4. Time and the Earth Moon Sun Cycles (Part 1 - Equation of Time)

Edexcel GCSE Astronomy Course
(Taught Concepts Only Sept 2020)

4.1 Understand the difference between sidereal and synodic (solar) days
4.10 Understand the difference between sidereal and synodic (solar) months
4.14 Understand the relationship between sidereal and synodic (solar) time

Anything **sidereal** (pronounced sigh dee real) is measured relative to the background pattern of stars or to the celestial grid, so a sidereal period or motion always starts and ends at the same point in space.

Anything **synodic** (pronounced sin odd ick) is measured relative to the position of another body, often the Sun, so a synodic period or motion may start and end in a different place in space.

A sidereal day is approximately 23 h 56 min 4.0905 s and is the time it takes for the Earth to spin once on its axis.

A solar or synodic day starts and ends when the Sun is at the same position relative to the observer on Earth and so is about 4mins longer than a sidereal day. This is because the Earth moved on a short distance in its orbit in the 24 hours it was spinning so the viewing angle to the Sun is slightly different and it takes 4mins more to get back to the same angle. https://www.space.fm/astronomy/earthmoonsun/day.html

A sidereal month is 27.3 days whereas a synodic month is 29.5 days.

A sidereal year is 365 days 6 hours 9 minutes 10 seconds so every four years there is a leap year to adjust for this.

4.2 Understand the role of the Sun in determining Apparent Solar Time (AST)
4.3 Understand the role of the Mean Sun in determining Mean Solar Time (MST) and Local Mean Time (LMT)

Apparent Solar Time (AST) is simply the time according to the position of the Sun in the sky. It will be different for observers at different places so not very convenient when people a long distance apart need to use the same time - for instance people in Penzance, at 5.5^0 West, would be about 20 mins late for a video conference with people in Greenwich if they agreed on local noon as a meeting time!

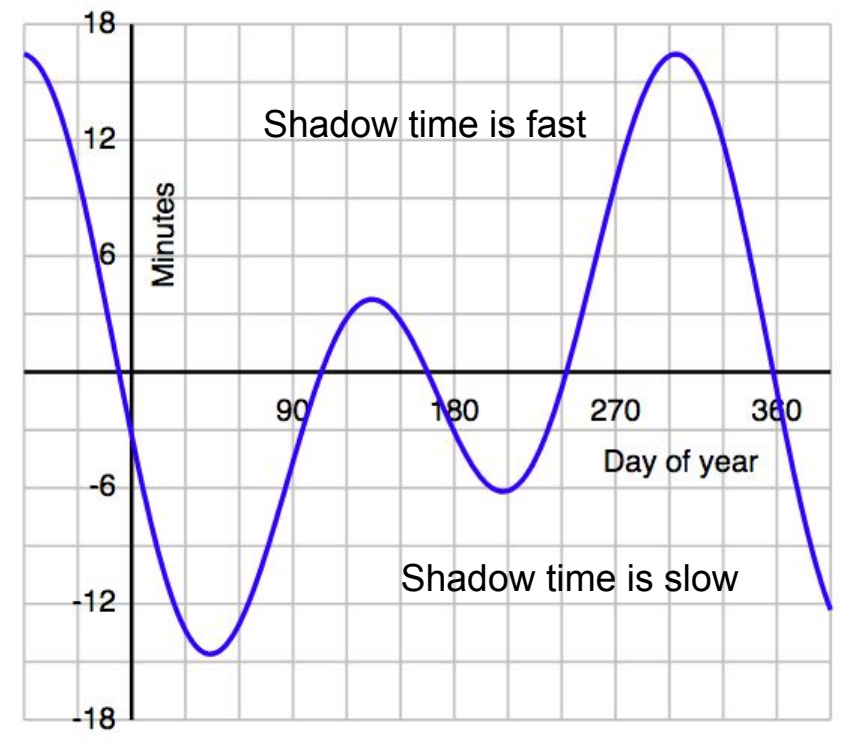
We use **Mean Solar Time (MST)** to correct for this and make sure that everyone uses the same reference system for clock time - only at Greenwich will AST and MST be the same.

Local Mean Time (LMT) is the AST corrected for variations in the rate of movement of the Sun across the sky during the year

https://www.space.fm/astronomy/earthmoonsun/apparentmeansun.html

4.4 Be able to use the

Equation of Time = Apparent Solar Time (AST) − Mean Solar Time (MST)



This graph plots out a correction to AST known as the Equation of Time (EOT).

The correction is shown in minutes on the vertical axis for each day of the year plotted on the horizontal axis.

The time from a shadow stick or sundial is AST so to get MST, or clock time, the EOT must be subtracted from the AST.

Why the correction is needed - for those that want more detail!

The shape of the EOT curve is a result of ‘superposition’ of two sine curves:

1) One of period half a year **due to the tilt of the Earth’s axis** - near the equinoxes the Sun’s apparent motion (from Earth) has more vertical component (in declination) than horizontal (in RA) and therefore moves relatively slower than the mean; near the solstices the apparent motion is more horizontal (in RA) increasing the rate of motion along the celestial equator and appearing faster than the mean Sun - hence the semi-annual period.
2) The **eccentricity of the orbit** adds an annual component - the interference pattern of both curves gives the EOT

Extra References on EOT:

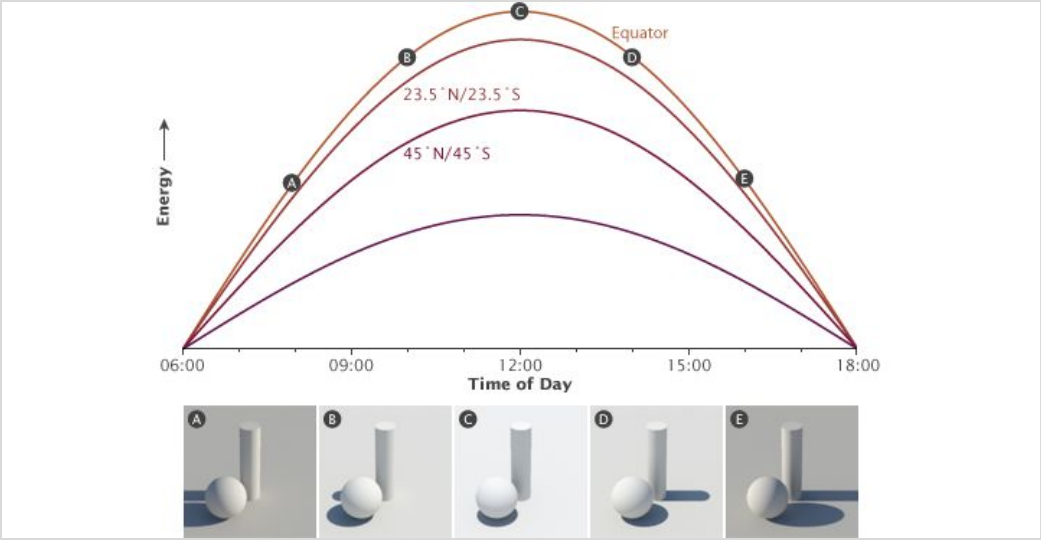
https://www.youtube.com/watch?v=rRHhO7Wj4Ik&ab_channel=ScienceOnline

https://en.wikipedia.org/wiki/Equation_of_time#:~:text=The%20equation%20of%20time%20describes,of%20%22reconcile%20a%20difference%22.&text=Apparent%20solar%20time%20can%20be,limited%20accuracy

See past paper questions on how to apply the knowledge of EOT to problems set in exam questions.

4.7 Understand how to determine the time of local noon using shadows, including use of a shadow stick

Watch this:
https://www.pbslearningmedia.org/resource/buac18-k2-sci-ess-sunposition/changing-position-of-the-sun-in-the-sky/



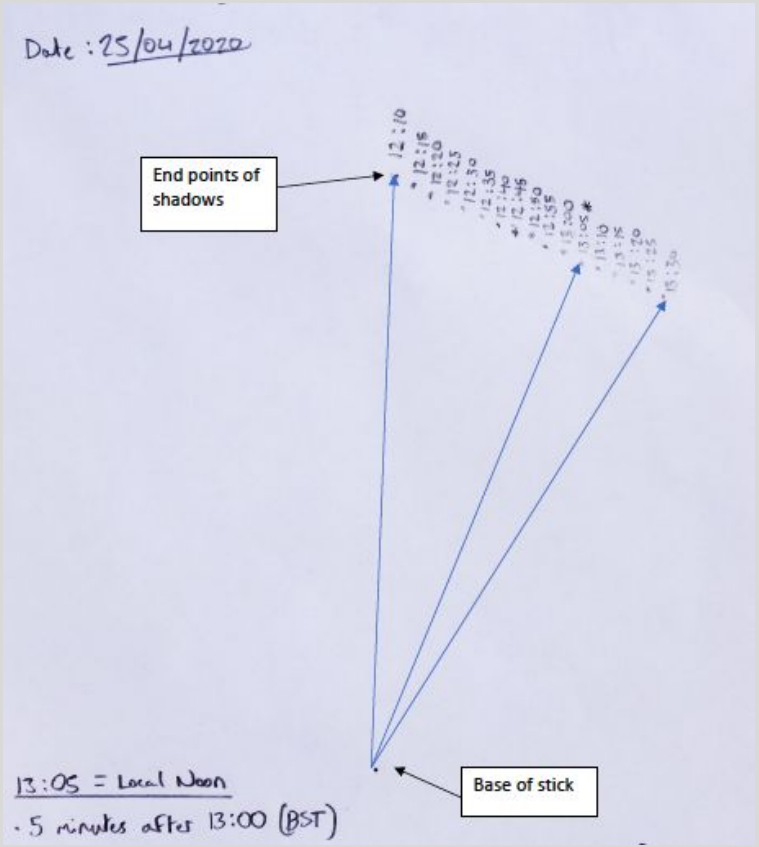
This diagram shows how the apparent movement of the Sun across the sky during the day changes depending on an observer's latitude. The length of shadows will change during the day with the shortest shadows occurring at local noon as shown in the photographs.

4.7 Understand how to determine the time of local noon using shadows, including use of a shadow stick (continued)

Recording the length of the shadow of a perfectly vertical stick or pole until you find the shortest shadow will therefore allow you to find the time of local noon at your location. This image is an example from a GCSE Astronomy student's own observations.

The student has set up a vertical stick at the point shown then marked the end of the shadow and recorded clock time against each mark.

The observations were made in summer so the times are in British Summer Time. The student has estimated that the shortest shadow was at 13:05BST so 5 minutes later than at Greenwich. This shows that the observing location was west of Greenwich as local noon is later.



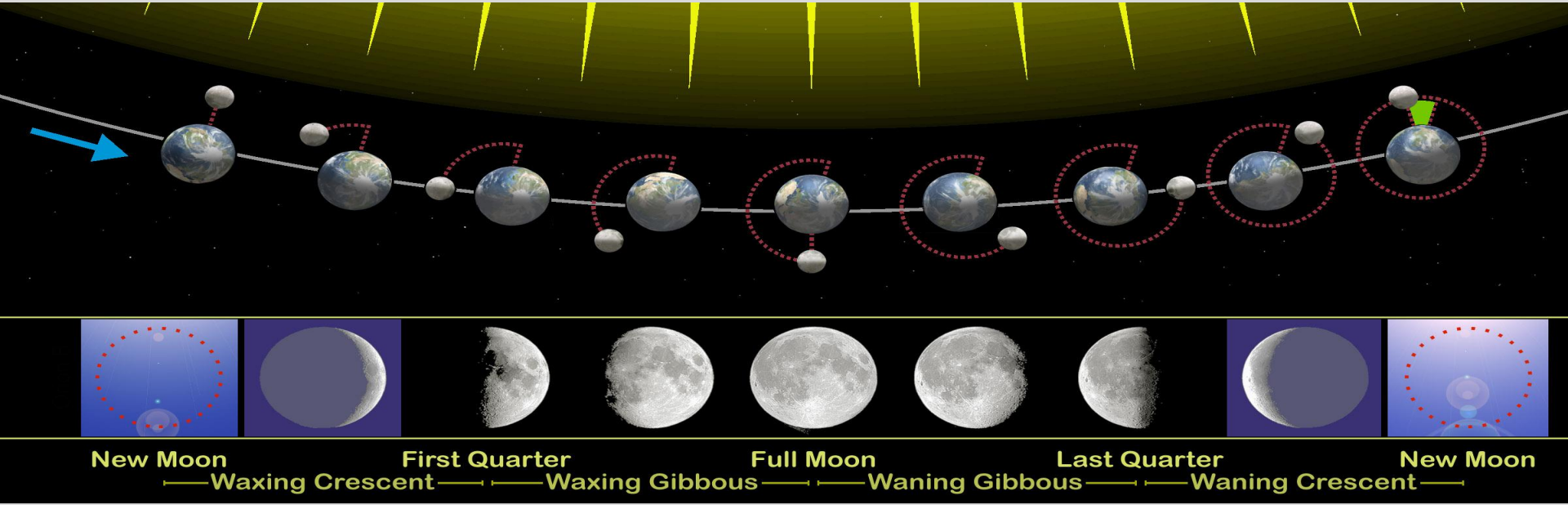
4.8 Understand the structure and use of sundials

Sundials are a more sophisticated way of using shadows to tell the time than just using a simple stick. They come in many varieties, sometimes horizontal on a pedestal in a garden and sometimes vertical on the wall of a church or civic building like the one in the photo. Before rapid travel and communication was possible over long distances, sundials were very important for telling local time in each, separate town or village https://www.sundials.co.uk/

Exercise:
The above photo was taken at 15:23BST by clock time (MST) on 11 October 2021.

1. What time do you think the sundial shows?
2. What is the sundial time adjusted from BST to GMT?
3. 11 October is Day 284 in a normal year (285 in a leap year). Go back to slide 4 and use the graph to estimate the EOT correction which must be applied to sundial time. What is your corrected answer for sundial time?
4. This sundial is in Abingdon, Oxfordshire which is at 1.28^0 Wset of Greenwich. How many minutes later is LST than MST in Abingdon?
5. Adding the correction for LST, as Abingdon is west of Greenwich, what is your final estimate for sundial time?

4.9 Understand the lunar phase cycle



This diagram shows several ways of understanding the lunar phase cycle and also shows the names of the phases, something already discussed in Topic 2. The upper diagram shows the position of the Moon in its orbit relative to Earth and Sun and the lower diagram shows the view of the Moon from Earth.

The coloured segment in the right hand diagram of the upper diagram shows the difference between the Moon's synodic period and its sidereal period.

4.11 Understand the annual variation in times of sunrise and sunset

Times of sunrise and sunset will depend on an observer's latitude and on the time of year.

This site is an interesting way to see the variation in sunrise and sunset times across the British Isles at different times of the year - look at the maps for March, June, September and December. What do you notice about the lines of equal sunset and sunrise times (isolines) in these particular months?

http://astro.ukho.gov.uk/nao/miscellanea/UK_SRSS/

The reason for the variation is the Earth's 23.5^0 tilt relative to the plane of the solar system. If there was no tilt, the times would not depend on season.

4.12 Understand the astronomical significance of equinoxes and solstices

Look at this link and write a definition of equinox:

https://www.space.com/what-is-an-equinox.html

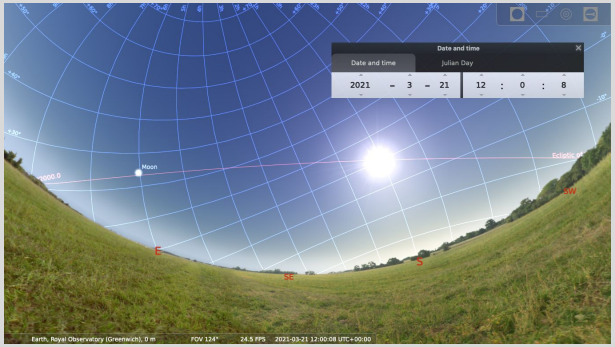
Note that the spring equinox is also referred to as the **vernal equinox** an alternative word for spring.

Look at this link and write a definition of solstice:

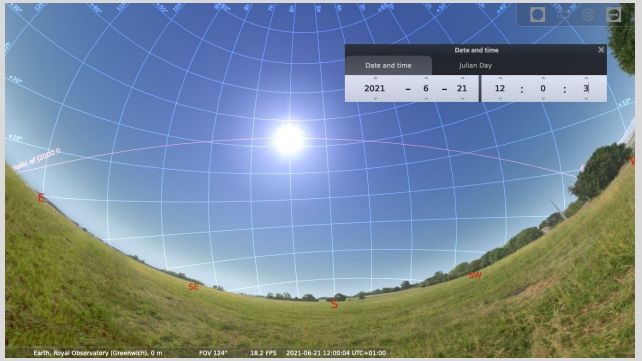
https://www.space.com/what-is-a-solstice.html

4.13 Understand the variation in the Sun's apparent motion during the year, particularly at the equinoxes and solstices

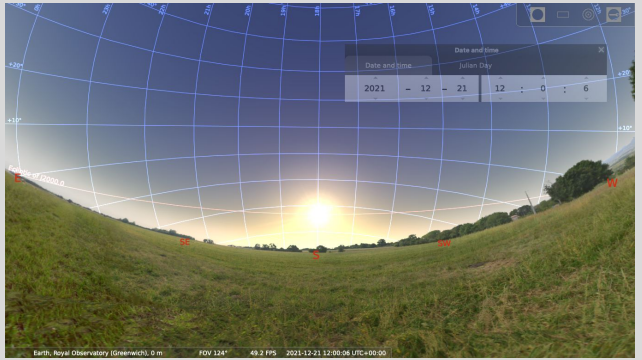
https://earthobservatory.nasa.gov/images/52248/seeing-equinoxes-and-solstices-from-space



At the equinoxes, the Sun is at the point where the ecliptic crosses the celestial equator



At the summer and winter solstices, the Sun is at the point where the ecliptic is 23.5^0 above or below the celestial equator



4.15 Understand the difference in local time for observers at different longitudes
4.16 Understand the use of time zones
4.17 Be able to use data related to time zones
4.18 Know that mean time at any point along the Prime Meridian is defined as Greenwich Mean Time (GMT), which is the same as Universal Time (UT)

The Earth's rate of rotation is 360^0 in 24 hours.

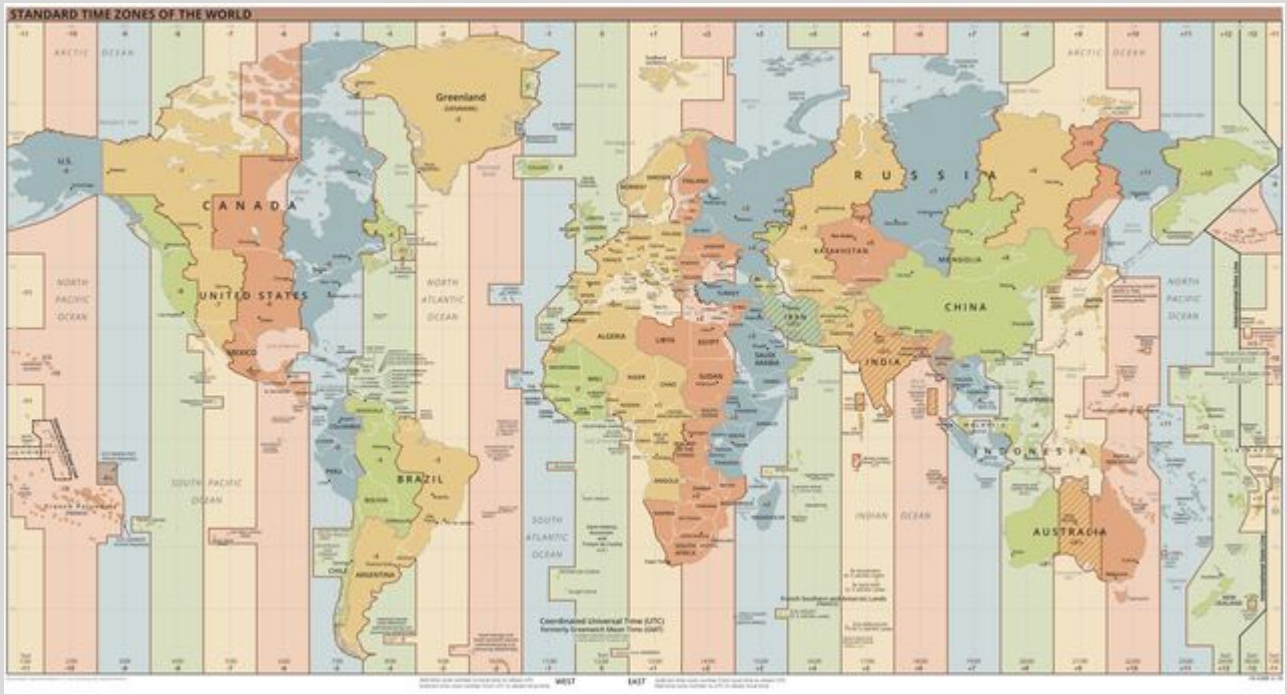
How many degrees does the Earth turn in 1 hour?

How many degrees does the Earth turn in 1 minute?

How long does it take for the Earth to turn by 1^0 ?

We have chosen, by international agreement, to start our global time system at Greenwich. Time at Greenwich is called Greenwich Mean Time (GMT) or Universal Time (UT). Places east or west of Greenwich will have different local solar times (LST) but time zones are used to keep time the same across countries or regions for social and economic reasons.

Time Zones:



This map shows that time zones would ideally change every 15^0 of longitude except where the shape of a country or a continent makes this inconvenient.