

3. The Earth-Moon-Sun System (3.5-3.10)

Edexcel GCSE Astronomy Course

3.5 Understand the relative effects of the Sun and Moon in producing high and low, spring and neap tides

- **Tides** - just watch, this is an incredible show of nature that reminds us of our place in space and the effects of gravity due to the Moon and the Sun: <https://www.youtube.com/watch?v=yQnpWyXMyL8>

This clip, from the Bay of Fundy in Nova Scotia, shows that the tides are not the same everywhere on Earth. In some places the tidal signal is much weaker, but in places like the Bay of Fundy, the Bristol Channel and the Bay of St.Malo, it is amplified by geographical effects, like the funnel shape of the Bristol Channel facing the open Atlantic Ocean. However, the basic mechanism causing the tides and their variation every fortnight from spring to neap tides is the same everywhere.

- The first thing you need to be able to explain is what causes tides and why there are two tidal bulges associated with the Moon and two associated with the Sun. Put simply:
 - The bulge on the side of Earth facing towards the Moon is due to its gravitational pull
 - The bulge on the side of Earth facing away from the Moon is due to the Earth accelerating in a circle around the centre of mass of the Earth-Moon system (like on a rollercoaster plunging downwards and leaving you behind - the Earth constantly changes direction around the centre of mass, leaving the ocean behind and causing a bulge outwards)
- Diagrams and videos on the next slide may help to explain this more clearly

Explaining the tides:

- The centre of mass of a system of two objects orbiting each other is called its **barycenter** - remember that the force of gravity causes a *mutual* attraction between two bodies - the Moon does not orbit the Earth, they both orbit the barycentre. This clip is an excellent illustration of the effect for Pluto and its moon Charon - you can see how Pluto appears to wobble:

https://en.wikipedia.org/wiki/Barycenter#/media/File:Barycentric_view_of_Pluto_and_Charon_29_May-3_June_by_Ralph_in_near-true_colours.gif

Here's a summary of ideas you need to be able to explain:

- What are tides? https://oceanservice.noaa.gov/education/tutorial_tides/tides01_intro.html
- Why do gravitational force and inertia cause two bulges?
https://oceanservice.noaa.gov/education/tutorial_tides/tides03_gravity.html
- What causes spring and neap tides?
https://oceanservice.noaa.gov/education/tutorial_tides/tides06_variations.html
- **Task** - read these pages and write notes to answer each of the questions.

3.6 Understand how the gradual precession of the Earth's axis affects the appearance of the Sun, Moon and stars, when observed from Earth, and its use in archaeoastronomy

- Precession is an effect that is seen in any object that rotates around an axis, like a spinning top, a gyroscope or a planet - you could try a simple experiment yourself if you have a fidget spinner
<https://www.youtube.com/watch?v=OXnE4erFLLI>
- Precession of the Earth's axis of rotation will change the appearance of the night sky from a particular place on Earth over the time period of the precession. Two important consequences of this are:
 - Polaris is only the pole star by accident. 1000 years ago or 1000 years in the future the Earth's axis points to a different place in space
 - The First Point of Aries, used to define the zero of right ascension in the celestial coordinate system, no longer coincides with the point where the Sun crosses the equator at the spring equinox as it did a few hundred years ago
- Task 1 - look up, write down and learn a definition of precession and be able to describe some of its consequences
- Task 2 - watch this video demonstrating precession
<https://www.youtube.com/watch?v=0qHjtp4cdCA> |
- Task 3 - experiment in Stellarium. Set the view with Polaris at centre and set the date to 2000 years ago or 2000 years in the future. Polaris will no longer be at the centre of rotation.

Archaeoastronomy

Archaeoastronomy links the study of archaeology with astronomy and can help in understanding how ancient people built structures like Stonehenge and Mayan temples to line up with astronomical events. This might have been for mystical reasons or for practical ones such as defining points in a calendar. How would *you* know what time of year it was without a paper or online calendar or someone to tell you?

Archaeoastronomy can get trickier because of precession - the night sky would have looked different at a given location thousands of years ago because the Earth's axis would be pointing in a slightly different direction. Archaeoastronomers have to take these changes into account when trying to understand the alignments of ancient structures as they may no longer be pointing at the same object or event in the sky.

If you are interested in the field of archaeoastronomy here are some links to help you find out more:

- Examples of alignments: <https://www3.astronomicalheritage.net/index.php/show-theme?idtheme=7>
- A detailed introduction to the subject:
http://www.bajr.org/BAJRGuides/43_Archaeo-Astronomy/43_ArchaeAstronomy.pdf
- Or find a MOOC on this subject <https://www.mooc-list.com/>

3.7 Be able to use data relating to the rate of precession of the Earth's axis

Edexcel Astronomy Past Paper Example - try to answer these questions, then check the mark scheme at the end of this presentation

Many ancient monuments were aligned with the rising and setting of the Sun and the Moon.

An ancient monument was built so that a star in constellation X aligned with two of the stones during the solstice, as shown in the figure.

- (i) These two stones are currently 35.4° from the star in constellation X.

Explain why precession would cause a star in constellation X to no longer be aligned with the stones during the solstice. (2)

- (ii) The average rate of precession is 1.38° per century.

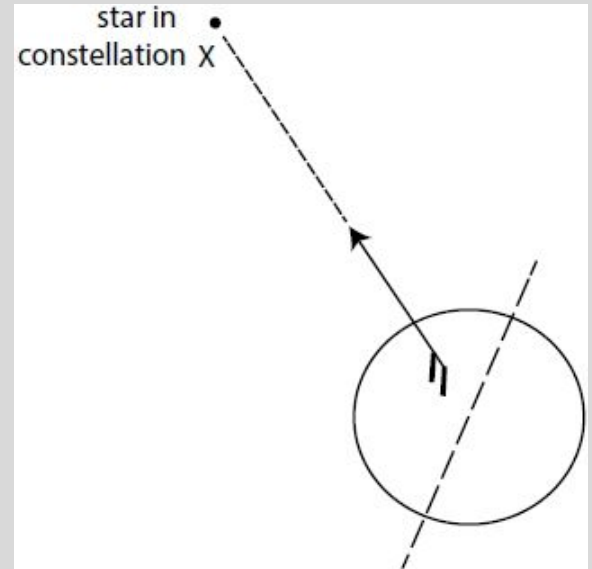
Calculate an approximate date for the building of this ancient monument.
date (2)

- (iii) Today, Polaris is the pole star.

In the past, it was Thuban.

In the future, it will be Alderamin.

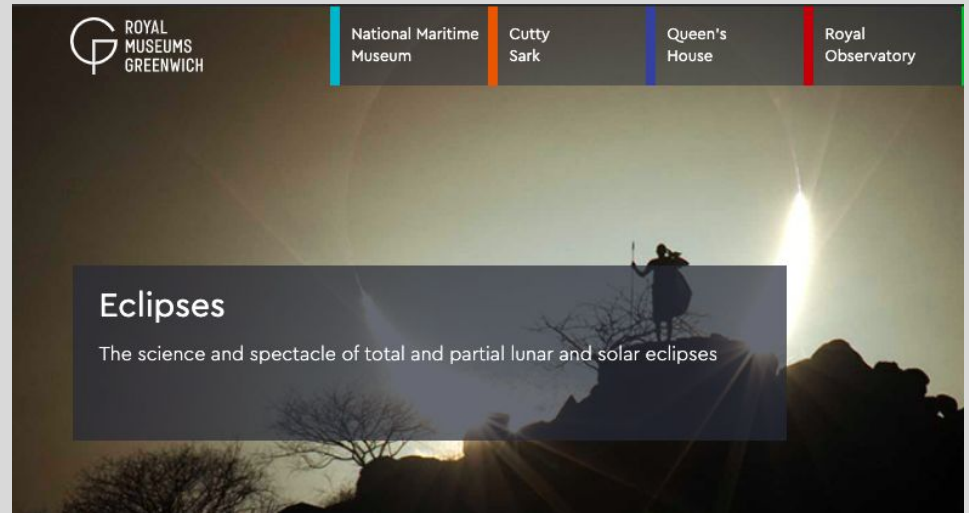
Explain why precession causes variation in pole stars. (3)



3.10 Understand the causes of solar and lunar eclipses

Many good resources are available explaining eclipses - you can't go wrong with this one from the Royal Greenwich Observatory:

<https://www.rmg.co.uk/explore/eclipses>



3.8 Understand the appearance of the Sun during partial, total and annular solar eclipses, including the terms first, second, third and fourth umbral contact

This site gives all the details of solar eclipses and the different types - partial, total and annular. Use it to find the definition of each and write these in your notes:

<https://nineplanets.org/solar-eclipse/>

This site gives good definitions of the four points of umbral contact - write a definition for each of these in your notes:

<https://www.space.fm/astronomy/earthmoonsun/solareclipse.html>

3.9 Understand the appearance of the Moon during partial and total lunar eclipses, including the terms first, second, third and fourth umbral contact

This site gives all the details of lunar eclipses and the different types - partial and total. Use it to find the definition of each and write these in your notes:

<https://solarsystem.nasa.gov/moons/earths-moon/lunar-phases-and-eclipses/>

This site gives good definitions of the four points of umbral contact - write a definition for each of these in your notes:

<https://www.space.fm/astronomy/earthmoonsun/lunareclipse.html>

Precession Past Paper Question Mark Scheme

Question number	Answer	Mark	
(i)	<p>An explanation that combines identification – application of knowledge (1 mark) and reasoning/justification – application of understanding (1 mark):</p> <p>Direction of the axial tilt has shifted since the building of the monument (1) so the star in constellation X would be located at a different place in the sky during the solstice now (1)</p>	(2)	
Question number	Answer	Additional guidance	Mark
(ii)	<p>$35.4 \div 1.38 =$ 25.7 centuries (2570 y) (1)</p> <p>554 BCE (1)</p>	<p>Award full marks for correct numerical answer without working</p> <p>Accept: BC Accept answers in the range of 560 BCE to 484 BCE</p>	(2)
Question number	Answer	Mark	
(iii)	<p>An explanation that combines identification – understanding (1 mark) and reasoning/justification – understanding (2 marks):</p> <p>The Earth's axis points to the pole star (Polaris) rather than the pole of the ecliptic which stays fixed (1) which means that precession causes the Earth's axis to describe a circle round the pole of the ecliptic every 26 000 years (1) and so the Earth's axis will point to different stars (e.g. Thuban/Alderamin) on the circle at different times (1).</p>	(3)	