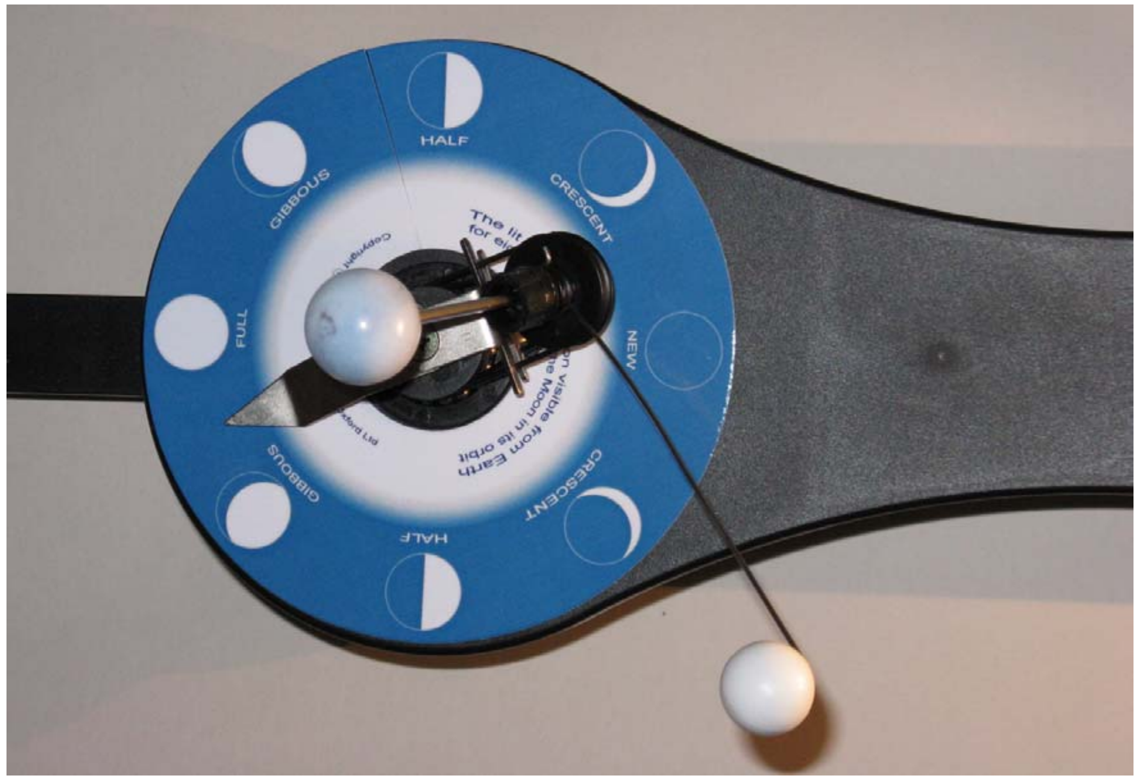
Appendix 4 Moon Chart: For each day draw the shape of the Moon, record the time and mark the position of the Moon in the sky in relation to a tree or chimney.
Always make your observation from the same position, it could be your garden, or nearby street corner.

Trim off this edge over the line

The Orbit™ Tellerium 2.1

The Tellerium with large Earth globe
for demonstrating seasons of the year, shadows and day and night.



The Tellerium with the small Earth
for demonstrating phases of the Moon and the eclipse cycle.

Published by:
Cochranes of Oxford Ltd.
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Info: www.cochranes.co.uk Email: sales@cochranes.co.uk

Cochranes of Oxford Ltd

Appendix 3 - Storage, maintenance and parts.

Storage

Keep the Tellerium in a cool dry place away form direct sunlight and sources of heat or dust. When not in use or display, cover the Tellerium with a dust-cover such as the protective bag supplied with the Tellerium.

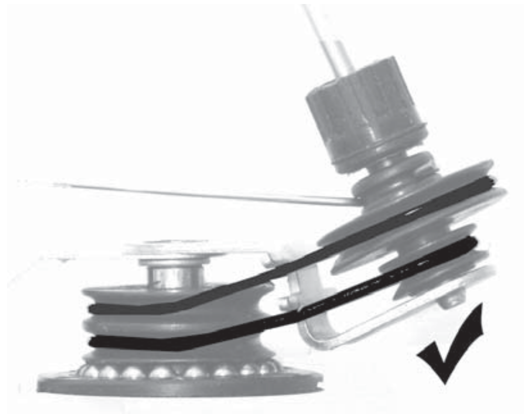
Cleaning /Maintenance.

The Tellerium can be cleaned with a lint-free cloth.

Remove the pulley wheel with the Moon attached and clean the wheel and the black spindle around which it rotates.

Once a year apply a very little light oil onto the ball-bearings.

Your Tellerium should rotate smoothly.
If the Tellerium does not rotate smoothly check the position of the black rubber rings on the wheels below the Earth. They should look like the picture on the right.



All screws will have been correctly tightened in the factory. Over tightening of the screws can cause stiffness in the rotation of the Earth and Moon.

Spare parts

Spare parts are available from your supplier and the manufacturer.

Bulb and Power supply

The bulb and power adapter provided with the Tellerium work together to give optimum light output. If either should fail, please order replacements from your supplier or the manufacturer, as replacement with other bulbs or transformers may result in poor lighting, damage to the components or an unsafe operation.

Other astronomy teaching aids from Cochranes of Oxford Ltd.

The Orbit Orrery. A simple model of the Solar System includes the nine planets and the Earth's Moon. All movement done by hand. The Sun lights up, showing it as the source of heat and light.

The Solar System to Scale. A set of ten posters of the Sun and planets printed to scale. Each print includes data on the planet's composition, size, daily rotation and distances. The distances between the planets and from the Sun is also given for the printed scale, so viewers can obtain an impression of the vastness of the Solar System.

The Helios Planetarium. A working orrery with planets as far as Saturn rotating at their correct relative speeds under a star dome. An 80 page booklet gives the user over 12 demonstrations that can be provided on this equipment from planetary motion, through the identification of the circumpolar stars, to how the tidal cycle fits into the lunar cycle.

For more information on these and other science teaching aids contact your supplier or visit our website, www.cochranes.co.uk

Cochranes of Oxford Ltd

England, UK
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Appendix 1 - How to construct a north/south line at your school

It is very useful to establish the positions of the points of the compass, both in your classroom and outside where you plan to observe the Sun. Only in this way can observations taken at differing locations be compared. There are several ways of constructing a north/ south line.

1. You can work with a magnetic compass, but remember to allow for magnetic variation, this will usually be shown on a good quality map. If the variation is 6° W, this means true north will be 6° to the East of the direction the compass points. You should also take care to ensure the compass is not being interfered with by metal in the building or electric fields; these can be particularly strong where there are electric motors; near a lift shaft for instance. For accuracy, it is safest to use a compass outside and to elongate the north south line into your classroom through a window if one happens to be handily placed.

2. Another method is to get a good local map in a large scale. With two pins mark your position and that of a prominent landmark. Lay the map flat and line up the two pins on the landmark. The north/south axis of the map will be the north/south axis of your position. Once established mark this axis permanently on the ground, two stakes in line are a good method, or copy Sir Isaac Newton who is reported to have scored a line on his windowsill.

3. You can use the Sun to help you find the north/south line by;-
- The direction of the shortest shadow, though this is sometimes difficult to establish precisely.
- The direction of a shadow at noon, but see appendix 2 for details on how to establish the time of your noon.
- Using the shadow thrown by a vertical stick that has been erected in the centre of a number of concentric circles. In the morning, mark the point where the tip of the shadow reaches one of the circles. In the afternoon the tip of the shadow will cross the same circle, mark the point. Draw a line between these two points, this is the East-West line. Repeating the exercise or using more than one circle minimizes any error.

Appendix 2 - How to relate the time on your clock to real solar time.

You may expect that at 12.00 on your clock the shadow of the Sun will lie along the north/south axis. This however is very unlikely and for three main reasons.

1. Your clock may have been adjusted for "summertime" or "daylight saving time" which usually advances the clock by one hour so that noon comes at 13.00 hrs.

2. Your clock will be telling the time for your time zone. To get your real solar time, you need to adjust your time by 4 minutes for each degree of longitude you are east or west of your time zone's base longitude. Your time zone's base longitude is 15° (360° /24hrs.) for every hour your standard time is ahead of or behind Greenwich Mean Time (which is based on 0 degrees longitude).

3. The Sun is telling you real solar time at your line of longitude, whereas your clock-time even as adjusted will be telling you mean (average) solar time. The difference can be as much as 15 minutes and is caused by the Earth's orbit round the Sun being slightly elliptical, which in turn means the speed of the Earth in space alters. This affects the time it takes for an observer on the Earth's surface to experience one noon followed by another.

Example.

Time on your clock	12.30	
Adjust for summertime		- 1.00
		11.30
Adjust for your longitude. If your school is 3 degrees west of the longitude on which your time is based. Your clock will be 3 x 4 minutes fast.	-0.12	
		11.18

Your sundial should read 15 minutes either side of 11:18.

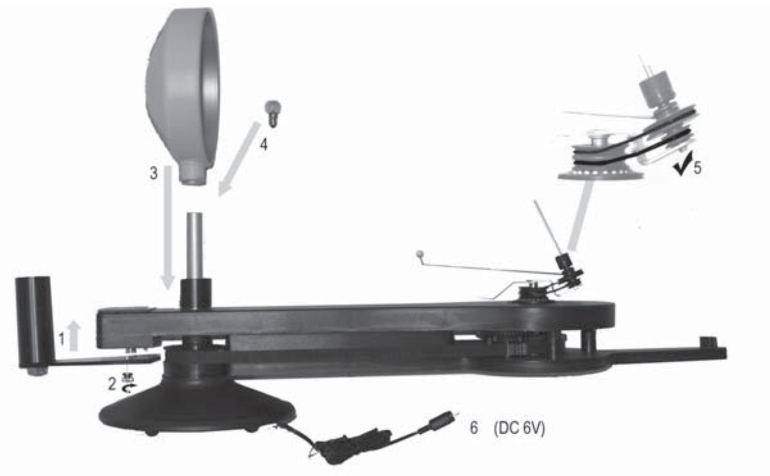
Contents

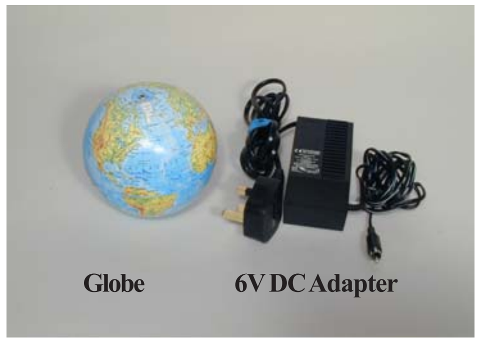
Introduction

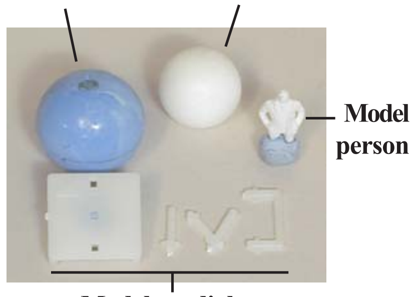
The Orbit Tellerium helps children understand core aspects of the curriculum by conveniently and accurately demonstrating the following:

- night and day
- the Sun's apparent motion across the sky
- the seasons
- changing length of daylight
- the use of sundials and shadow sticks
- the phases of the Moon
- the changing length and direction of shadows
- eclipses of the Moon and Sun.

Parts and Assembly







You can set up the Orbit Tellerium as different models depending on what you want to teach. The setup of each model is described at the start of each section of this book.

Movements of the Tellerium

Rotate the Tellerium by pushing either end by hand.

During rotation of the Tellerium, gears drive the Moon around the Earth and spins the Earth globe around its axis in synchrony with the Earth's orbit around the Sun. The gearing creates just over twelve lunar months per year, which allows festivals that are linked to the Moon, e.g. Ramadan and Easter to be discussed.

The Tellerium's gearing also maintains the 23.5 degree tilt of the Earth's axis in a constant direction. The plane of orbit of the Moon around the Earth is set at an angle to the Earth's orbit around the Sun (the ecliptic). In real life, this angle is 5 degrees. On the Tellerium the angle is exaggerated in order to clearly demonstrate its affect on the occurrence of eclipses.

The final drive of the Moon and Earth globe is by friction. This reduces the likelihood of damage to the gears by misuse and gives the teacher easy control of the positioning of the globe and Moon when teaching.

Eclipses of the Moon and the Sun - Model C

Background

A solar eclipse occurs when the Moon lies exactly between the Earth and the Sun. The shadow cast by the Moon will not cover the whole of the Earth's surface - see figure 16. At any one time a small part of the Earth may be in total eclipse, another small part in partial eclipse, but most will not be eclipsed. So what an observer sees (if anything) is dependent upon their location. As solar eclipses may last several hours in total, the Earth will rotate during the eclipse bringing a band of different places on the Earth into and out of eclipse. It is the Earth's rotation that causes this band, not movement of the Moon (which moves very little during the eclipse).

A lunar eclipse occurs when the Moon passes through the shadow of the Earth. Anyone able to see the Moon during that time will see the eclipse.

Whilst a solar eclipse requires the Moon to be in its New Moon phase and lunar eclipses require a Full Moon eclipses do not occur every month. The plane of the Moon's orbit around the Earth is inclined at an angle to the plane of the Earth's orbit around the Sun. It is only when a Full or New Moon happens AND these planes intersect that an eclipse occurs. This occurs approximately every six months.

Activity

Set up the Tellerium as Model C (shown right).

1. Place the **blue sphere** on the Earth's axis to make a small Earth.
2. Use the **small Moon**
3. Place the **white card** in the card-holder to see the shadows of the Earth and Moon.

In this model the Earth and Moon are to scale in size and the distance between them is indicative of the large space between us and the Moon.

Turn the arm and point out the Earth and Moon's shadows on the card. Most months the Moon's shadow will miss the Earth's shadow, but sometimes they will coincide giving an eclipse of the Sun and/or Moon in that month. When an eclipse occurs on the model, you can see the Moon's shadow on the Earth (solar eclipse) or the Moon getting less bright as it falls into the Earth's shadow (Lunar eclipse).

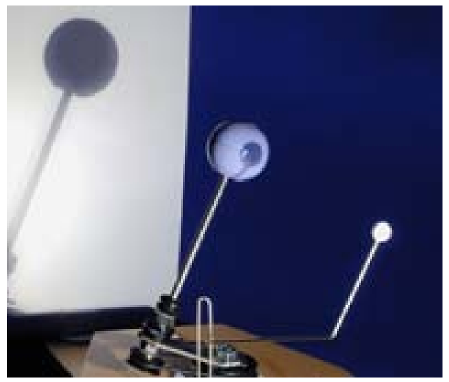
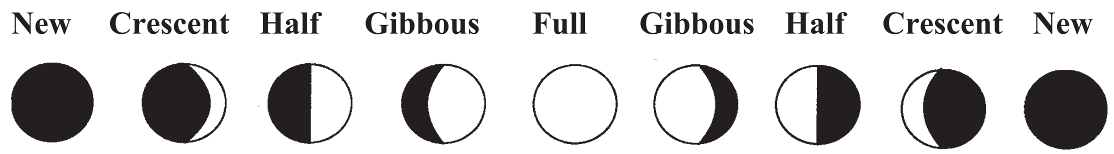


Fig. 16. Eclipse of the Sun.
The Moon's shadow falls on the Earth.
The position of the shadow on the Earth will vary from one eclipse to another.

Fig. 17. No eclipse.
Most months there is no eclipse because the Moon passes above or below the line of the Earth and Sun.



Phases of the Moon seen on the tellerium model

Learning Point

The phases of the Moon are caused by the changing proportion of the Moon's lit surface that is visible from the Earth. During the course of a lunar month, the proportion of the Moon visible from Earth increases from none (New Moon) to the full face (Full Moon) and then back to none again.

The phase of the Moon's depends onwhere the Moon is in relation to the Earth and Sun.

Extra Moon Facts

- The mean time for the Moon to go through its cycle of phases, from New Moon back to New Moon, is 29½ days.
- Whilst it orbits the Earth, the Moon rotates once on its axis, so a lunar day is the same length of time as a lunar month (29½ Earth days). This also means that the Moon always presents the same face to the Earth.
- There are 12 calendar months in the year, but 12 lunar months is only 354 days (29.5 x 12). So festivals like Ramadan that occur every 12 lunar months start 11 days earlier every year.

The Crescent Moon from Different Latitudes

Background

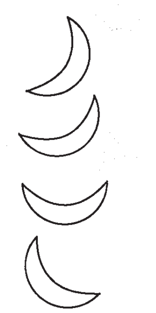
The crescent Moon has always attracted interest as it is such an unusual shape. But does it look the same from everywhere on the Earth's surface?
The answer is No, the shape is the same but the orientation of the shape with respect to the viewers' horizon is quite different.

From northern Europe the New Crescent Moon looks roughly like

From northern Africa it looks roughly like

From the Equator it looks roughly like

From Australia it looks roughly like



It is not surprising that in some parts of the world the crescent Moon was likened to a boat.

Activity

Set the Tellerium up as Model B (Phases of the Moon).

Stick the model person on the small blue sphere at the desired latitude and turn the sphere so that an observer at the location of the model person would be in late evening and able to see the Moon. Then look at the Moon from directly behind the observer and if possible draw the Moon and the angle of the observer's horizon below it. Then rotate your paper so that the horizon is horizontal. The Moon will have rotated as well.

Which way to go?

If you are looking down at the North pole, rotate the earth anticlockwise around the Sun. The Moon also rotates anticlockwise. The Earth spins on its axis anticlockwise. If looking down at the South Pole, all rotations should be clockwise.

What's the date?

The Orbit Tellerium date disc helps you to set the Tellerium for different times of the year and to identify the time of year whilst using the Tellerium. The date disc shows the 12 months and the dates of the Spring and Autumn equinoxes and Summer and Winter solstices.

Equinoxes and Solstices are part of the Earth's Solar calendar. The 365 day calendar year and its 12 months is kept in line with the solar year by the addition of leap days every 4 years.

The Sun

The Sun is modelled by a powerful bulb with a parabolic reflector. With the light coming from the parabolic reflector, this makes the shadows on the globe both visible and sufficiently accurate to compare with real-life observations. For best results, we recommend you semi-darken the room when demonstrating with the model.

Observations.

The Orbit Tellerium shows how rotations of the Earth and Moon can cause many effects that we observe. The fullest understanding can come from comparing observations of the real world with what is observed on the Tellerium model. Observations of the real world can be drawn from:
- Prior knowledge of the group (e.g. in which direction the Sun rises)
- The class making its own observations as part of a course of study
- Taking information from books, newspapers, the internet or studies by previous classes

The background section of each topic gives suggestions for compiling this information. Using a mixture of all three sources will make for an interesting and enjoyable course of study.

An effort should be made to mark the points of the compass in the school to be a constant reference point for observations. See appendix 1 for suggestions on how to do this.

Scale

The Orbit Tellerium contains large and small models of both the Earth and Moon. This makes teaching different topics easier and enables a better representation of scale.

The small Earth and Moon are to scale in size and give a fair idea of the space between them. In reality, the small Moon is farther from the Earth and the Sun is much larger and much farther from the Earth and Moon.

The large Earth globe is used to study day and night, seasons of the year and how sundials work. The model person is of course vastly out of scale; when you use it on the globe, it enters daylight when the light touches its toes, not when the light touches its head.

When using the large globe and teaching subjects in which the Moon is not involved, the Moon with its supporting wire can be removed in order to prevent it distracting pupils or causing a misinterpretation of scale.

Day, Night and Seasons of the Year - Model A

Set up the Tellerium as shown below (model A):

1. Place the large **globe** on the Earth axis.
2. Push a thin **stick** into the globe to see the angle of the Earth's axis (optional).
3. Place the model person on the globe with reusable adhesive (supplied).
4. If you include the Moon in the model, make the Moon larger by placing the **white sphere** on top of the small Moon. Alternatively, you may remove the Moon entirely.
5. Place the date disc on the flat surface under the Earth with the June solstice closest to the Sun

Activity 1 : What Causes Night and Day?

Background:

Ask pupils to describe night-time and to give their explanation for the event. Expect a wide variety of answers.
1. The Sun is switched off and goes to bed
2. The Sun goes behind the Moon
3. The Sun falls out of the sky
4. The Sun goes behind the Earth

Explanation 4 is reasonably correct as far as an observer on Earth is concerned but an observer in space looking down on the Solar System would see things very differently.
Ask pupils if they think night-time occurs at the same time all over the world.

Activity

Set up the Tellerium as Model A.
The demonstration will be clearest when the Earth is at an equinox position.
Spin the Earth slowly by hand in an anticlockwise direction
Draw attention to the model person as he goes into and out of the sunlight.

Learning point

Day and Night occur because the earth rotates on its axis once in 24 hours; someone standing on its surface (but not near the North or S poles) will have part of each 24 hours in sunlight (daytime) and part in darkness (night-time).

Activity 2 : What causes the Sun to move and our shadows to change during a day?

Background

Ask pupils to draw or describe how the Sun appears to move across the sky and how their shadow, or that of a vertical stick in the playground, changes in length and direction during a day. Ideally, pupils would make a series of observations of the sun's height (altitude) and direction and the length and direction of a stick's shadow. They can do this by using simple observation instruments.

*****Pupils must not look directly at the Sun as this can permanently damage their eyesight.*****

Pupils will need reference points such as local landmarks or points of the compass. Points of the compass are useful as they are universally applicable and can be applied to the Tellerium model.

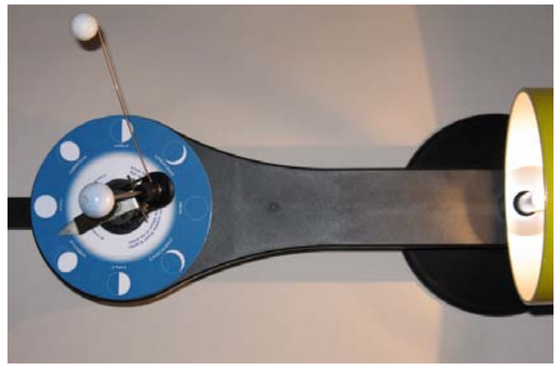
Phases of the Moon - Model B

Background Observations

Give your pupils two copies of the chart in Appendix 4 and ask them to draw the shape of the Moon for as many days as they can. This can be from a mixture of their own observations and other sources. If they miss a day they must leave a blank space in the chart. They should complete the chart for two months if possible. If they do, then enough information will have been gathered for them to use.

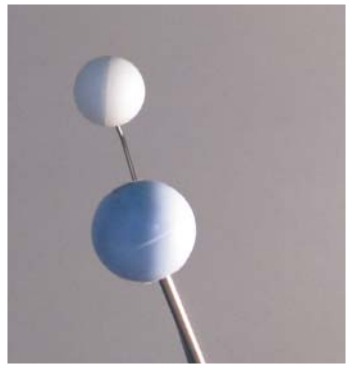
Following this period of observation you can ask your pupils to describe the Moon, why it shines and changes its shape and to estimate from their data:
- the length of a month
- the shape the Moon would be 14 days after their last observation
- how they think the Moon might have looked on nights for which they have no record.

Activity - A Half Moon



Set the Tellerium up as shown right (model B):
1. Enlarge the Moon by placing the **white sphere** on top of the small Moon.
2. Use the **blue sphere** to show the Earth.
3. Position the **Moon Phases Disc** on the Tellerium arm with the circle marked New Moon closest to the Sun.

N.B. On the Moon Phases Disc, the pictogram underneath the model Moon gives the Moon's phase. CAUTION : The date pointer does not indicate the phase of the Moon.



N.B. Using the smaller Earth model creates more distance between the Earth and Moon and enables you to easily see the Moon.

Move the Moon to a 'Half Moon' position. Part-darken the room and note the following:

1. The Sun's light lights half the Moon's surface at any time (just as it lights half the Earth's surface).
2. An observer on Earth usually only sees lit areas of the Moon because the unlit area is too dark to see.
3. With the Moon in this position, only half of the Moon that faces the Earth is lit by the Sun, so an observer sees a 'Half Moon' (see picture, right).

Activity - Crescent, Gibbous and Full Moons

Move the Moon to the Crescent, Gibbous and Full Moon positions and look at the area of lit Moon visible from the Earth in each position. You will see how the shape of the lit surface visible from Earth changes.

It is very helpful if the pupils can also get close to the Tellerium and look at the Moon from the direction of the Earth, changing their position as the Moon is made to orbit the Earth.

If they have time, pupils could also draw the shape of the Moon that they see at each point. Their drawings should approximate to the sequence shown below. They may also replicate their sketches of the real Moon, although the exact orientation of the Crescent, Gibbous and Half Moons will depend on the season, latitude and hemisphere of the observer (see next topic).

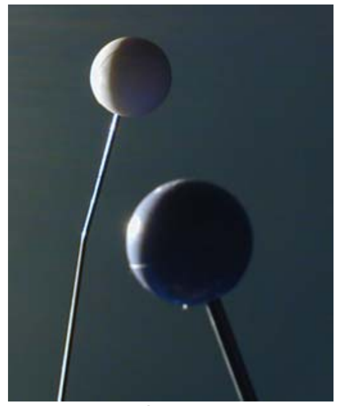


Fig 15. The Crescent Moon seen from Earth.

Sundials and shadow sticks

Background

A sundial made with a vertical stick does not usually tell the same time all year round and sundials moved from one location to another also become inaccurate.

The following activity uses the Tellerium to show why this is so. Making the equivalent recordings on the ground will make the activity more real, fun and understandable .
If making observations at your location, the angle of the inclined stick from the horizontal should be equal to your latitude (e.g. for latitude 40 degrees north, your inclined stick should point 40 degrees up and to the north).

Activity

Make the table shown right.
Set up the Tellerium as model A
Stick the model sundial base onto the globe at 30 degrees latitude (for example, Cairo, Egypt,) with the arrow pointing to the nearest pole (north pole in this example). Place the double-stick in the centre hole with the inclined stick pointing to the pole. Check the alignment of the base against the longitude lines.

	Vertical stick		Inclined stick	
	12.00	15.00	12.00	15.00
Summer				
Equinox				
Winter				

Move the globe into the midwinter position and record the positions the two shadows fall at 12.00 and 15.00 hrs. (At 15.00 hrs. in Egypt it will be midday in the Canary Islands (45 degrees to the west), so line up the Canary Islands with the Sun as at midday)

N.B. If you live in the southern hemisphere place the globe with Antarctica uppermost. The inclined stick should point to the South pole and Norfolk Island and Auckland can be substituted for Egypt and the Canary Islands.

Fig 14. Shadows of inclined and vertical sticks.

Repeat the above with the globe at the equinox and midsummer. Your table should look like this:

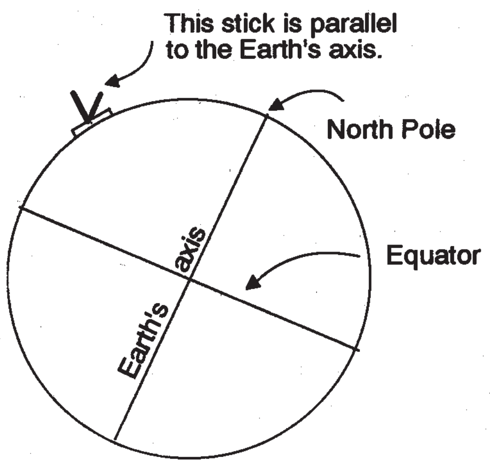
	Veritcal Stick		Inclined Stick	
	12.00	15.00	12.00	15.00
Summer	|	—	|	/
Equinox	|	/	|	/
Winter	|	/	|	/

All 12.00 (midday) shadows point to the (North) pole; the directions of the 15.00 shadows vary for the vertical stick, but are constant for the inclined stick.

Learning Point

The tilt of the Earth's axis and orbit of the Earth around the Sun causes the direction of the shadow cast by a vertical stick at a particular time of day (say 15.00) to vary through year. This can be compensated for by inclining the stick to an angle from the horizon equal to the latitude. Then the shadow for a certain time always lies in the same direction and the stick can be used to tell the time over the whole year.

A sundial will only work accurately at the latitude for which it was designed.



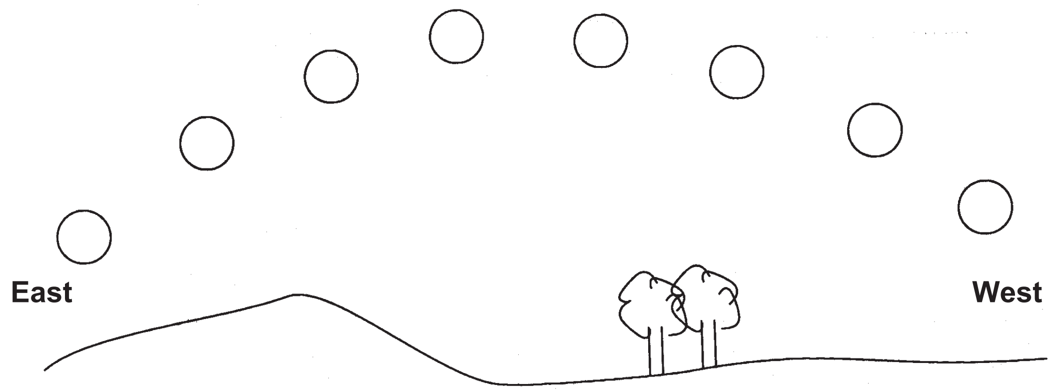


Fig 3. A drawing of the Sun's path in the sky.

Pupils should compare their results for the Sun's position and the length of their shadows at different times of the day.

The Sun moves in an arc from East to West across the sky. The length and direction of our shadows is determined by the Sun's position in the sky.

Activity

Set up the Tellerium as Model A.
For clearest results, position the Earth at approximately an equinox. Rotate the Earth slowly on its axis in an anticlockwise direction and ask:

As the model person moves from dark to light (morning , Figure 4a);
-which way does the person look to see the Sun?
(Answer: the East and low down).
-how long is his shadow and in which direction does it lie?
(Answer: Long and to the West)

As the model person comes to midday (Figure 4b);
-which way does the person have to look to see the Sun now?
(Answer: South and higher up in the sky)
-how long is his shadow and in which direction does it lie?
(Answer: Short and to the South)

As the model person moves from light to dark (evening, Figure 4c), ask these questions again.

The answers should mirror the pupil's own observations outside.

Learning point

The Sun appears to move across the sky because the Earth rotates on its axis.

Figure 4. Rotation of the Earth causes changes to the direction of the Sun and length of our shadows.

Figure 4a. morning

Figure 4b. midday

Figure 4c. evening

The Seasons

In polar and temperate regions, the seasons of spring, summer, autumn and winter are caused by changes in the length of daylight and the altitude (height) of the Sun at noon. When teh Sun is at higher altituded it is more directly overhead and its light and heat are more intense on that part of the Earth. Longer days come at the same time as an increased altitude of the Sun at noon. These factors combine to deliver more (or less) light and warmth from the Sun each day and hence affect the weather and vegetation growth. At or close to the Equator the changes in length of daylight and height of the Sun at noon are smaller so other factors have a more marked effect on the weather.

Activity 3 : The length of daytime and height of the Sun at Noon

Background

Pupils can be asked to obtain sunrise and sunset times for each month of the year and to calculate the length of the days. They can get this information from almanacs and from the astronomy section of newspapers. Pupils could also record the direction of sunrise and sunset and height of the Sun at noon at different times of the year.

Activity - Introducing the Earth's Axis and Hemispheres

Set up the Tellerium as model A

1. Remove the globe and point out the Earth's axis, the axis is at an angle of 23.5^{o} to the vertical.
2. Replace the globe and add the axis extension stick.
3. Push the Earth around the Sun and show how the axis always points in the same direction in the room, but how its direction changes in relation to the Sun.
4. Place the model person and vertical sundial stick on the globe in the Northern and Southern Hemispheres respectively. Explain how we describe the Earth in two halves called hemispheres.

Rotate the Tellerium and show how as the Earth orbits the Sun teh two hemispheres are tilted alternately towards and away form teh Sun. When teh model person's hemisphere is tlted towards the Sun, that hemisphere appears brighter and the Sun is more directly overhead the person.

Fig. 5 The Earth's axis pointing 'up and left' creates a northern hemisphere summer (right) and, six months later on the opposite side of the Sun, winter (left). The season and date are indicated by the position of the pointer over the date disc.

Activity - The length of daytime

Set up the Tellerium as model A with the model person on your country.
Push the Earth around the Sun and stop at the spring equinox, summer solstice, autumn equinox and winter solstice. At each position look at how much of a day the model person or shadow stick spends in daylight and how much in night. (This is equal to the proportion of that latitude in daylight and night)

The results should roughly agree with information gathered by the pupils and their own observations.

At the Spring equinox:
- Days and nights are of equal length at all latitudes.
- The line of day and night passes through the poles (Figure 6). At the poles it would be perpetual twilight.

At the Summer solstice (midsummer):
- Now more of the Earth's surface in your hemisphere is in sunlight than in darkness. Hence the days are longer than the nights.
- One pole is in continuous daylight, the other in continuous darkness (Figure 7).

At the Autumn equinox:
The results should be the same as for the Spring equinox.

At the Winter solstice (midwinter):
- Now most of the Earth's surface in your hemisphere is in darkness, so the days are shorter than the nights.
- One pole is in continuous daylight, the other in continuous darkness.

If you look at latitude 60^{o}, which, in the northern hemisphere, passes across the Hudson Bay in Canada, during midwinter you will see that only one third of the line is in sunlight at any one time. So days will be 8 hours and nights 16 hours long.

Activity - The height (altitude) of the Sun at noon for different times of the year

The 'height' of the Sun is given by its angle above the horizon and is called its altitude. It is measured in degrees.

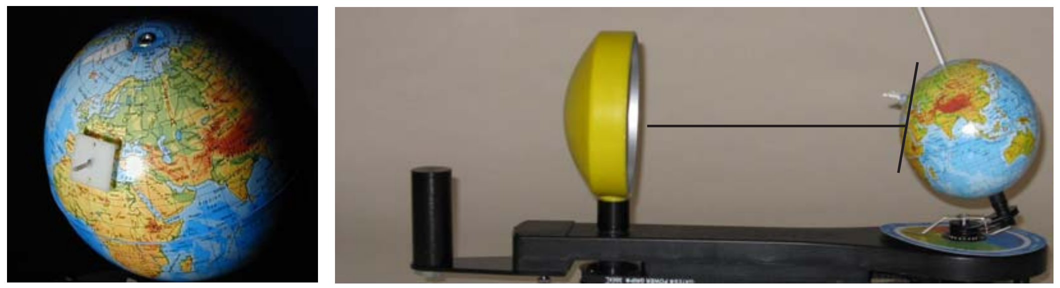
Set up the Tellerium as Model A. For each quarter of the year (spring equinox, summer, autumn equinox and winter) record the altitude of the sun at noon and the length of shadow of the person or shadow stick.

Figures 9-12 show stick shadow lengths and altitudes of the Sun at a latitude of 30 degrees North.

Fig. 6 The day/night line passes through the poles at an equinox.

Fig. 7. The North Pole in continuous daylight during dsummer.

Figs 9 & 10. In midwinter the shadow at noon is long and the sun is low in the sky



Figs 11 & 12. In midsummer the shadow at noon is short and the Sun appears high in the sky.

Learning Point

The tilt of the Earth's axis means that as the Earth orbits the Sun the length of daylight and apparent height of the Sun as it traverses the sky for any one observer changes over the year. When the hemisphere of the observer is tilted towards the sun, the observer has longer days and shorter shadows at midday (higher Sun) and it is normally hotter. When the hemisphere is tilted away from the sun, the observer has shorter days and longer shadows (lower Sun) and it is normally cooler. At the equinoxes both hemispheres have days and nights of equal length.

At the Poles the extreme conditions of six months daylight and six months darkness occur.