Activity Pack 2: Latitude and Longitude

Topics covered: time zones, ratios, proportions, triangles, SOHCAHTOA

This activity pack goes along with the second video, Latitude and Longitude, so make sure you've watched that first!

We'll be looking at the Earth's tilt, how to work out our latitude using the Sun, and how we can use shadows to work out how tall a building or tree is.

Outdoor Activities

Lines of latitude are those that run laterally around the Earth - they tell you how far north or south of the equator you are.

What latitude are you at?

If we measure the angle of the Sun at its highest point (midday), this will tell us the latitude!

Because the Earth's orientation in space isn't lined up exactly with the plane of its orbit around the Sun, it is only precisely accurate on the **21st of September** and the **21st of April** (at the spring and autumn equinoxes, when day and night are equal in length). More on what we mean by this on page 3.
It wouldn't be very far off your true latitude if you're doing this during Maths Week Scotland 2021 (27th September - 2nd October 2021).

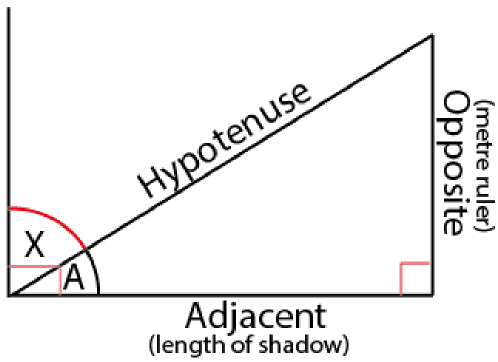
How to measure your latitude:
Equipment needed:
- Metre ruler
- Spirit level or plumb line
- Tape measure

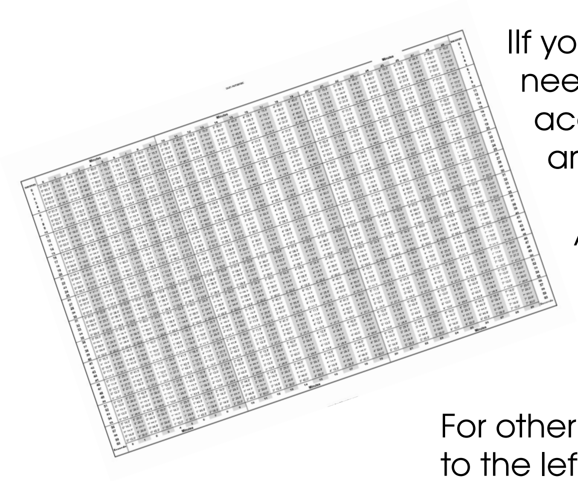
Most smartphones have a level in their built in software, in iPhones it's with the compass, on Androids you need to install an app.

A plumb line is simply a weight tied to a string, which will hang exactly vertical when allowed to move freely. You could align one of these with your metre ruler to make sure it's vertical.

Instructions:
1. Take a metre ruler outside, hold vertically (use a spirit level or plumb line) and measure the length of the shadow.
2. On paper, a draw diagram of a right angled triangle.
3. We want to know the angle between the hypotenuse and the horizontal (adjacent) to get the angle of the sun in the sky relative to the horizon. So the opposite will be 1m (or 100cm), the adjacent will be the length of the shadow, and we are looking for angle X (90-A).

Hint: Are we going to need to use SOH CAH or TOA for this triangle?





Ilf you're doing this activity at any other time of year you'd need to make some adjustments to your calculations to account for changes caused by Earth's tilt relative to its orbit around the Sun.

At the midwinter solstice (21 December) you should take away 23.4° from your reading, and at the midsummer solstice (21 June) add 23.4°. More info on why on the next page!

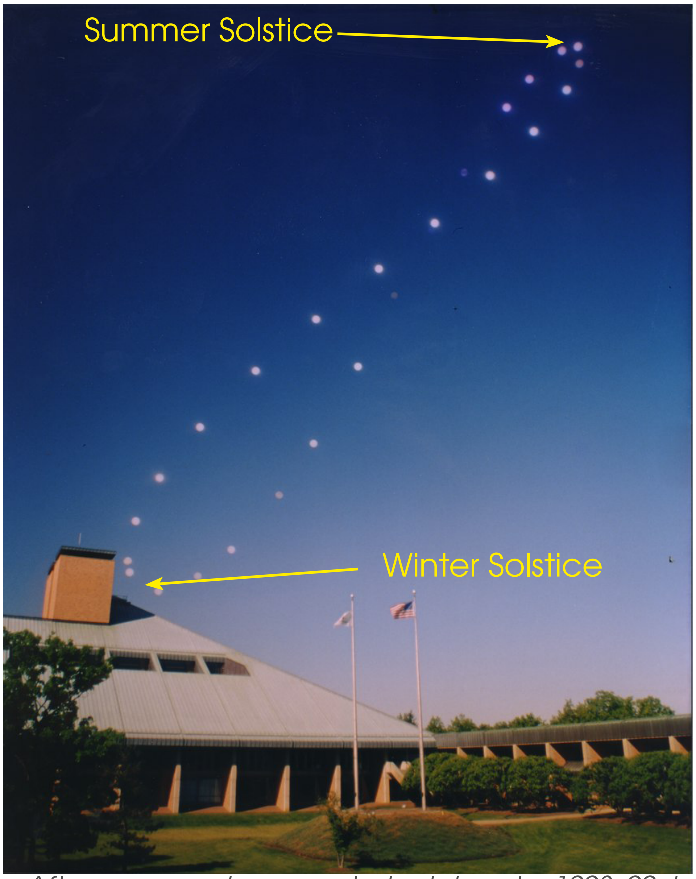
For other times of the year, complex tables (almanacs, like the one to the left) are used to account for the tilt, because the highest point of the Sun at midday doesn't follow a straight line path throughout the year.

Analemma

An analemma is a diagram (or photo) that shows the changing position of the Sun in the sky throughout a whole year, as seen from the same place and the same time of day. For example, taking an image of the Sun in the sky from the same place, looking in the same compass direction, every Monday at midday. If you then combine these images, you have an analemma.

This shape is the reason you have to use the complex almanacs to account for Earth's tilt.

You can see that the amount the Sun moves in the sky is much larger closer to the equinoxes, and much smaller closer to the solstices.



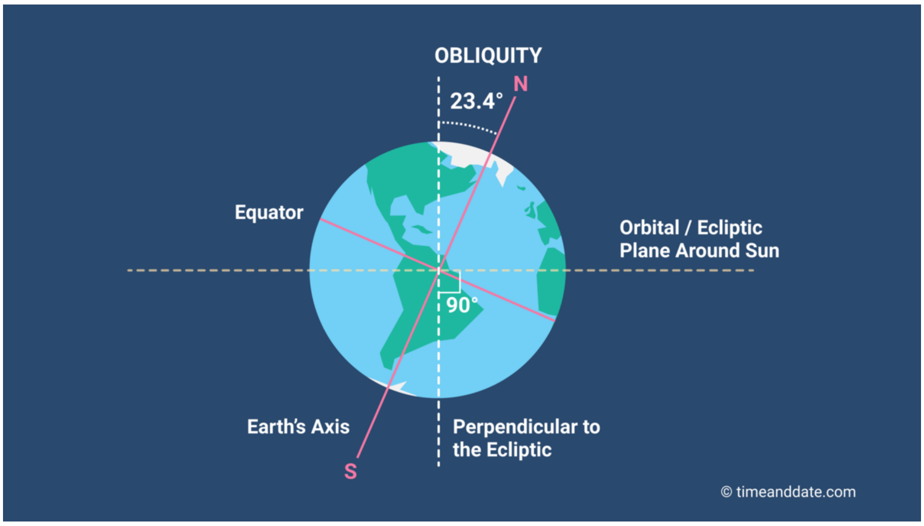
Afternoon analemma photo taken in 1998–99 in Murray Hill, New Jersey, USA, by Jack Fishburn. Image credit: Jfishburn at English Wikipedia

Daylight Savings (click here for dates):
Because of daylight savings time (when the clocks go forward in the summer months by an hour), you'll note that the time that the Sun reaches its highest point in the sky is actually closer to 1pm than midday. To get the most accurate result, you can take a few measurements at different times and use your longest shadow measurement for the calculation.

Earth's tilt

The Earth is moving in lots of different ways.
It rotates about its north-south axis once every 24 hours - the length of a day.
It orbits the Sun once every 365.256 days (this additional 0.25 adds up to a full day every 4 years, which is why we get a leap year!).

While it's orbiting the Sun, it is also on a bit of a tilt. We call this its **axial tilt**, or its **obliquity**.



The Giant Impact Hypothesis is the best explanation we currently have for how the moon came into being, and also why Earth is on a consttant tilt relative to its axis. Evidence suggests that around 4.5 billion years ago, something the size of Mars crashed into the newly formed Earth, forming the Moon and contributing to the Earth's current tilt of 23.4°.

This tilt relative to our orbital path around the Sun remains approximately the same over long periods but means that the hemisphere receiving the most sunlight varies over the course of a year. It's responsible for our seasons. (See diagram below)

What we call 'summer' is when the hemisphere we are in (Northern for Scotland) is tilted towards the Sun, so it gets more direct sunlight, longer days, and warmer weather! Winter is the opposite; when we are tilted away from the Sun we get shorter days, and cooler weather.

The tilt, and therefore the different lengths of days throughout the year are more noticeable the closer to the North or South Pole you are. Right at the poles, you get whole months of constant darkness or light because of the tilt!

Have a look at the diagram

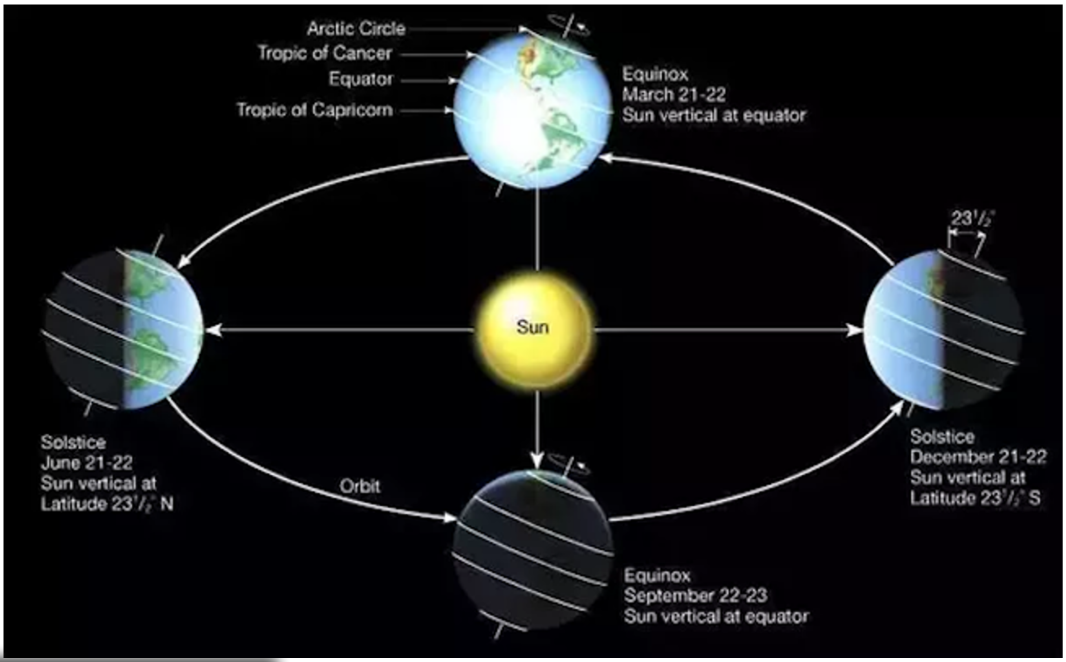


Diagram not to scale. Image credit: Online Star Register

Height using shadows

We could measure the height of a small tree with a regular tape measure, but what if we want to know the height of a tall building or a big tree? We can use their shadows and the idea of ratios to work it out!

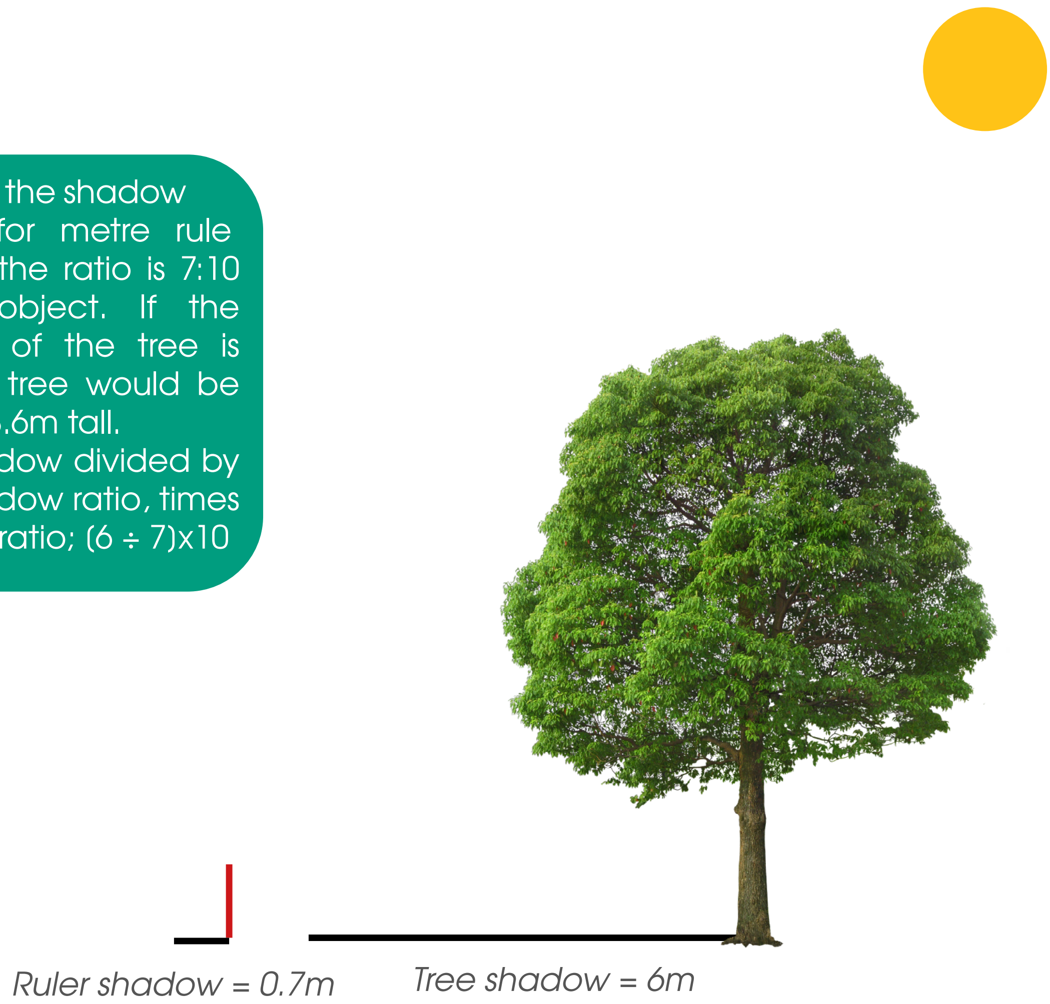
Equipment needed:

- Metre ruler
- Tape measure
- Calculator (optional)

Instructions:

1. Take metre ruler outside near tree, don't be in the shadow of tree to start with.
2. Hold the metre rule vertically (use a spirit level or plumb line).
3. Measure the length of the metre ruler's shadow with a tape measure.
4. Measure the length of the shadow of the tree.
5. The metre ruler vs its shadow will give a ratio of object:shadow.
6. Apply this ratio to the shadow length for the tree/building.

E.g. if the shadow length for metre rule is 0.7m, the ratio is 7:10 shadow:object. If the shadow of the tree is 6m, the tree would be 8.6m tall.
Tree shadow divided by ruler shadow ratio, times by ruler ratio; (6 ÷ 7)x10



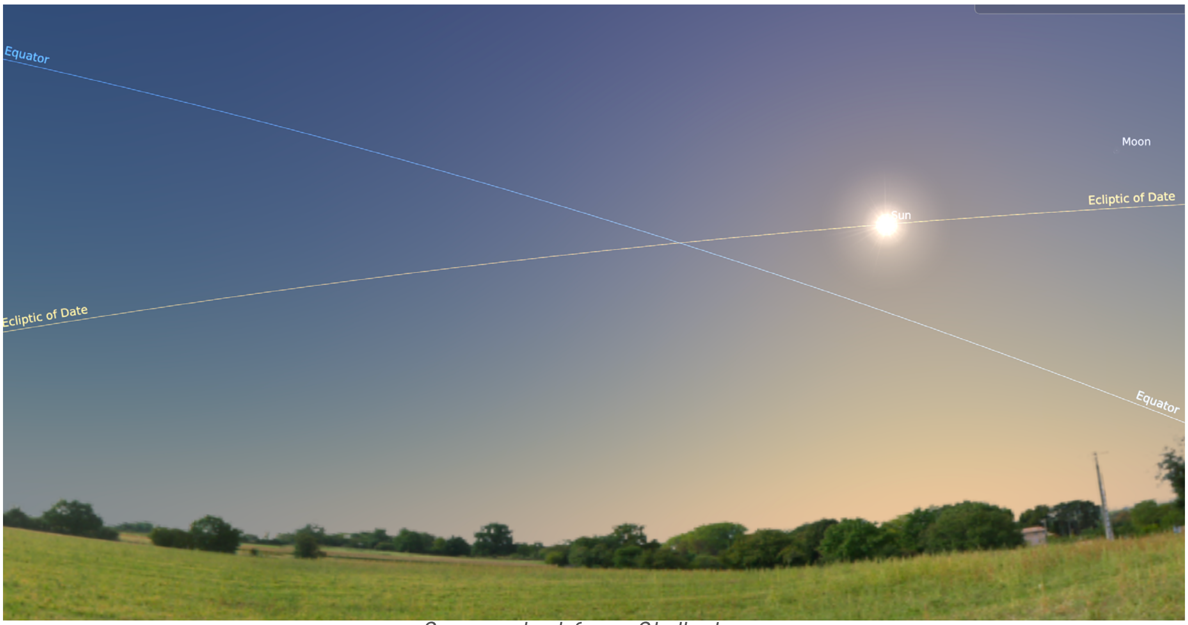
Indoor Activities

Stellarium

Stellarium is a free piece of software that lets you visualise the Sun in the sky from anywhere on Earth, at any time of year. It also does many other cool things, so have a play with it!

1. Download the desktop app here (the web version doesn't have the same functionality as the desktop version).
2. Once downloaded and opened, make sure Stellarium knows your correct location, the left-hand menu option allows you to change this as needed.
3. Press the comma and fullstop keys on your keyboard.
4. This will bring up lines showing the path that the Sun follows in the sky throughout the year (called the ecliptic), and the Earth's equator (imagine increasing the size of the Earth's equator so that you could see it on the sky).
5. You can then move through the days of the year using + and - keys.
6. Try moving one day at a time until the Sun crosses over the equator line. Which date do you think this might be?
7. By clicking on the Sun, lots of information will come up on the left hand side. The most useful here is the az/alt line, which will tell you the compass direction the Sun is in, and the angle above the horizon it is.

Hint:
Think solstices and equinoxes.



Screenshot from Stellarium

A Note on Time Zones

In video 2, we talk about how a difference in longitude of 15° roughly translates to a difference of hour in time.

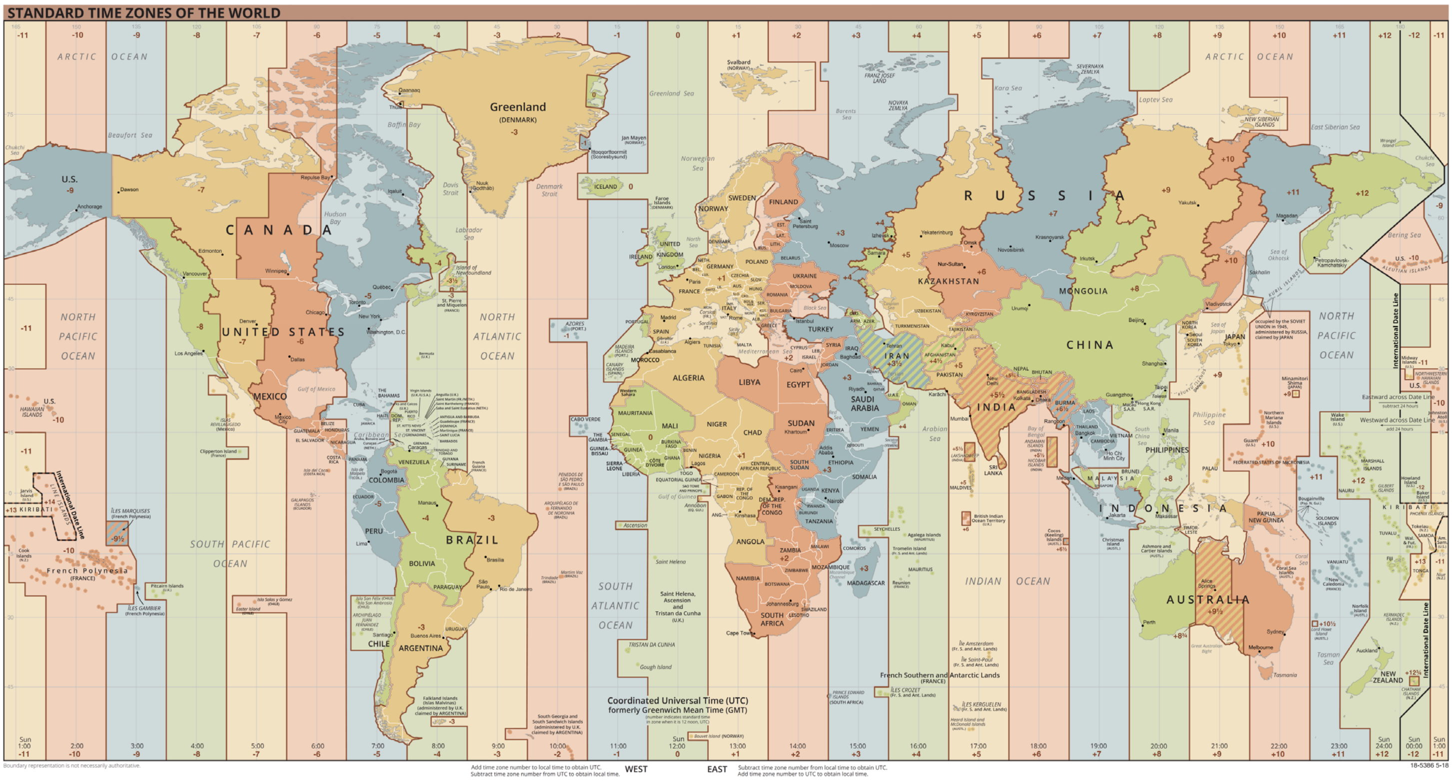
This is due to the number of hours in a day (24) and the number of degrees in a full rotation of the earth (360°); 360° ÷ 24 = 15°.

This is true in a scientific sense, if you travelled 30° longitude, the difference in time of noon (when the sun is at its highest point in the sky) would be about 2 hours from where you started.

However, the world is very complex and many countries choose to operate the whole country on one time zone, even though from west to east they might span 15°+ of longitude. So noon on the western edge might happen many minutes, or even hours after the eastern edge.

Also some countries that are on roughly the same longitude are in different time zones!

Here’s a map showing the different time zones countries use:



Additional Resources:

BBC Bitesize - Latitude and Longitude
Stellarium
NASA - What Causes the Seasons?
NASA - Orbital Cycles
NASA Space Place
National Geographic - Longitude
National Geographic - Latitude
National Geographic - Map Maker
Wikipedia - Dead Reckoning