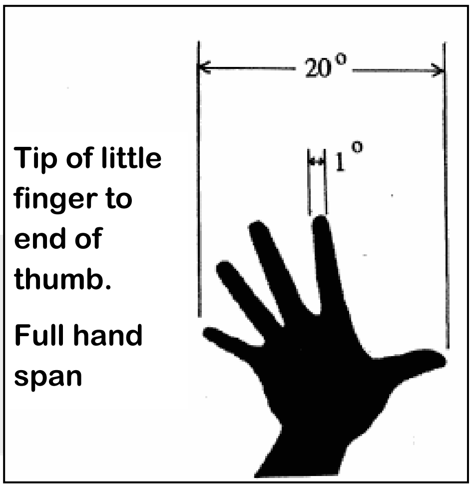
A Skills Training Sheet

Most astronomy books will tell you how many degrees apart objects are. You can use your hands to create these measurements.





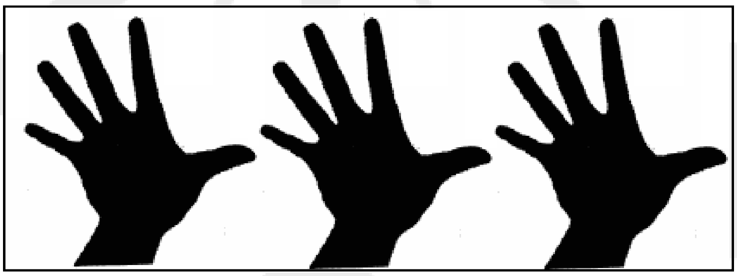




If you are doing this in the daytime, NEVER LOOK DIRECTLY AT THE SUN. To shield your eyes Always hold one hand to cover the Sun or stand in the shadow of a building so that the Sun is barely hidden.

Tips for successful measuring:

- Keep your arms out straight
- Hold one fist/ finger/ hand span so the widest part sits on the horizon or initial object
- Move your fist/ finger/ hand towards the second object one 'width' at a time counting as you go. Example: Three hands spans would be 60°



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How do we Measure the Brightness of Stars and Planets?

The measure of the brightness of objects in the sky is called *magnitude*. In the 2nd Century BC Hipparcus classified the stars into 6 magnitudes (brightness). First magnitude being the brightest going down to sixth magnitude, which is the faintest visible to the unaided eye. The simplest way to remember this is to think of awards -1st prize is the best whereas 6th prize is hardly noticeable!

In the 19th Century it was found that a star of the first magnitude was about 100 times fainter than one of sixth magnitude. That is, it would take 100 stars of sixth magnitude to be as bright as first magnitude star.

It was then decided to adopt a precise mathematical scale of magnitude in which the ratio is exactly 100:1.

The brightest star that we can see is our Sun at magnitude -27. Sirius, the next brightest is -1.6, the faintest stars observed through the largest telescopes are at +25. Planets are often brighter than Sirius.

Name of Star	Magnitude = Apparent Brightness	Distance from Earth	Absolute Magnitude = True Bright-ness	Luminosity Sun = 1
Sun	-26.7	150m Km	5	1
Sirius	-1.4	8.8 l.y.	0.7	16
Canopus	-0.7	110 l.y.	3.3	2100
Alpha Centauri	-0.3	4.3 l.y.	4.6	1.4
Arcturus	-0.06	40 l.y.	-0.3	130
Vega	0	26 l.y.	0.3	76
Rigel	+ 0.1	773 l.y.	-7	6300
Capella	+ 0.1	42 l.y.	0.37	71
Procyon	+ 0.3	11.4 l.y.	2.8	8
Achernar	+ 0.5	70 l.y.	-1.3	330
Beta Centauri	+ 0.6	525 l.y.	-4.3	5200
Betelgeuse	+ 0.7	650 l.y.	-5.5	16000
Aldeberan	+ 0.8	65 l.y.	-0.2	120
Altair	+ 0.8	168 l.y.	2.1	15
Acrux	+ 0.9	280 l.y.	-3.8	3300
Antares	+ 1	604 l.y.	-4.5	6300
Spica	+ 1	200 l.y.	-3.2	1900
Fomalhaut	+ 1.2	24 l.y.	-1.8	20
Pollux	+ 1.2	32 l.y.	0.7	53
Beta Cruxis	+ 1.3	353 l.y.	-4	4000
Deneb	+ 1.3	1500 l.y.	-7	6300

Investigations

Q: Explain if there is there a correlation between the brighter stars and the distance they are from Earth.

Q: How does the absolute magnitude of stars compare to their apparent magnitude?

Q: Can you work out what type of star these are just by looking at their luminosity?

Cross Curricular Ideas

- **Students create a press release or newspaper article announcing the radio communication from an alien civilization.**
- **Ask your students if we could count all the stars in the night sky. How do astronomers come up with a number of how many stars there are? Experiment with how many stars can be seen through a toilet roll tube at any one time in the night sky and estimate how many stars you can see in the entire night sky.**
- **Do constellations look the same from every point in space? Experiment using the Southern Cross. Create a 3D Southern Cross hanging form your classroom ceiling to show that these stars do not form a cross, but it is just how we see them.**
- **Astronomers believe there are approximately 400 billion stars in the Milky Way. But how long would it take to count them all? How long would it take to count to one billion?**
- **If we can't travel to a star, how do we know what it is made out of? Use light spectra of known elements to investigate an imaginary planet.**
- **Invent an alien. Think about what the e planet would be like and the adaptions that aliens would need to make to live on that planet. Where on the planet would the aliens live? What would the aliens eat?**
- **Create a 'random alien substance' (like cornflour, water and food dye) and ask students to investigate this alien substance. What information can they get from it?**
- **Create a lander to land on this random alien substance. What would the lander need? How can you stop it from sinking / getting stuck and how will it leave again? Create a design and make your lander.**
- **Investigate how much a can of beans would weigh on another planet.**
- **Create a human sundial. Use this to predict the time using the movement of the Sun across the sky.**
- **Can students determine the diameter of the moon without travelling to it?**
- **What is a birthday? How long does it take the different planets to go around the Sun? Investigate whether your birthday would be the same length on different planets.**