Sample of the GCSE Astronomy Course from Section 3

Topic 2

The Moon's orbit

Introduction

We can see that the Moon changes its appearance by the day. In this topic you will study the orbit of the Moon and the changes that this brings about. You will learn about the phases of the Moon, why you can only see one side of the Moon from Earth, and what gives rise to our ability to see a small fraction of the far side.

You will probably need 2 hours to complete this topic.

Objectives

When you have completed this topic you will be able to:

- explain the rotation and revolution (orbit) of the Moon
- describe the phases of the lunar cycle
- explain the synchronous nature of the Moon's orbit and rotation
- explain the causes of lunar libration and its effect on the visibility of the lunar disc.

Rotation and orbit of the Moon

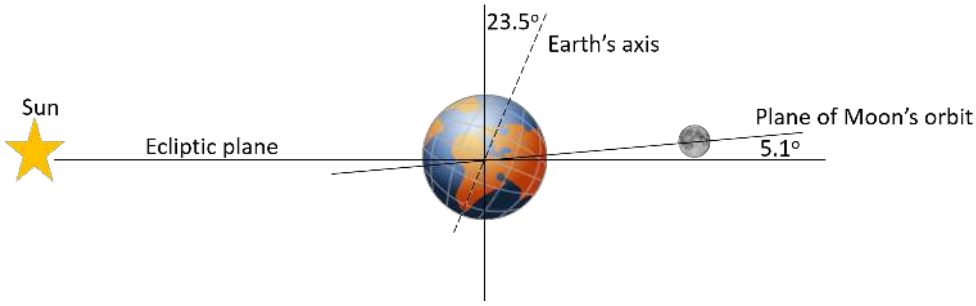
The Moon rotates about its axis in 27.3 days. The Moon orbits round the Earth in a period which is also 27.3 days. This means that we only see one side of the Moon (around 59 per cent of the lunar disc).

The axis of the Moon has a slight tilt. The Moon's equator is tilted by 1.5° to the plane of its orbit around the Earth.

You may recall from Section 2 that the plane in which the Earth orbits the Sun is called the ecliptic. The plane of the Moon's orbit is 5.1° to the ecliptic and the orbit is elliptical. The elliptical orbit means that the distance between the Earth and the Moon varies during the month.

Figure 2.1 illustrates these angles and planes. The distances and sizes of the objects are not to scale, but the angles are to scale.

Figure 2.1 The planes of the orbits of the Earth and Moon



- When the Moon is at its closest to Earth, it is termed the **perigee**.
- When the Moon is furthest away, it is termed its **apogee**.

Study hint

To help you remember, 'away' and 'apogee' both start with a letter 'a'.

The perigee and apogee are shown in Figure 2.2. Note that this diagram is not to scale.

Figure 2.2 Perigee and apogee

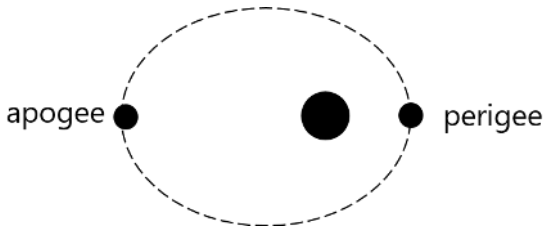
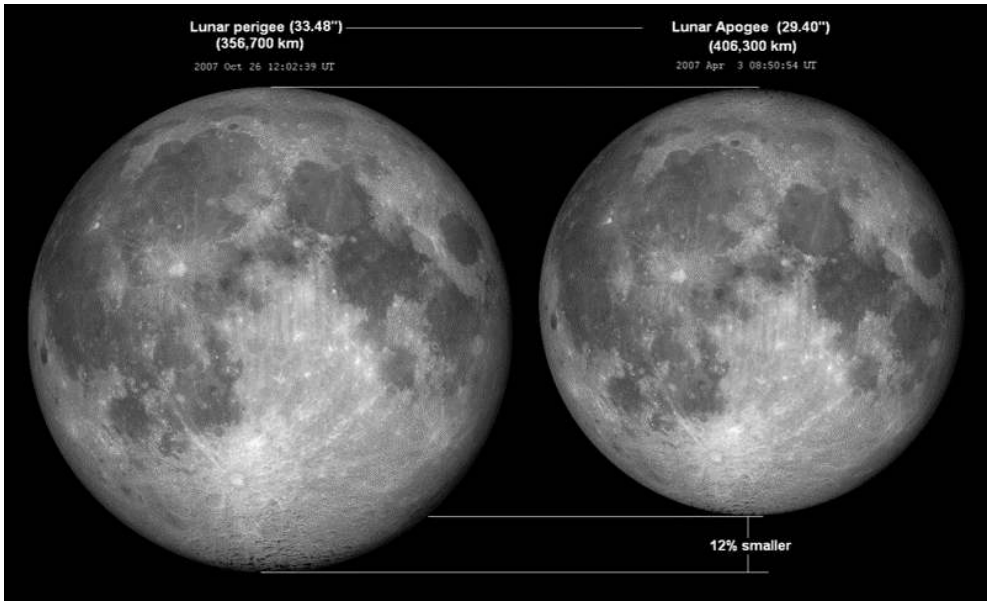


Figure 2.2 is exaggerated, but there is a perceptible difference in the apparent size of the Moon at different times as a result of this elliptical orbit. Figure 2.3 shows photographs of the full Moon taken at its perigee and apogee for comparison.

Figure 2.3 The apparent size of the Moon at perigee and apogee



Phases of the Moon

When the Moon lies between the Earth and the Sun, it is called the new Moon (position 1 in Figure 2.4 below). This is the first phase in the lunar cycle. The visible part of the Moon's surface does not receive any direction radiation from the Sun, but you may still be able to see it – although not easily – because the Sun's radiation is reflected from the Earth and illuminates it a little.

When the Moon is at the opposite end of its orbit, the Sun is behind the Earth and the surface of the Moon is fully lit by the Sun. This is the full Moon (position 5). Figure 2.4 illustrates the phases of the Moon, and how they relate to the relative positions of the Earth, Moon and Sun. Figure 2.5 shows the illumination of the Moon as it appears from Earth during the eight phases of the lunar cycle.

Figure 2.4 The positions of the Moon during the course of one orbital period

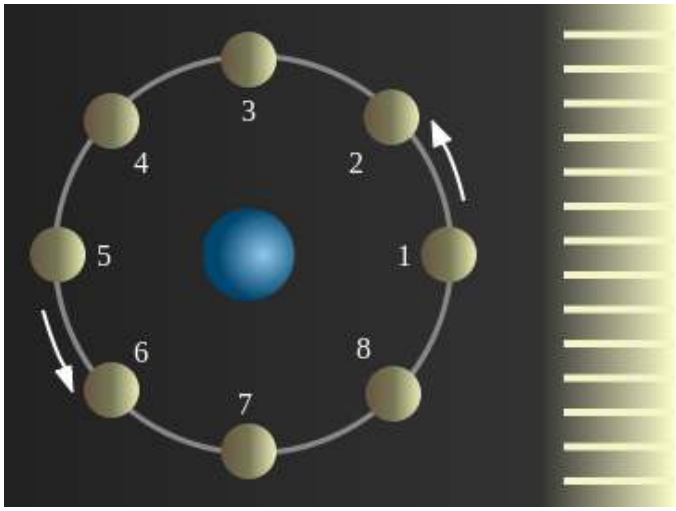


Figure 2.5 The illumination of the Moon as seen from Earth

- You have already seen that position 1 is the new Moon and position 5 is the full Moon, when the surface is fully illuminated.
- Positions 4 and 6 are known as **gibbous** moons, i.e. the Moon has more than half its surface illuminated.
- Positions 2 and 8 are often referred to as 'crescent' moons.
- We say that the Moon is **waxing** when it is on the path from new Moon to full Moon (1 to 5) and **waning** when on the path from full Moon back to new Moon again (5 to 8, and then 1).

Study hint

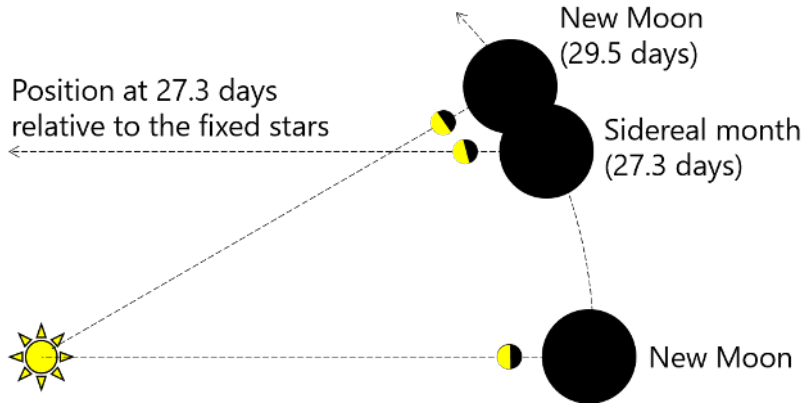
In the Northern Hemisphere you can tell that the Moon is waxing when the right side of the Moon is lit up. It is waning when the left side is lit up. The opposite is true in the Southern Hemisphere.

While the orbital period is 27.3 days, it does not follow that it takes 27.3 days to get from new Moon to new Moon. The period 27.3 days returns the Moon to the same position relative to the fixed stars, and is termed a **sidereal month**.

To achieve the same degree of illumination actually takes approximately 29.5 days because the Earth has, in the meantime,

moved round the Sun. The period of 29.5 days is called a **synodic month**. Figure 2.6 shows what has happened. During the month that it took for the Moon to orbit the Earth, the Earth has advanced almost 30° around its orbit of the Sun.

Figure 2.6 Sidereal and synodic month



Therefore, if there is a full Moon on the first of the month, then we can predict that there will be a New Moon on about the 15th of the month.

By looking at the Moon at night we can estimate what phase it will be in, say, a week or two weeks' time, or what it would have looked like a week or two ago.

Synchronous orbit and rotation

The orbit of the Moon is synchronised with its rotational period, as we saw earlier. This **synchronous orbit** is brought about by the **tidal gravitational forces** between the Earth and Moon. The Earth pulls on the Moon and causes it to bulge a little. As the Moon rotates, the bulge travels round the Moon. The body of the Moon resists this motion, and the forces induced as a result eventually cause the rotation period to become the same as the orbital period.

At this point, the same side is always facing the Earth and the bulge no longer has to travel across the Moon. Synchronous orbits have been found in a number of inner moons of other planets. This is known as **tidal locking**.

Activity 1

(Allow 20 minutes)

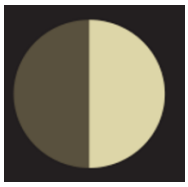
1 Which of the following best describes the synchronous orbit and rotation of the Moon?

(a) The Moon rotates with the same period as the Earth's rotation.

(b) The Moon rotates with the same period as the Sun's rotation.

(c) The Moon rotates with the same period as its orbit around the Earth.

2 If the Moon resembles the picture below on 15 February, what will it look like on 22 February?



3 What did it look like on 1 February?

4 Fill in the gaps in the paragraph below. The words available to you are: **Earth**, **Sun**, **Moon**.

The lunar cycle starts with a new Moon when the ___ lies between the ___and the ___ and the surface of the ___is not lit by the ___. After about two weeks the Moon is at the opposite end of its orbit. The ___ is behind the ___ and the surface of the ___ is fully lit, giving a full Moon.

You will find the answers at the end of the topic.

Libration

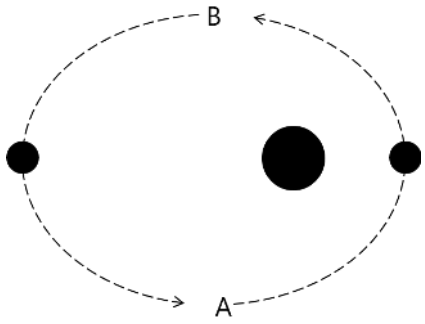
Libration is a term you may not have encountered before. It means oscillation or quivering. Libration allows us to see a little more than 50% of the Moon's surface, despite the fact that its orbit is synchronous.

There are several reasons for libration, and their combined effect is that, at different times, we are able to see up to 59% of the Moon's surface.

Libration in longitude

The orbit of the Moon is elliptical. When it is at perigee, it is closer to the Earth, and this means that the gravitational force between them is stronger, causing the Moon to accelerate. Therefore it takes less time to go from point A to B than it does from B to A, in Figure 2.7. However, the rotation about its axis is constant, and this results in us being able to see a little bit round each one of the two sides of the Moon when it is at either A or B.

Figure 2.7 Libration in longitude



Libration in latitude

The small tilt of the Moon's axis relative to the plane of the orbit (1.5°), and the 5.1° tilt of the plane of orbit of the Moon to the ecliptic, allows us, at different times, to see slightly over the North Pole of the Moon, and under its South Pole. This is libration in latitude.

Diurnal libration

Every day, because the size of the Earth is substantial, we see the Moon from various angles. These extremes again allow us to see a little over the edges of the Moon.

The combined effects of all the causes of libration and change in size are shown in this video (2:26), which consists of photographs taken at hourly intervals:

https://commons.wikimedia.org/wiki/File:Phase_and_libration_of_the_Moon_at_hourly_intervals_(2012).ogv#file

As a result of libration, astronomers spotted a feature on the extreme western edge of the Moon which they thought might be a major sea; they called this Mare Orientale.

Activity 2

(Allow 10 minutes)

1 At times the Moon looks a lot bigger. Why?

(a) Because of the effects of libration.

(b) It is a full Moon.

(c) It is at perigee.

(d) It is at apogee.

2 Fill in the gaps in the paragraph below. The terms available to you are:
lunar cycle, synodic month, sidereal month, synchronous orbit.

The Moon rotates about its axis in 27.3 days. The Moon also orbits the Earth in 27.3 days. The period of this ___ is a ___. While this is happening the Earth also moves around the Sun. So the ___ takes 29.5 days and is called a ___.

You will find the answers at the end of this topic.

Summary

You have now studied the phases of the Moon. You know how the Moon has its rotation and orbit period locked and understand how we can sometimes see a little more than 50% of its surface from Earth.

Self check

Before you move on, check what you've learnt in this topic by doing the Topic 2 self-check quiz.

Key terms

apogee: the point in the orbit of the Moon or other satellite when it is furthest away from the Earth

gibbous: a word used to the describe the Moon when it is more than half way to full Moon, but not completely full

libration: an apparent wobbling of the Moon, which allows us to see more than 50% of its surface

perigee: the point in the orbit of the Moon or a satellite when it is closest to the Earth

sidereal month: the time in which the Moon orbits the Earth, which is 27.3 days

synchronous orbit: a body orbiting another, where the period of its orbit and the period of its rotation are exactly the same; this leads to the same side of the orbiting body being seen at all times

synodic month: the time from one full Moon to the next, which is 29.5 days

tidal gravitational forces: the gravitational force between two bodies is not uniform – the nearer side is attracted more strongly than the far side, giving rise to tides

tidal locking: two objects are tidally locked when the period of rotation of one, or both, is the same as the orbital period; the Moon is tidally locked to the Earth

waning (of the Moon): from one day to the next the area of the Moon that is illuminated is smaller

waxing (of the Moon): from one day to the next the area of the Moon that is illuminated is larger

References

Phase and libration of the Moon at hourly intervals (2012), video by NASA/Goddard Space Flight Center Scientific Visualization Studio, Wikimedia Commons

Figures 2.1 and 2.2: Author's own work

Figure 2.3: The original uploader was Tomruen at English Wikipedia - Transferred from en.wikipedia to Commons by Mike Peel using CommonsHelper., CC BY-SA 3.0, https://commons.wikimedia.org/w/index.php?curid=8627371

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Video*: Phase and libration of the Moon at hourly intervals (2012)*: From Wikimedia Commons,

https://commons.wikimedia.org/wiki/File:Phase_and_libration_of_the_Moon_at_hourly_intervals_(2012).ogv#file

Video: *Understanding the night sky 2: What is the ecliptic plane?* YouTube video uploaded by Michael van Biezen 28 Aug 2014, accessed 17 Aug 2018

Going further

This video (4:04), *Understanding the night sky 2,* gives a useful explanation of the ecliptic plane:

https://www.youtube.com/watch?v=nrP4a4MCo8A

Feedback to activities

Activity 1

1 The correct answer is (c).

2 On February 22 it will be a full Moon. This is because it has gone through approximately one quarter of the lunar cycle shown in Figure 2.4.

3 February 1 was 14 days ago, so it would have looked like position 7 in Figure 2.4.

4 The lunar cycle starts with a new Moon when the Moon lies between the **Earth** [or **Sun**] and the **Sun** [or **Earth**] and the surface of the **Moon** is not lit by the **Sun**. After about two weeks the Moon is at the opposite end of its orbit. The **Sun** is behind the **Earth** and the surface of the **Moon** is fully lit, giving a full Moon.

Activity 2

1 The correct answer is (c).

2 The Moon rotates about its axis in 27.3 days. The Moon also orbits the Earth in 27.3 days. The period of this **synchronous orbit** is a **sidereal month**. While this is happening the Earth also moves around the Sun. So the **lunar cycle** takes 29.5 days and is called a **synodic month**.

What next?

We hope this sample has helped you to decide whether this course is right for you.

If you have any further questions, please do not hesitate to contact us using the details below.

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