A PHYSICS LESSON

The Moon

Our neighbour in space

The Moon makes no light of its own. So why does its shape change from one evening to the next?

1 Our satellite
2 The phases
3 Eclipses and tides
4 Going to the Moon



“Earthrise”, photographed by Bill Anders on 24 December 1968, during Apollo 8, the first crewed flight around the Moon. NASA

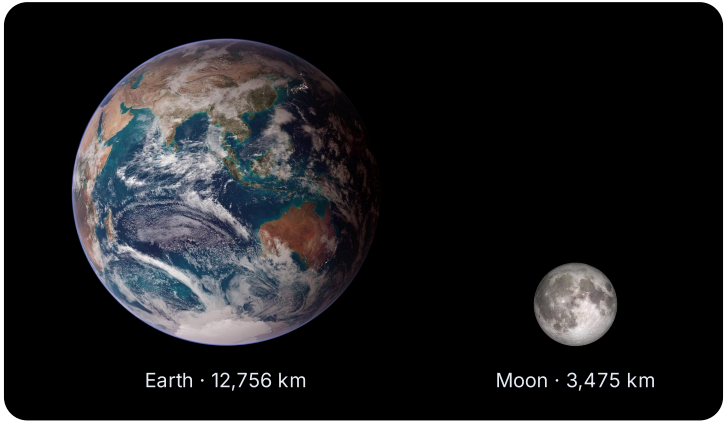
1 · OUR SATELLITE

Earth’s natural satellite

The Moon is the Earth’s only natural satellite: it goes around us, and we take it along on our trip around the Sun.

- **Size:** 3,475 km across, a little more than a quarter of the Earth.
- **Mass:** 81 times less than the Earth.
- **Gravity:** 6 times weaker than on Earth (1.62 m/s² instead of 9.8 m/s²).
- **No air:** no wind, no rain, no sound, and a sky that stays black even in daytime.
- **Temperature:** up to 120 °C in sunlight, below −130 °C at night.
- **Age:** about 4.5 billion years, almost as old as the Earth.

> **A VERY LONG DAY**
>
> On the Moon, the Sun rises only once every 29.5 Earth days: two weeks of daylight, then two weeks of night.

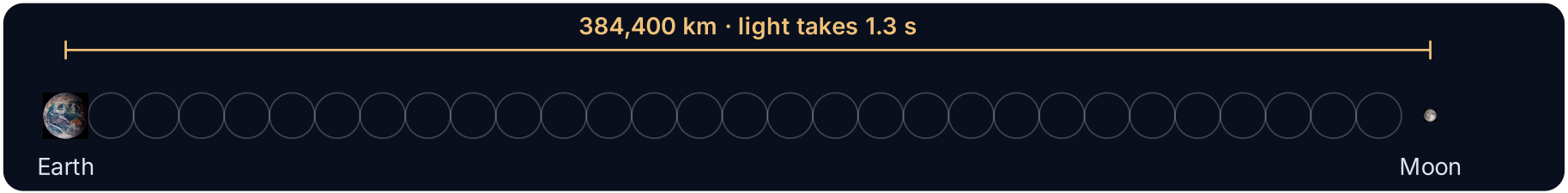


The Earth and the Moon at the same scale, but much closer together than they really are. NASA/GSFC

1 · OUR SATELLITE

How far is the Moon?

On average, **384,400 km** separate the centre of the Earth from the centre of the Moon: you could line up about 30 Earths between them.



Sizes and distance at the same scale. The dotted circles are Earths lined up between the two.

1 By car at 100 km/h, without stopping?

384,400 ÷ 100 = 3,844 hours: 160 days, more than five months.

2 By rocket, like the Apollo astronauts?

About 3 days to reach the Moon.

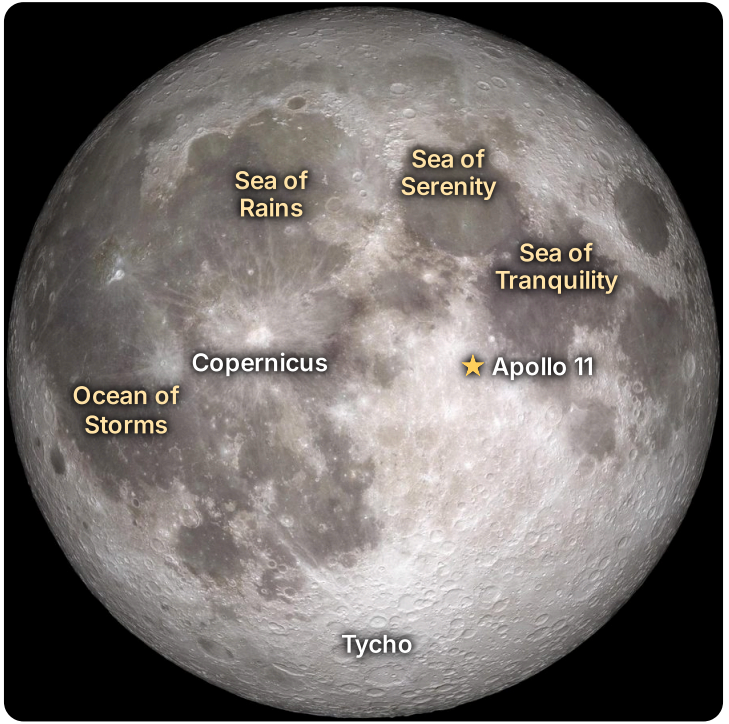
3 Does the Moon stay at the same distance?

Not quite. Its orbit is an ellipse: between 363,000 and 406,000 km. And it drifts away by 3.8 cm a year, measured by bouncing lasers off mirrors left by the Apollo astronauts.

Seas and craters

Look at the full Moon: it has dark patches and bright areas. Some people see a face in them, others a rabbit.

- The **seas** (maria) are the dark patches. They hold no water: they are plains of lava that flowed out and hardened more than 3 billion years ago. The first astronomers took them for seas, and the name stayed.
- The **highlands** are the bright areas: older, higher, covered with craters.
- A **crater** is a hole dug by a rock from space that crashed into the Moon. With no air, no wind and no rain, nothing wipes them away: they pile up for billions of years.
- Everything is covered with a fine grey dust, the **regolith**.



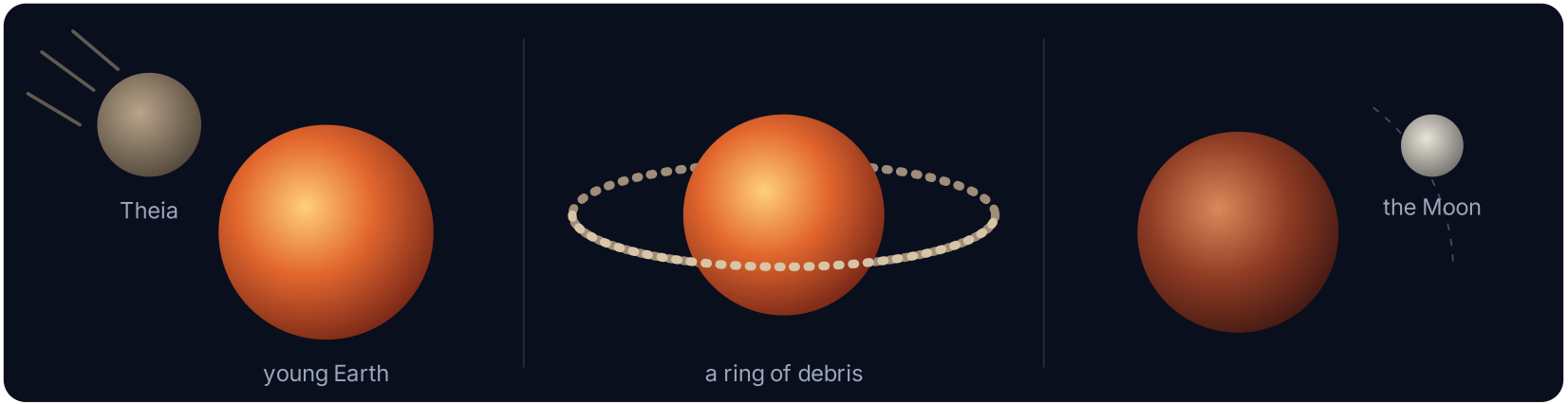
The near side of the Moon, rebuilt from the measurements of NASA's Lunar Reconnaissance Orbiter. Copernicus and Tycho are young craters: bright rays of debris spread out around them.

NASA/GSFC Scientific Visualization Studio

1 · OUR SATELLITE

Where does the Moon come from?

The explanation most scientists accept today: a giant collision, when the solar system was still young.



1 About 4.5 billion years ago, a planet the size of Mars, called **Theia**, crashes into the young Earth.

2 The shock throws molten rock out into space. It forms a ring of debris around the Earth.

3 Gravity gathers the debris into one ball: the Moon, much closer to the Earth than it is today.

THE CLUE

The rocks brought back by the Apollo astronauts look very much like the rocks deep inside the Earth: the Moon is partly made of a piece of the Earth.

2 · THE PHASES

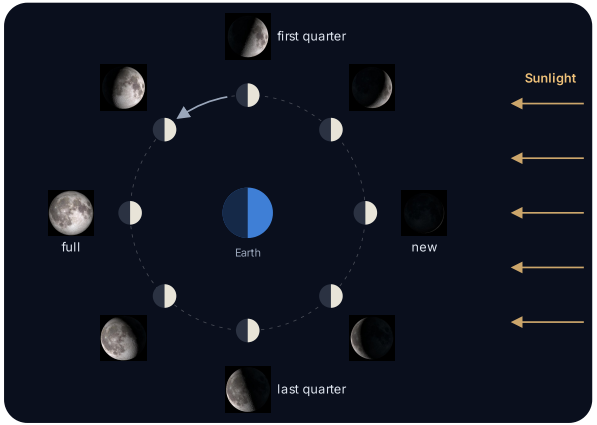
Half lit, always

The Sun always lights up **one half** of the Moon, the half that faces it. From the Earth, we see a bigger or smaller part of that lit half, depending on where the Moon is on its orbit.

- **New moon:** the Moon is between the Earth and the Sun; its lit half faces away from us.
- **Full moon:** the Earth is between the two; we see the whole lit half.
- **Quarters:** we see half of the lit half.

ONE TRIP, 29.5 DAYS

The Moon goes around the Earth in 27.3 days. But meanwhile, the Earth has moved along its orbit around the Sun: it takes two more days, **29.5 days** in all, to see the same phase again. The word *month* comes from *moon*.



Inside: the Moon on its orbit, seen from far above the North Pole. Outside: what we see from the Earth at each spot. Not to scale. NASA/GSFC SVS

The eight phases of the Moon

In 29.5 days, the Moon grows (it is **waxing**) from new to full, then shrinks (it is **waning**) back to new.



New moon	Waxing crescent	First quarter	Waxing gibbous	Full moon	Waning gibbous	Last quarter	Waning crescent
day 0	day 4	day 7	day 11	day 15	day 18	day 22	day 26

TO TELL THEM APART

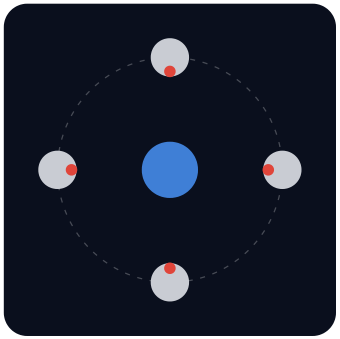
In the Northern Hemisphere, think **DOC**: lit on the right like a **D**, it is waxing; round like an **O**, it is full; lit on the left like a **C**, it is waning.

The Moon is often up in daytime: at first quarter, it rises around noon; at last quarter, it is still high in the morning sky.

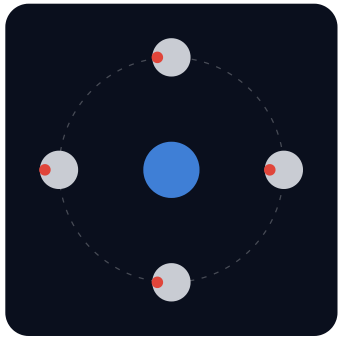
Look at a thin crescent: the rest of the disc glows faintly. That is **earthshine**, sunlight bounced off the Earth onto the Moon.

The far side of the Moon

We always see the same face of the Moon. It does spin, but it turns once on itself in exactly the time it takes to go once around the Earth: 27.3 days.



What happens: the red mark always faces the Earth.

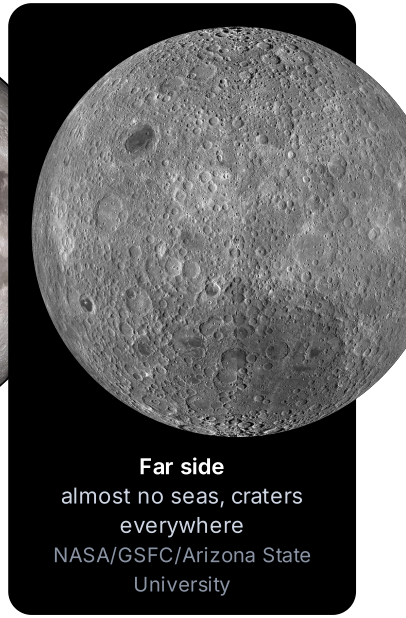


If it did not spin, the mark would always point the same way: we would see every side of it.

The far side is **not dark**: at new moon, it is in full sunlight. It was first photographed in 1959, by the Soviet probe Luna 3, and first landed on in 2019, by the Chinese probe Chang'e 4.



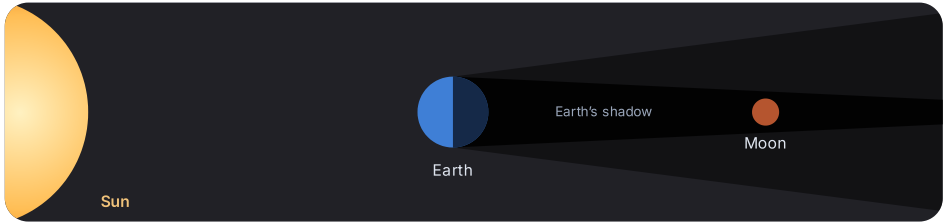
Near side
with its large dark seas
NASA/GSFC



Far side
almost no seas, craters everywhere
NASA/GSFC/Arizona State University

Eclipses of the Moon

When the Earth passes exactly between the Sun and the Moon, the Moon moves into the Earth’s shadow: it is an **eclipse of the Moon**. It can only happen at **full moon**.



Sizes and distances not to scale.

- Everyone who can see the Moon at that moment, on the night half of the Earth, sees the eclipse.
- The total part can last more than an hour and a half.
- It is safe to watch, with the naked eye or with binoculars.

NOT EVERY MONTH

The Moon’s orbit is tilted by about 5°. Most months, at new and full moon, the Moon passes a little above or below the Sun–Earth line. It must cross the plane of the Earth’s orbit at the right time: that happens about every six months.



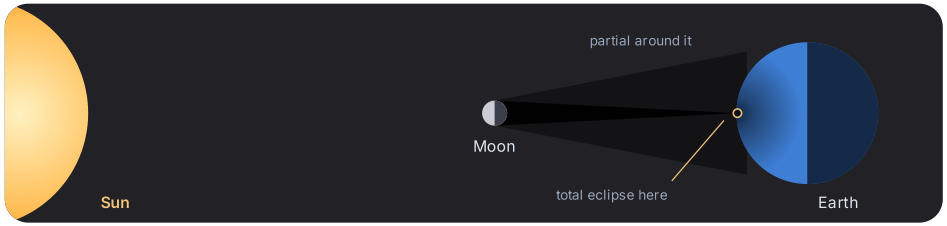
The eclipse of 8 November 2022, seen from NASA’s Kennedy Space Center, in Florida. NASA/Joel Kowsky

A RED MOON

In the shadow, the Moon does not vanish: it turns copper red. The Earth’s air bends a little sunlight into the shadow, mostly red light, as at sunset. The Moon is lit by all the sunrises and sunsets on Earth at once.

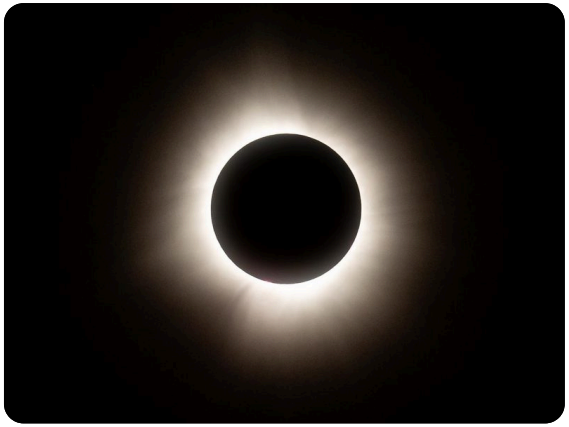
Eclipses of the Sun

When the Moon passes exactly between the Sun and the Earth, it hides the Sun: it is an **eclipse of the Sun**. It can only happen at **new moon**.



Sizes and distances not to scale.

- The Sun is about **400 times** wider than the Moon, but also about 400 times farther away: in the sky, they look the same size. That is why the Moon can just cover the Sun.
- The Moon's shadow only covers a narrow strip of the Earth: the eclipse is total only there, for a few minutes.
- On 8 April 2024, a total eclipse crossed North America, from Mexico's Pacific coast to Newfoundland.



Totality on 8 April 2024, seen from Cleveland, Ohio: around the black Moon, the Sun's outer atmosphere, the corona. NASA/Jordan Salkin

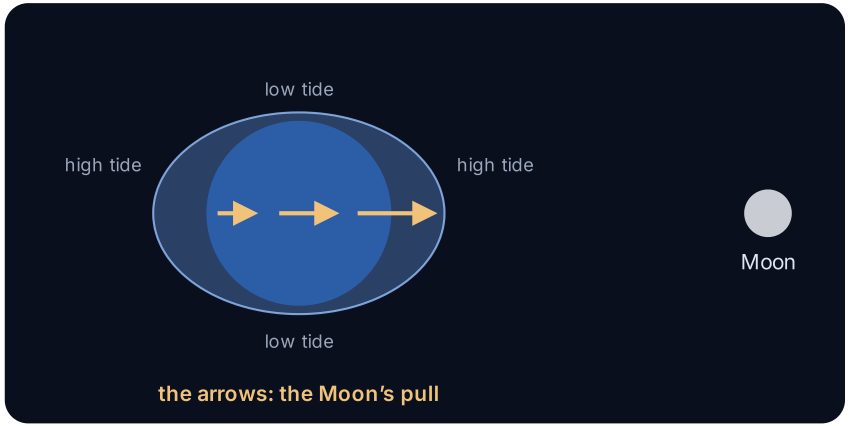
CAREFUL

Never look straight at the Sun, even during an eclipse, without special eclipse glasses. Its light can damage your eyes for good.

The tides

The Moon pulls on the whole Earth, but a bit harder on the side nearest to it and a bit less on the far side. The oceans, which move easily, stretch into **two bulges**: one facing the Moon, the other on the opposite side.

- The Earth spins under these bulges: each day, a harbour goes through two high tides and two low tides, a high tide about every **12 h 25 min**.
- The Sun raises the oceans too, about half as much as the Moon. At new and full moon, the Sun and the Moon pull along the same line: the tides are biggest (**spring tides**). At the quarters, they are smallest (**neap tides**).



Seen from above the North Pole. The bulges are greatly exaggerated: in the open ocean, they are less than a metre high.

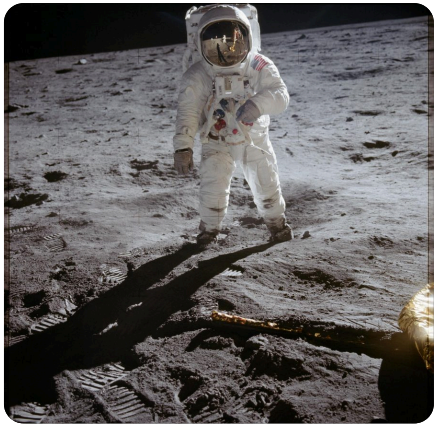
A WORLD RECORD IN CANADA

In the Bay of Fundy, between New Brunswick and Nova Scotia, the sea rises and falls by up to 16 m, the height of a five-storey building.

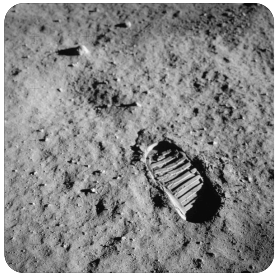
The first steps on the Moon

On 20 July 1969, Apollo 11 landed on the Sea of Tranquility. Neil Armstrong, then Buzz Aldrin, walked on the Moon, while Michael Collins waited for them in orbit.

- From 1969 to 1972, six Apollo missions landed: **twelve astronauts** walked on the Moon.
- They brought back 382 kg of rocks and dust, still studied today.
- Their footprints are still there: with no air, there is no wind or rain to wipe them away.
- With gravity six times weaker, they moved forward in little hops, even in a spacesuit of more than 80 kg.



Buzz Aldrin, photographed by Neil Armstrong. NASA



A bootprint from Apollo 11. NASA

? Your mass is 36 kg on Earth. And on the Moon?

Still 36 kg: your mass does not change. It is your **weight** that is six times smaller, because the Moon pulls on you six times less hard.

Back to the Moon: Artemis

More than 50 years after Apollo, NASA's Artemis programme, with the Canadian Space Agency and other countries, is sending people back to the Moon.

- **November 2022, Artemis I:** the Orion capsule goes around the Moon, with no crew.
- **April 2026, Artemis II:** four astronauts go around the Moon in 10 days. Reid Wiseman, Victor Glover and Christina Koch, of NASA, and **Jeremy Hansen**, of the Canadian Space Agency: the first Canadian to travel to the Moon.
- On 6 April 2026, passing behind the far side, they went farther from the Earth than anyone before them: more than 406,000 km.
- **Next:** landing near the Moon's South Pole, where water ice hides at the bottom of craters that never see the Sun.



"Earthset": the Earth disappears behind the Moon, photographed by the Artemis II crew on 6 April 2026, during their flyby of the far side. NASA

REVIEW

Test yourself

1 **Does the Moon shine by itself?**

No. It reflects the light of the Sun, which always lights up one half of it.

2 **How long from one full moon to the next?**

About 29.5 days, roughly a month.

3 **This evening, the Moon is a crescent lit on the right. Waxing or waning?**

Waxing (in the Northern Hemisphere): it looks like a D. In a few days, it will be at first quarter.

4 **At which phase can there be an eclipse of the Moon? Of the Sun?**

An eclipse of the Moon at full moon; an eclipse of the Sun at new moon.

5 **Why do we always see the same face of the Moon?**

It turns once on itself in the same time as it goes once around the Earth: 27.3 days.

6 **How many high tides in a day, and what causes them?**

Two. Mostly the Moon’s gravity, helped by the Sun’s.

TO SUM UP

The big ideas

1. The Moon, the Earth’s satellite, does not shine by itself: it reflects sunlight. It is 384,400 km away, and a little more than a quarter of the Earth’s size.

2. Its lit half shows more or less depending on where it is on its orbit: these are the **phases**, from one new moon to the next in 29.5 days.

3. When the Sun, the Earth and the Moon line up exactly, there is an **eclipse**. The Moon’s gravity raises the **tides**.

Go further

▶ The Phases of the Moon | Drop a ball on the Moon | The Solar System in Motion | Practise in the Practice Room

Photos: NASA, in the public domain (Apollo 8, Apollo 11, Artemis II, Lunar Reconnaissance Orbiter with Arizona State University, Goddard Scientific Visualization Studio; eclipses: Joel Kowsky, Jordan Salkin).