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**2018** HIGHER SCHOOL CERTIFICATE COURSE MATERIALS

# Year 9 Headstart Science

## The Dynamic Earth

## Term 1 – Week 2

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Class day and time ……………………………………………

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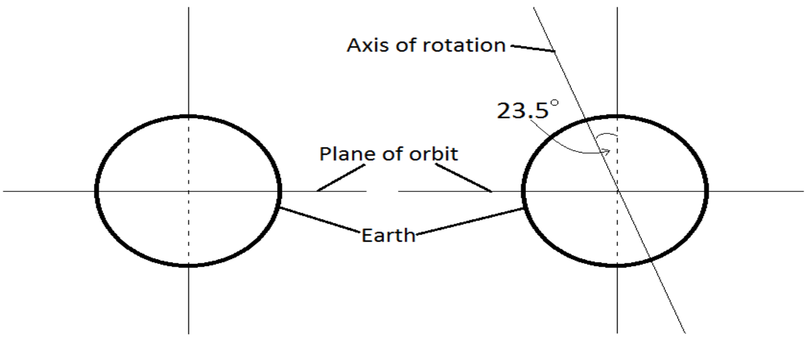
# Term 1 – Week 2 – Theory

## NEWTONIAN MODEL OF THE SOLAR SYSTEM CONTINUED

### AXES OF ROTATION

What makes the behaviour of the Solar System even more interesting is that none of the planets are actually aligned straight up-and-down. Each planet is tilted a precise amount away from the vertical, and rotates around this axis. An **axis** is defined as an imaginary straight line through a planet or a moon about which the object rotates, and all the planets rotate as they orbit the Sun. The amount that a planet's axis of rotation is shifted from a vertical line (perpendicular to the orbit path) is called the **rotational tilt** or **axial tilt**.

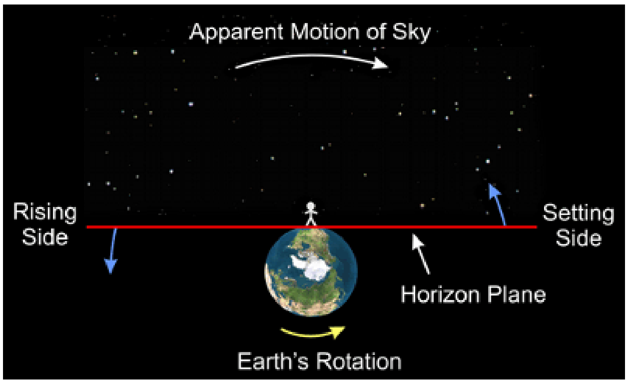
In the Earth's case, this is equal to 23.5°. Other planets are shifted by different amounts – Venus actually rotates "backwards", with its North Pole facing downwards (axial tilt of 177°), whilst Uranus rotates on its side (axial tilt of 97°.)




### NIGHT AND DAY

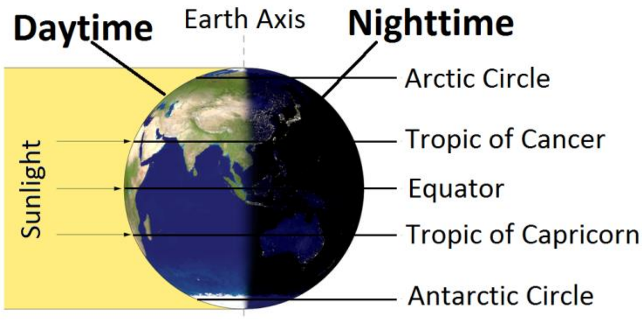
The relative movements of the Earth, the Sun and the Moon through the Solar System are important in explaining events on Earth that we see every day. Did you ever wonder why the sunrise in Sydney happens before the sunrise in Perth? How about just why the Sun rises and sets?

The Sun rises in the east every morning, and sets in the west every evening. Whilst it may seem that it is moving across the sky throughout the day, it is in fact stationary. It is the Earth that is moving instead, through the rotation on its axis, creating the phenomena of night and day.




The Earth spins on this axis once every 24 hours. This period is known as one day. Jupiter, by contrast, rotates much faster, meaning that a day on Jupiter takes only ten hours. Venus is much slower – a day on Venus is equivalent to 243 Earth days.

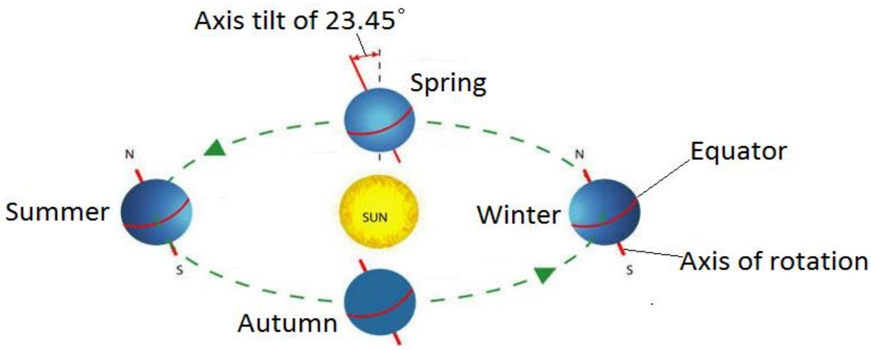
The direction of Earth's rotation, counterclockwise, is also important. It rotates towards the East, resulting in eastern areas receiving sunlight before western areas. This is why the Sun rises in the east, and sets in the west.




## SEASONS OF THE YEAR

As well as rotating on its own axis, the Earth orbits the Sun in an elliptical path, as discussed last week. Because of the rotational tilt (~23.5°), different areas of the Earth experience more or less sunlight at different periods of the year. One orientation receives the maximum possible sunlight, one has the least possible, and there are two intermediate phases. For the Southern hemisphere, the maximum stage occurs in December-January, the minimum from June to August, and the two moderate stages from February to May, and from August to November.

We know these periods better as the seasons – Summer, Winter, Autumn and Spring.




The hemisphere that is more tilted towards the Sun at any time is hit more directly by the rays. These have a smaller area to spread out over as well, meaning that the sunlight is more concentrated, combining to produce greater amounts of heating – i.e. summer. By contrast, the hemisphere that is pointed away has fewer rays hitting it, and these then are spread out over a larger area. This results in less efficient heating, causing winter. When neither hemisphere is entirely tilted towards the Sun, the rays are split relatively equally, meaning that there's not much difference in the amount of heat generated. This is why some stages of autumn can feel similar to spring, and vice versa.

At any given time during the year, there is always a part of the planet that is directly exposed to the rays of the Sun. This exposure alternates as the Earth orbits the Sun, meaning that regardless of the Earth's position, the Sun's position or the season itself, the Northern and Southern Hemispheres always experience opposite seasons – summer vs. winter, and spring vs. autumn.

The changing seasons and the changing amounts of sunlight that they result in directly affect the wildlife of the Earth. As an area moves into Autumn and Winter, and the amount of sun exposure decreases, cycles of dormancy and hibernation are triggered in both plants and animals; for instance, deciduous trees and bears respectively.

# THE OBSERVED SKY

## STARS, MOONS AND PLANETS

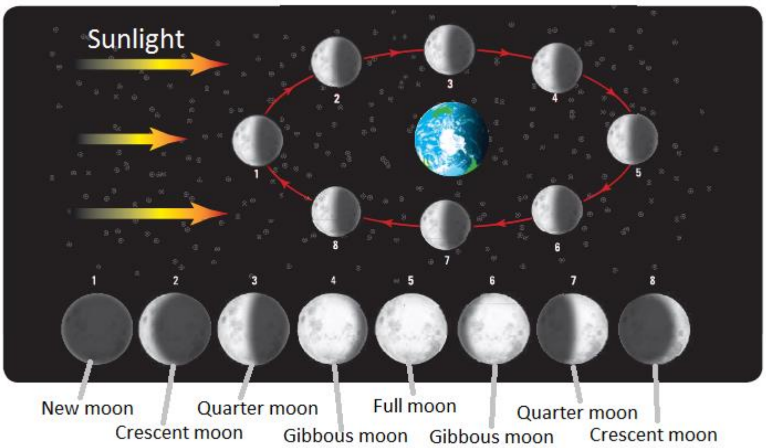
Humans have been observing the night sky for at least the last four thousand years. Ancient astronomers noticed the circular movement of the stars, as well as five other bright celestial objects. These were the planets Mercury, Venus, Mars, Jupiter and Saturn – the only planets visible to the naked eye from Earth.

At night-time, the Moon is easily the largest and brightest object in the sky. Even though the Moon is absolutely tiny compared to virtually all the stars in the Universe, we see it as the largest object because it is by far the closest. As discussed last week, the closest star, other than the Sun, is Alpha Centauri A, 4.27 light years away. By contrast, the Moon is about one light second from Earth, and this leads to its domineering presence in the night sky.

We actually only ever see one side of the Moon. It takes roughly the same time for the moon to rotate on its own axis as it does for it to orbit the Earth. Because of this, we can only ever see one face of the moon – 41 percent of it is never visible from Earth.

But how is the Moon so bright, especially when it has no light source itself? The Moon does not give off any light, yet we see it in the black night sky. The moon can be seen from Earth only because it reflects the light from the sun. At night, when we are in darkness, the visible face of the moon is sometimes completely bathed in sunlight, and we see a full moon in the sky. When the moon is between the Sun and the Earth, its near side, the side that we see, is facing away from the Sun and is therefore in complete darkness.

We then see a new moon; basically, no moon in the sky. When the near side is partly bathed in sunlight, and partly in darkness, we see a crescent moon in the sky, because we can only see the parts that are in light. The different shapes of the moon that can be seen from Earth are called the **phases of the moon.** The length of time between two full moons is called a **lunar month**.



## COMETS AND ECLIPSES

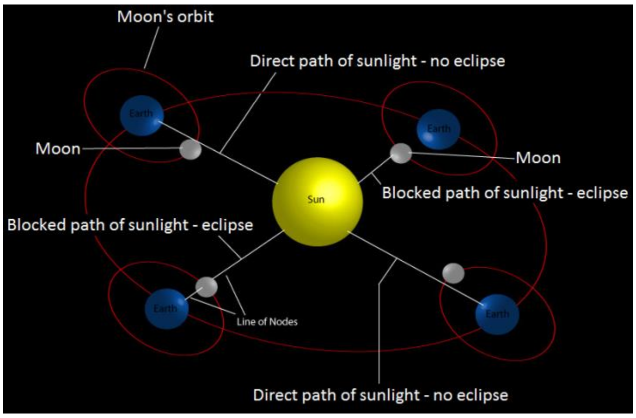
A **comet** is a large mass of metallic and rocky particles clumped together amongst ice and frozen gases. The majority of the comet, by weight, is located in its 'nucleus', but what we see in the sky is more usually the tail of the comet. A glowing, bright stream of gas and dust billows behind the comet as it hurtles through space, becoming larger and larger as the comet moves closer to the Sun, allowing us to see it. Whilst the nucleus or centre of the comet may only be the size of an asteroid, the tail can be up to millions of kilometres long, stretching far back into space. It eventually gets blown away by bursts of particles and energy from the Sun called **solar wind**.

On Earth, it's pretty obvious that any solid object casts a shadow. The same happens in space – in particular, the Earth and the Moon both cast shadows, and when these fall on other objects, some incredibly phenomena occur.

When the moon passes between the Sun and the Earth, the moon's shadow falls on the Earth. Because the Moon is much smaller in volume than the Earth, the shadow only covers a small region of the globe. This is called a **solar eclipse**, and happens approximately once every two years.

The shadow of the moon is not constant and not very sharp either, with most of the shadow being only partly dark. Usually, the whole shadow passed either above or below the Earth – on the rare occasion that the dark centre of the shadow hits the Earth, it is known as a **total solar eclipse.**

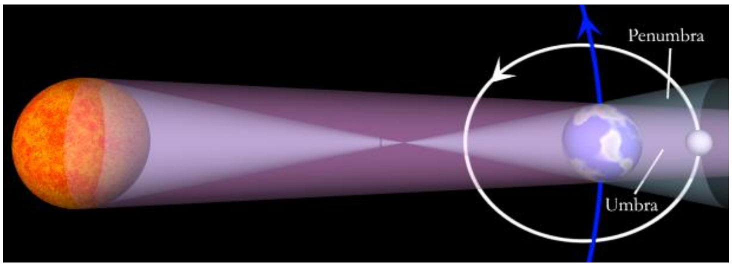
During an eclipse, the Sun and the Moon appear to be roughly the same size, allowing the Moon to "blot" out the entirety of the Sun.




This is because whilst the Sun is about four hundred times larger than the Moon, the Moon is around four hundred times closer than the Sun.

Just as the Moon can cast a shadow on the Earth, the Earth can cast a shadow on the Moon – this is called a **lunar eclipse**.

This can only happen during a full moon, when the Earth lies directly between the Sun and the Moon. Lunar eclipses occur far more often than solar eclipses, but because the Moon's orbit around the Earth is not flat, it doesn't occur every time there is a full moon.



# HISTORICAL DEVELOPMENT OF THE SOLAR SYSTEM MODEL

Whilst early astronomers used the stars as navigational guides, or used observations of their movements and mathematical knowledge to create calendars, for a large period of history, the model of the Solar System was ultimately wrong. The incorrect model, generally accepted for an incredible 1500 years, is usually named Ptolemy's Model of the Universe.

## PTOLEMY

The Greek astronomer Ptolemy proposed in around 150 A.D. that whilst the universe was the entirety of space and existence, the Earth existed at the centre of it, and everything else orbited around the Earth. The Earth was designated to be stationary, surrounded on all sides by something Ptolemy labeled the 'celestial sphere', essentially a giant canvas to which all the stars were attached. The celestial sphere rotated around the Earth, causing the stars to orbit the Earth, as well as the moons and planets which were already apparently doing so.

## COPERNICUS

It took until 1473, almost a millennium and a half later, for someone to stand up and challenge Ptolemy's ideas – Nicolaus Copernicus, a Polish mathematician and keen astronomer. The main problem he spotted in Ptolemy's model was that whilst it explained the orbits of the stars quite well, it didn't really explain the movements of the planets across the sky. Copernicus could see only one solution to this problem – the Sun couldn't orbit around the Earth, the Earth must orbit the Sun! This would explain how the planets moved across the sky perfectly, but what about the stars? Rather than sticking with Ptolemy's 'celestial sphere' theory, Copernicus realised that if the Earth rotated on its axis at the same time as orbiting the Sun, this revolution would result in the movement of the stars across the sky. Copernicus published his findings supported by rigorous mathematics, but died on the day that his book was released – after his death, the book was banned by the Church because his theories disputed the teachings of religion at the time and were therefore viewed as morally wrong. According to the Church, the Earth had to be the centre of the universe, and so Copernicus was doomed to be forgotten for another sixty years.

## KEPLER

Interestingly, not everyone associated with the Church agreed with their view on the Universe. Johannes Kepler, a deeply religious Dutch astronomer, supported the Copernican model of the Universe and set out to derive equations that would support his theories. He applied mathematics to observations of Copernicus and other earlier astronomers, and developed laws that describe the Solar System that we still use today. Kepler was the first astronomer to suggest that orbits were not circular – rather, orbits were elliptical, as discussed last week. His theories have stood up to centuries of rigorous testing with far more advanced equipment, and as such, are regarded as permanent laws governing the universe. In general, Kepler's three laws stated that planets orbit in elliptical patterns, the speed of an orbiting planet depends on its position in the orbit, and his third law described how more distant planets took longer to orbit the Sun.

## GALILEO

However, Copernicus would have the last laugh - sixty years later after his death, a brilliant scientist would come along and prove him correct! Galileo Galilei, after hearing about the invention of the telescope, quickly designed his own and pointed it at the sky, in particular, at Jupiter. In 1610, he discovered four of Jupiter's moons – Io, Europa, Ganymede and Callisto. Galileo also noticed that the moons orbited Jupiter, proving for the first time that not all objects in space orbit the Earth. Despite strong censorship, threats and direct orders from the Church, Galileo supported the theories of Copernicus publicly, declaring that the Earth orbited the Sun, and not the other way around. Under threat of torture the following year courtesy of the Church, Galileo denied his beliefs in public, and switched his allegiance back to the Church/Ptolemy model of the Universe. His book was banned in a similar fashion to Copernicus', and he was sentenced to life imprisonment. On an interesting side note, it appears that all the punishments and threats in the world could not silence Galileo – there are rumours of a secret third publication, spreading the truth of his theories, as well as his famous quote just before his trial; *"Eppur si muove"*– "and yet it moves."

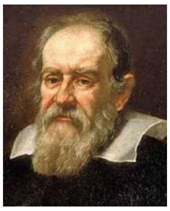
## NEWTON

The Church could not silence the accuracy and truth of the Copernican model forever. Shortly after the death of Galileo Galilei, the observations of other astronomers using rapidly improving telescopes began to confirm more and more that the Church and Ptolemy were actually incorrect. Sir Isaac Newton, the British scientist, confirmed in the mid-1680s that the Sun was undoubtedly at the centre of our Solar System. Of the notable scientists discussed above, Newton would probably have been the most encouraged, finally managing to convince the scientific community, and almost the world itself that the Earth was neither the centre of the Universe, nor the centre of the Solar System. Indeed, the Earth was not a centre for anything but our very own Moon.

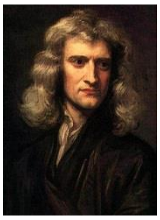
**Ptolemy**

**Copernicus**

**Kepler**



**Galileo**



**Newton**

# Term 1 – Week 2 – Homework

1. Define axial tilt, and identify its value for Earth. **[2 marks]**

2. Describe Copernicus' model of the Universe. **[3 marks]**

3. Discuss the reasons why Ptolemy's model of the Universe was accepted for so long. **[3 marks]**

4. Identify the invention that allowed Galileo to discover the first solid evidence for the Copernican model of the Universe. **[1 mark]**

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5. Account for only one side of the Moon being visible from Earth. **[3 marks]**

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6. Explain why stars are not visible during the day. **[2 marks]**

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7. Identify what is in shadow during a lunar eclipse, and what casts the shadow. **[1 mark]**

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8. Describe a main reason that there is not a lunar eclipse every time there is a full moon. **[2 marks]**

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9. Construct a labeled diagram to explain how a quarter-moon occurs. **[4 marks]**

10. Explain how a day on Venus can be 243 Earth days long. **[2 marks]**

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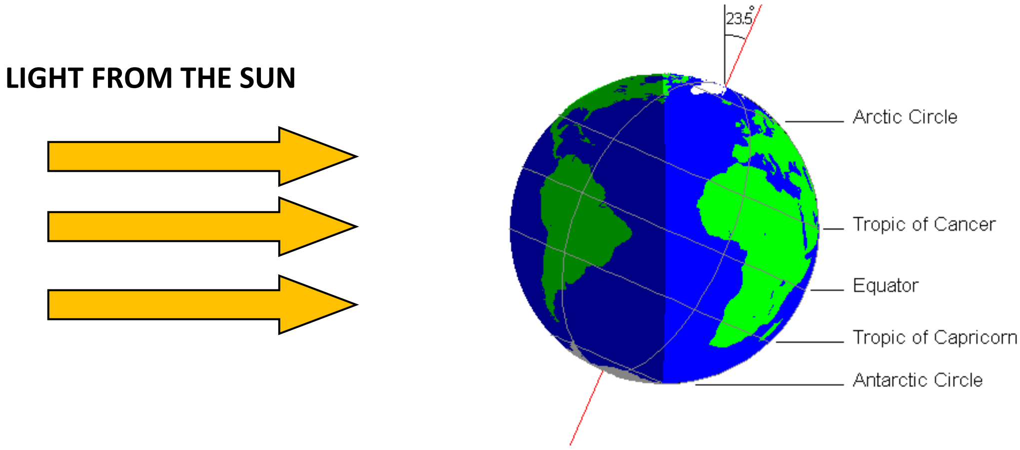
11. Identify what comets are made of. **[2 marks]**

12. Identify the season that Australia would be experiencing in the image below, and explain your reasoning. **[3 marks]**



13. Identify the major flaw that Copernicus found in Ptolemy's model of the universe. **[1 mark]**

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14. Describe the changes that Kepler proposed to the Copernican model of the Universe. **[2 marks]**

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15. Explain how the Moon can appear to block out the Sun during a solar eclipse, despite the fact that it is much smaller. **[2 marks]**

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16. A student once stated:

    *"From the Moon, you wouldn't be able to see the Earth, because it doesn't give off any light, unlike the Sun."*

    Evaluate the accuracy of this statement, including an alternative explanation if you need to. **[5 marks]**

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**End of homework**