

# How Astronomers Learnt that The 'Heavens' Are Not Perfect

## Introduction

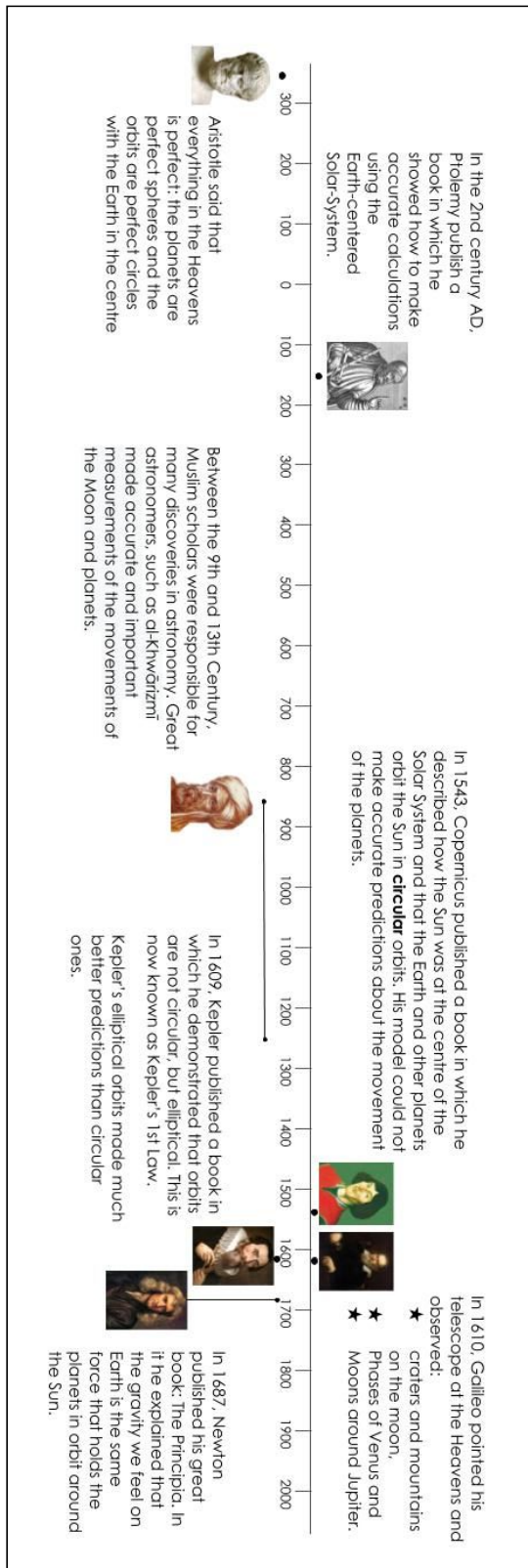
In this packet, you will read about the discoveries and theories which changed the way astronomers understood the Universe.

I have used the term 'the Heavens' to mean the place where the Sun, stars, Moon and planets move about. It is an old term, but it helps us understand how ancient astronomers viewed the Universe - perfect, wonderful and mysterious.

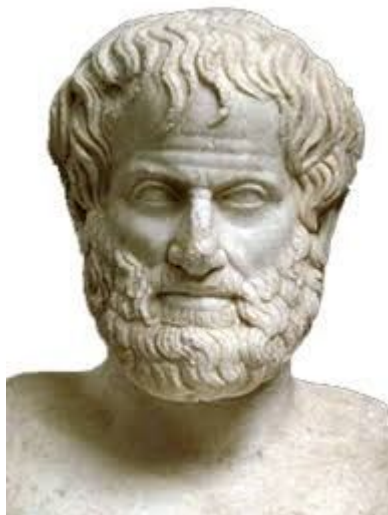
Today, we call it space.

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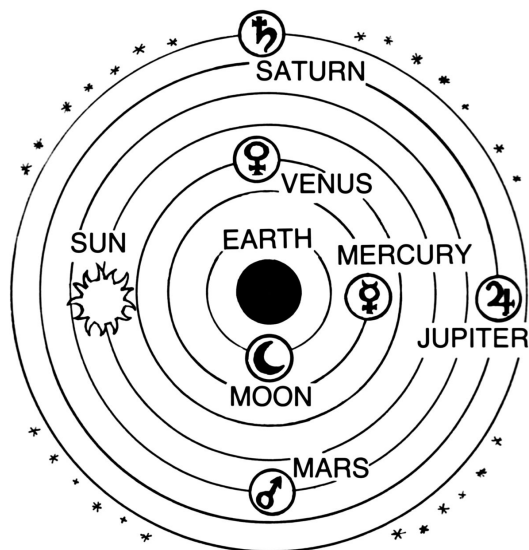
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## Aristotle (384 BC - 322 BC)



Aristotle (384 BC - 322 BC)



The Geocentric Model  
(Geo means Earth)

Aristotle believed that everything in the sky is perfect: the planets are perfect spheres and the orbits are perfect circles with the Earth in the centre.

Look at the diagram of this model above. See where the Earth has been drawn. Where is the Sun? Where is the Moon? What do the lines show?

This is called the Geocentric model (*Geo* means *Earth*, *centric* means *at the centre*). Aristotle thought that the stars were pin-holes in a giant sphere which let the light of heaven through.



Ptolemy (100 AD - 170 AD)

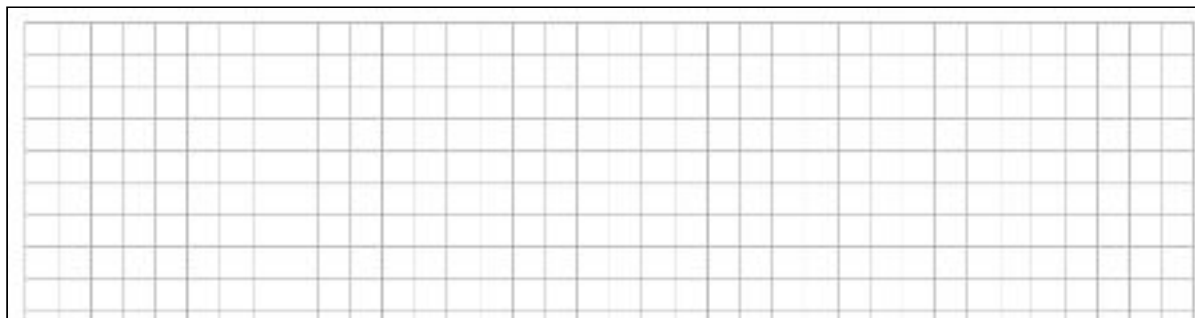
This idea was so effective that it allowed astronomers to develop a model (known as the Geocentric model). The astronomer Ptolemy (100 AD-170 AD) was able to use this model to make accurate predictions about the movements of the planets through the sky.

These ideas were believed for more than 1400 years.

**Write:** Describe the Geocentric model in your own words.

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Discuss:


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Rewrite:

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Now complete these sentences:

In the geocentric model, the Earth is at the centre, but \_\_\_\_\_

\_\_\_\_\_

In the geocentric model, the Earth is at the centre, because \_\_\_\_\_

\_\_\_\_\_

In the geocentric model, the Earth is at the centre, so \_\_\_\_\_

\_\_\_\_\_

## The Islamic Golden Age of Astronomy

(9th -13th Century)

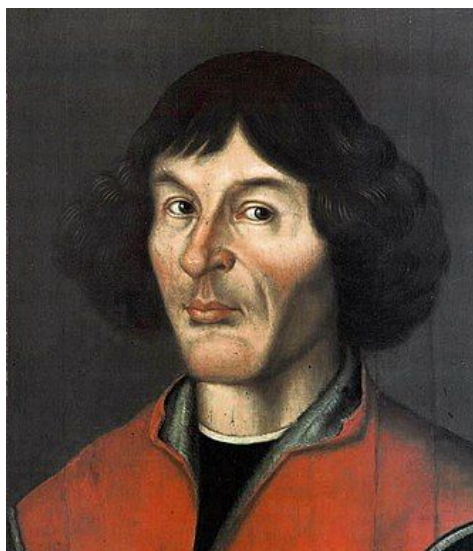


Muhammad ibn Musa al-Khwarizmi  
Died 850 AD

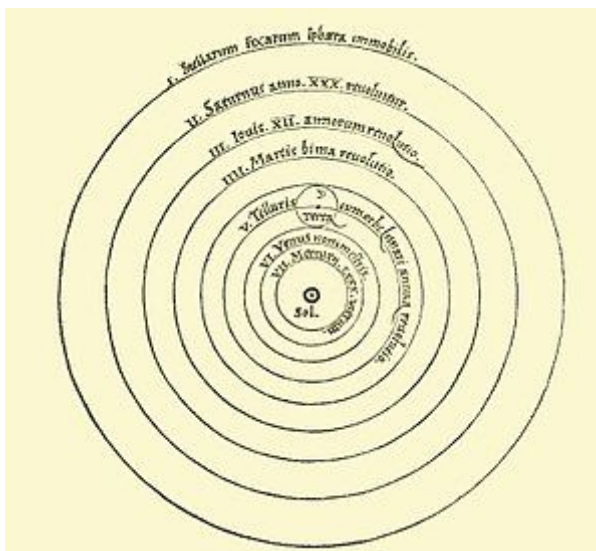
We know and remember the ancient astronomers because of a group of Muslim scholars between the 9th and 13th Century AD. These Muslim scholars were responsible for many discoveries in astronomy. Great astronomers, such as al-Khwārizmī made accurate and important measurements of the movements of the Moon and planets.

These measurements were very important to later astronomers.

## The Heliocentric Model



Copernicus  
1473 AD - 1543 AD



The Heliocentric Model  
(*Helio* means *Sun*)

In 1543, in the last year of his life, Copernicus published a book. The book described the Sun at the centre of the Solar System and explained that the Earth and other planets orbit the Sun in **circular** orbits.

This model is called the Heliocentric model (*Helio* means *Sun*).

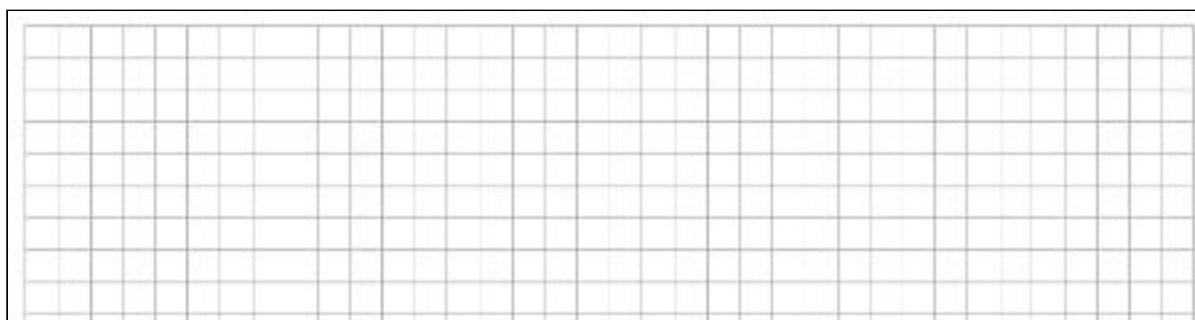
Copernicus still thought that the Heavens (the sky) was perfect - he believed the

orbits must be perfect circles. Because of this, his model could not make accurate predictions about the movement of the planets, but it was so much simpler than the Geocentric model that many astronomers believed it must be correct.

**Write:** Describe the Heliocentric model in your own words.

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Discuss:


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Rewrite:

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Now complete these sentences:

In the heliocentric model, the Sun is at the centre, but \_\_\_\_\_

\_\_\_\_\_

In the heliocentric model, the Sun is at the centre, because \_\_\_\_\_

\_\_\_\_\_

In the heliocentric model, the Sun is at the centre, so \_\_\_\_\_

\_\_\_\_\_

## The Orbits Are Not Circles

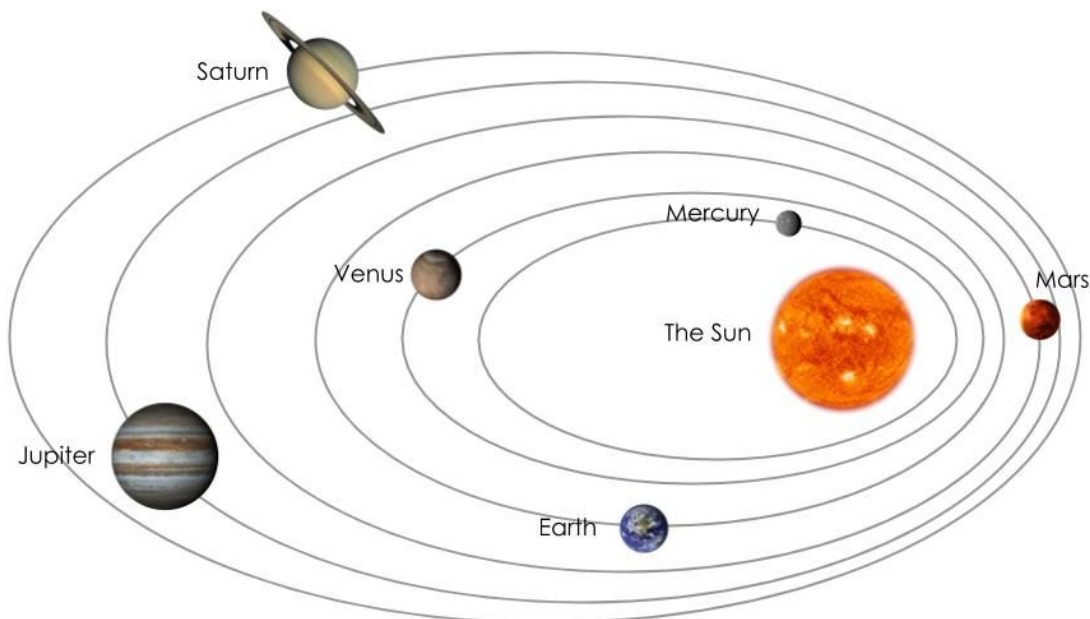


Kepler 1571 - 1630

Until 1609, astronomers believed that the planets travelled in circular orbits. It took a genius to calculate their actual paths - Kepler discovered that planets travel in ellipses.

This was a problem for astronomers. No one understood what force could make the planets travel in elliptical orbits. At first, Kepler thought it might be magnetism.

### Kepler's Elliptical Orbits (Kepler's First Law)



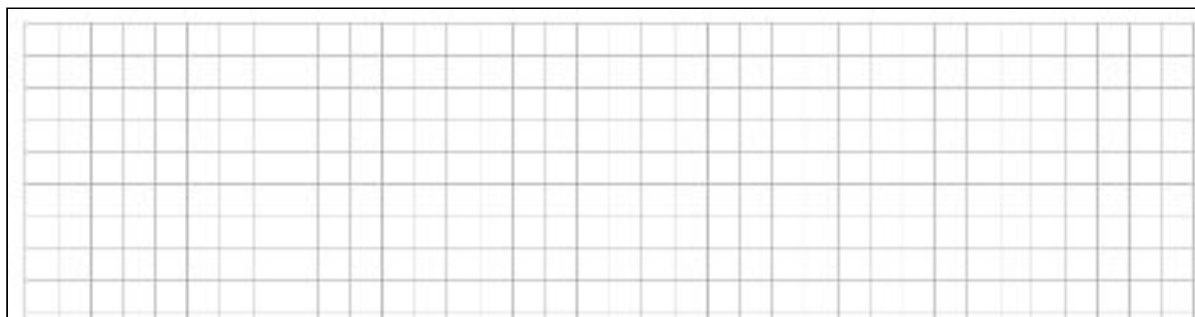
Note: to represent the **real** Solar System:

1. the orbits would have to be **much** larger.
2. The planets would need to be **much** smaller.
3. The ellipses would not be as stretched as this (that's why it took a long time to realise the orbits were not circles).

**Write:** Describe the Heliocentric model in your own words.

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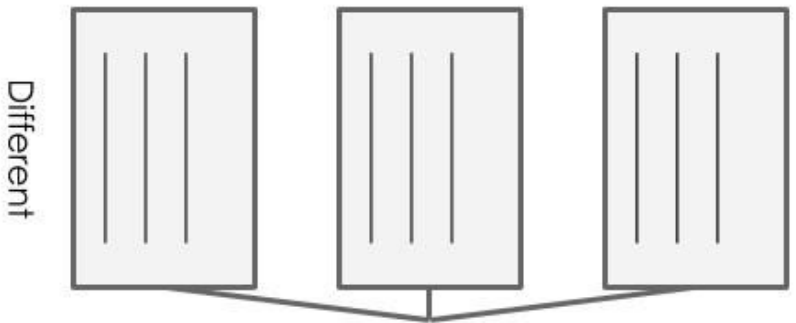
Discuss:


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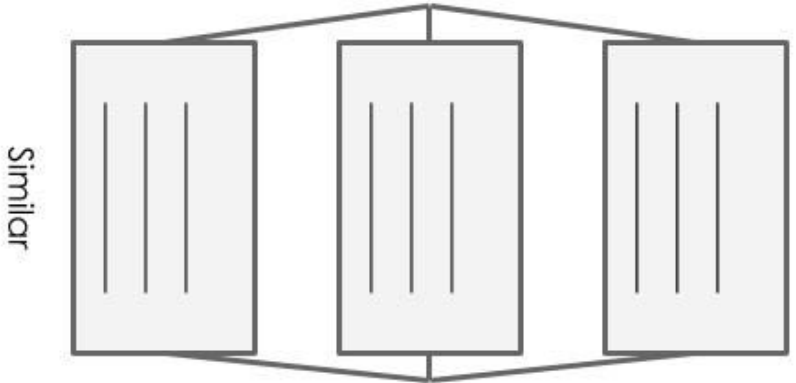
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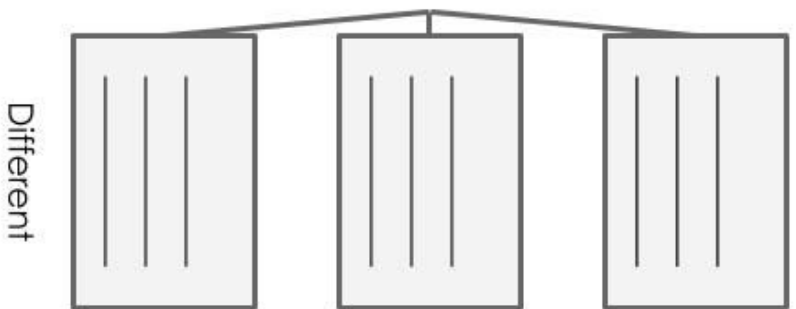
Now complete the Similar/Different task on page 8.



Geocentric Model



Heliocentric Model





## The First View of the Heavens Through a Telescope



Galileo  
1564 AD - 1642 AD

(He is holding a telescope)

Observations Jupiter (1610)	
2. J. 9. 12 marc H. 12	○ **
3. marc'	** ○ *
2. J. 12.	○ ** *
3. marc'	○ * *
3. H. 5.	* ○ *
4. marc'	* ○ **
6. marc'	** ○ *
8. marc H. 13.	* * * ○
10. marc'	* * * ○ *
11.	* * ○ *
12. H. 4. 12.	* ○ *
13. marc'	* * ○ *
14. marc'	* * * ○ *

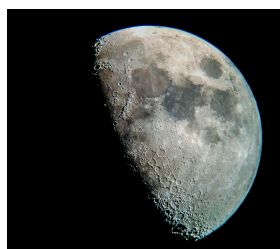
Galileo's drawing of the moons of Jupiter on different nights. You can see Jupiter as a ○ and the 4 moons as \*s.




You can see the moons are in a different position each night. They are orbiting Jupiter.

Galileo was a brilliant scientist. He made great discoveries about how objects move and made many inventions. He was also the first person to point a telescope at the 'Heavens'.

Because no one else had a good enough telescope, he was the first person to see the following things:

- ★ Craters and mountains on the moon,

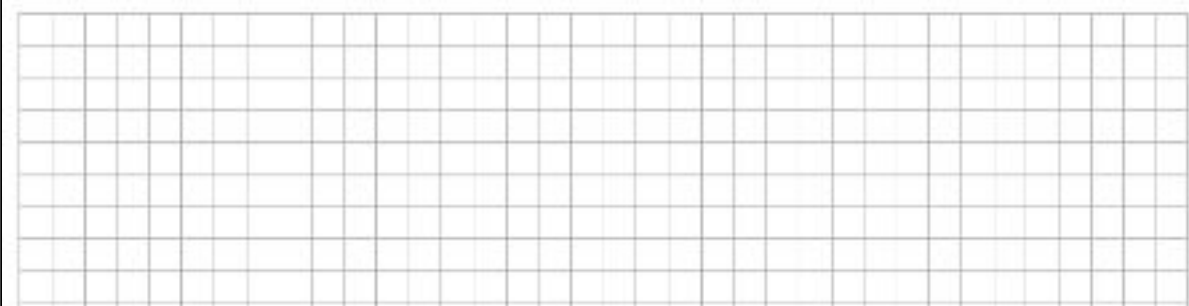


★ The phases of Venus,	
★ Moons around Jupiter and	
★ The rings around Saturn.	

**Write:** How did Galileo's observations with a telescope change the way we understand the 'Heavens'?

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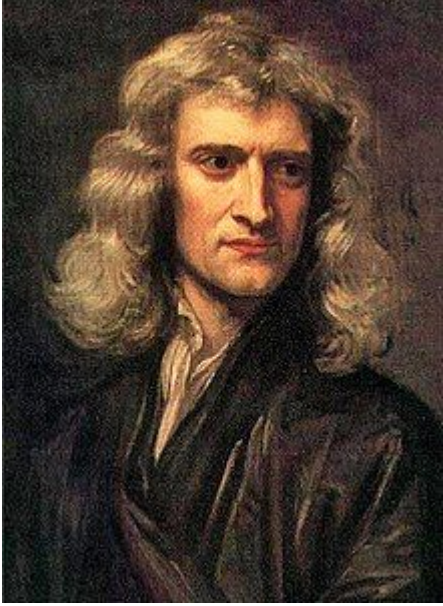
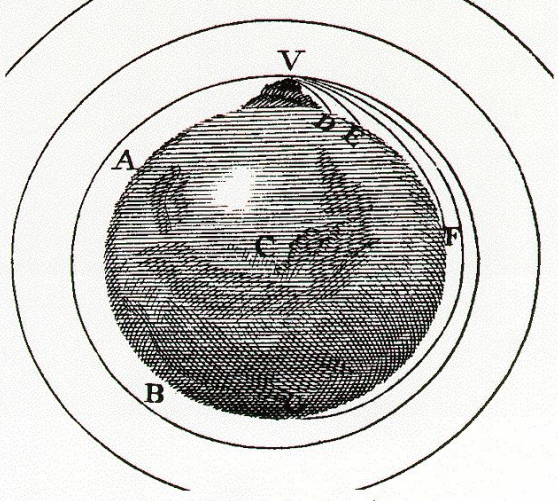
Discuss:


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Rewrite:

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## The Law of Gravitation

	
<p>Newton 1643 AD - 1727 AD</p>	<p>Newton imagined a little moon - a cannon ball. Could you fire a cannon ball fast enough that it would go into orbit? His theory says you can (and he was correct: this is how satellites, moons and planets stay in orbit).</p>

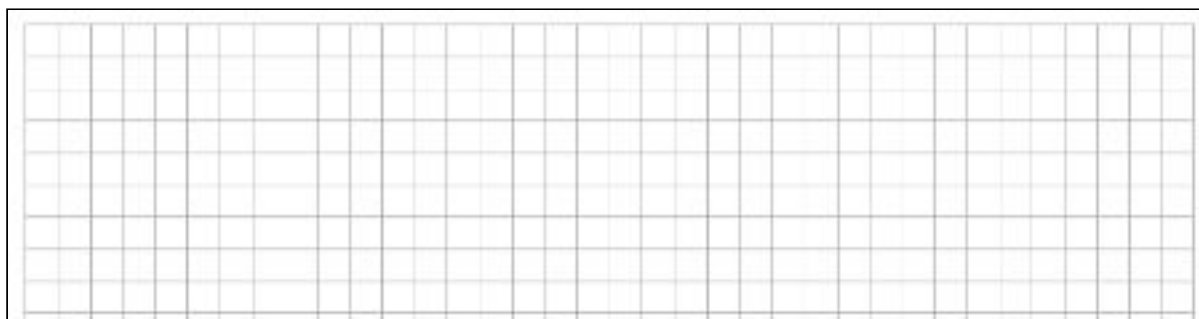
In 1686, Isaac Newton published the greatest science book of all time: *The Principia*. In it, he wrote down the law of gravitation which could explain Kepler's discovery of elliptical orbits.

Newton realised that the same force which could make an apple fall to the ground (gravity) was the same force which kept the planets travelling around the Sun.

**Write:** In full sentences, explain how Newton's law of gravitation was new.

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Discuss:


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Rewrite:

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## Low Stakes Questions

Which is the third planet from the Sun?

- Mars
- Venus
- Earth

Which force keeps the planets in orbit?

- Friction
- Gravity
- Magnetic

Why does an astronaut weigh less on the Moon than on the Earth?

- The Moon has no atmosphere
- The Moon has no gravity
- The force of gravity is weaker on the surface of the Moon than on the surface of the Earth

The orbits of the planets are:

- Perfect circles
- Ellipses
- Spheres

The further away from the Sun:

- The faster the planet moves
- The hotter the planet is
- The longer the planet's orbit takes

Why is a day on Mars about 37 minutes longer than a day on Earth?

- Because Mars is further away from the Sun
- Mars spins more slowly on its axis than Earth does
- Mars spins faster on its axis than Earth does

Why do we have seasons on Earth?

- The Earth is closer to the Sun in summer than it is in winter
- The Sun is brighter in summer than it is in winter
- The Earth's axis is tilted

What shape are the Earth, Sun and Moon?

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Which is largest, the Earth, Sun or Moon?

- The Earth
- The Sun
- The Moon

How long does it take the Earth to travel once around the Sun?

- 24 hours
- 27 days
- 365 days

How long does it take the Moon to travel once around the Earth?

- 24 hours
- 27 days
- 365 days

How long does it take the Earth to turn once on its axis?

- 24 hours
- 27 days
- 365 days

Which part of the Earth is in daylight?

- The part facing the Sun
- The part facing away from the Sun
- The part facing the Moon

Why does the Moon seem to change shape?

- Because it gets bigger and smaller
- Because we only see the part of the Moon that is lit by the Sun
- Because of clouds in the Earth's atmosphere.

Imagine you were standing underneath a tree. When would the shadow of the tree be shortest?

- At sunrise
- At midday
- At sunset

Why, in some parts of the world, are the days longer in the summer than in the winter?

- Because the Earth is tilted as it moves around the Sun
- Because the Sun gets brighter in the summer
- Because the Earth spins more slowly in the summer

Which is the smallest?

- a planet
- a star
- the Sun

What do we call an object that is in orbit around a planet?

- a star
- a satellite
- a comet

Which is the third planet from the Sun?

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Which force keeps the planets in orbit?

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The orbits of the planets are:

- perfect circles
- ellipses

Which planet is hotter?

Venus	Mars
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In a full sentence, explain your answer above:

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Why do we have seasons on Earth?

- the Earth is closer to the Sun in summer than it is in winter.
- the Sun is brighter in summer than it is in winter.
- the Earth's axis is tilted.

Which phase of the Moon is this?



- full Moon.
- new Moon.
- crescent Moon.



Mercury is hotter than the Earth, but \_\_\_\_\_

\_\_\_\_\_

Mercury is hotter than the Earth, because \_\_\_\_\_

\_\_\_\_\_

Mercury is hotter than the Earth, so \_\_\_\_\_

\_\_\_\_\_

Many people believe that there is no gravity on the Moon, but \_\_\_\_\_

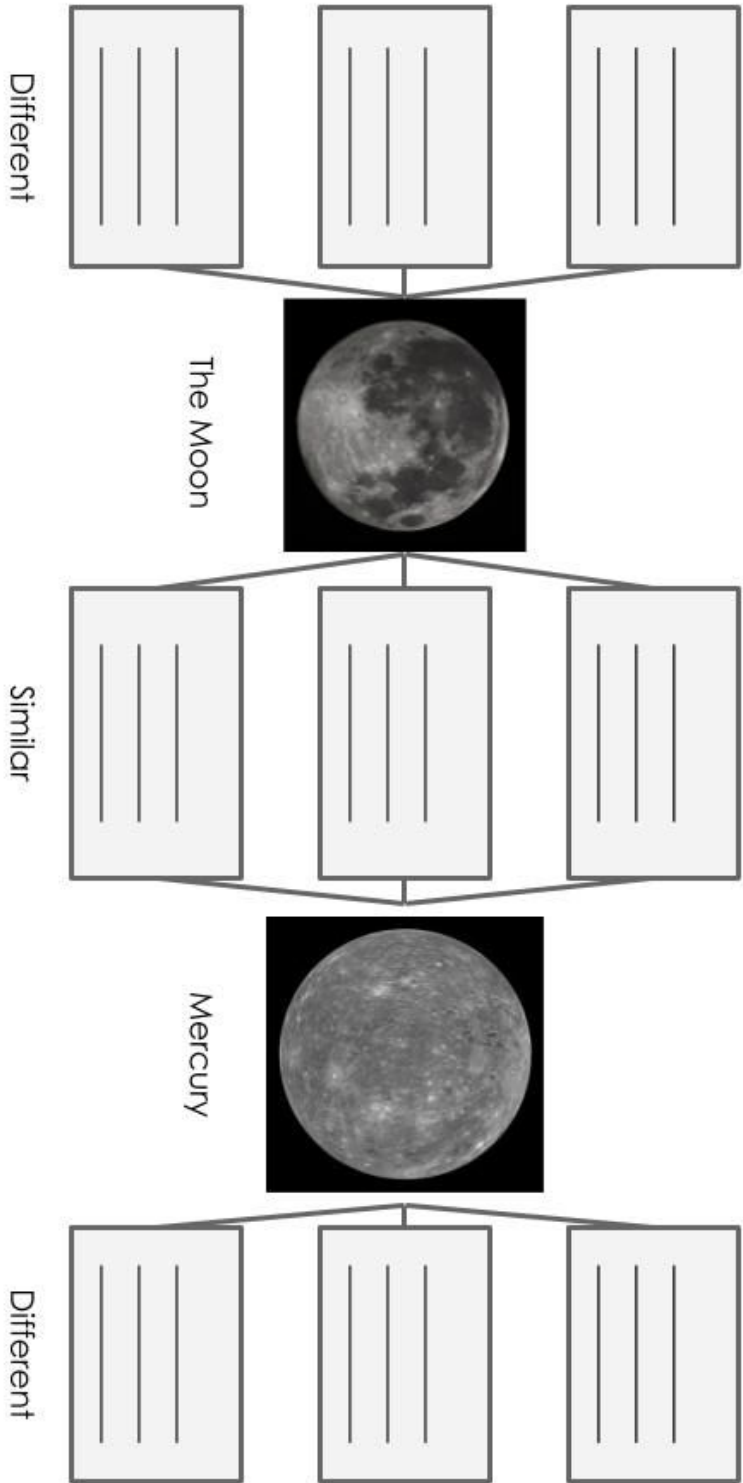
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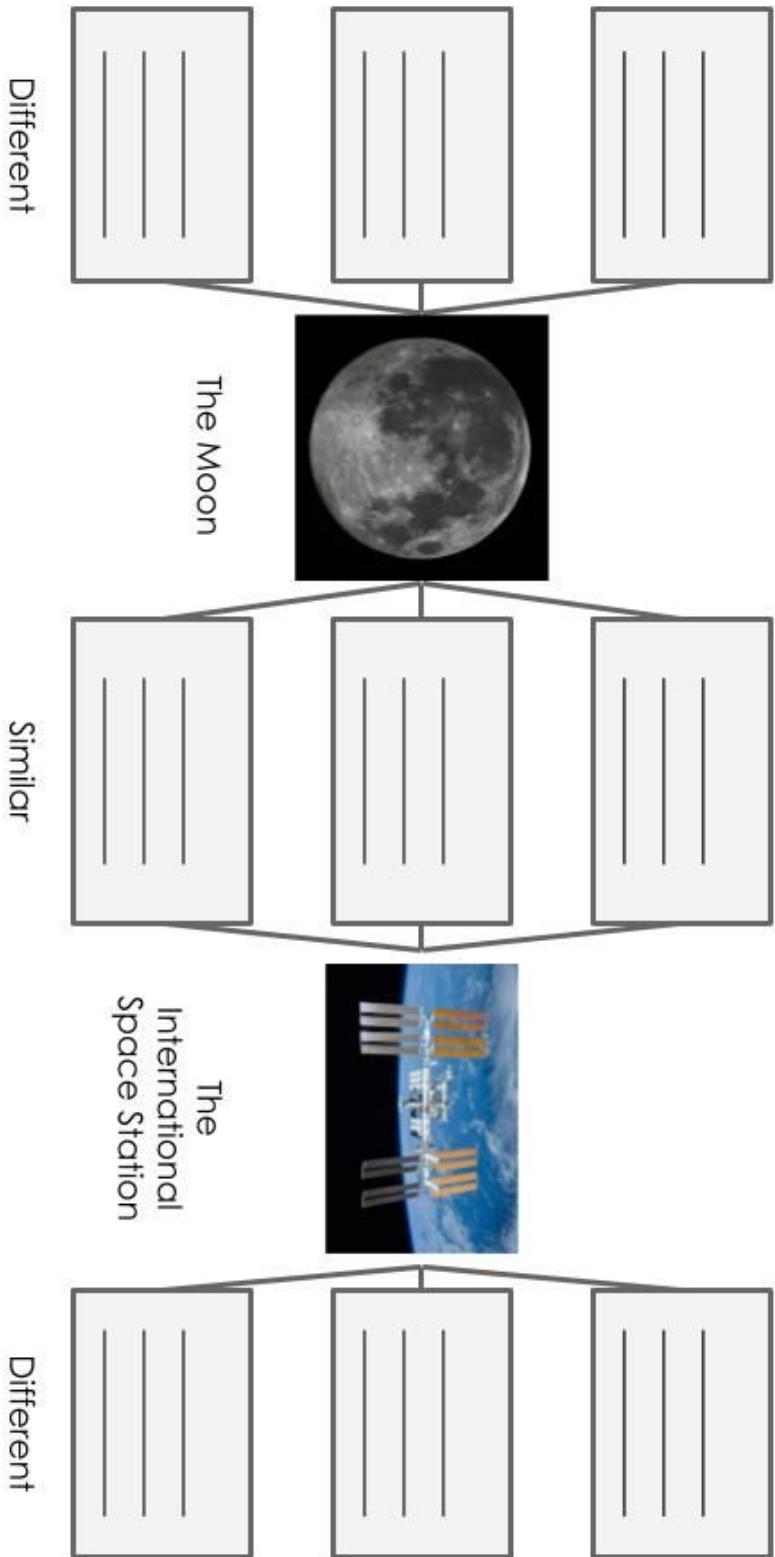
Many people believe that there is no gravity on the Moon, because \_\_\_\_\_

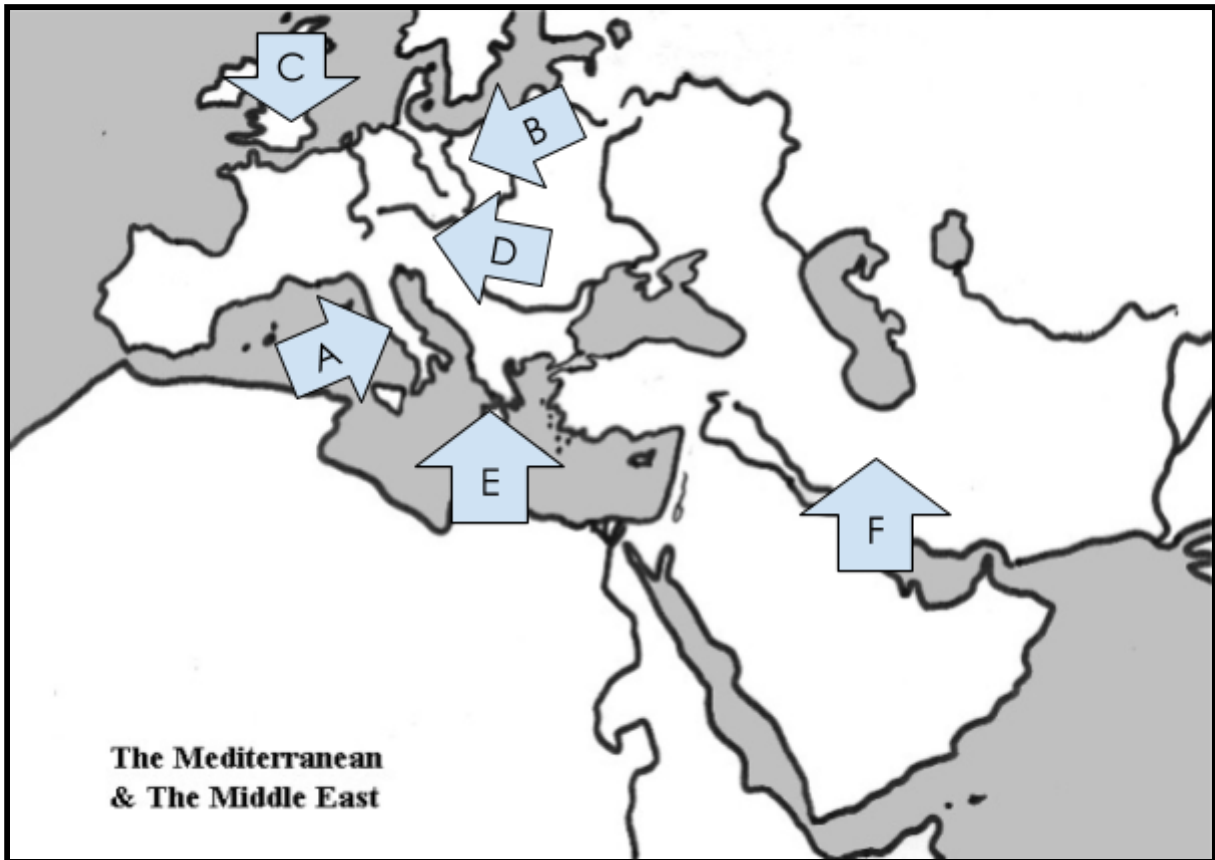
\_\_\_\_\_

Many people believe that there is no gravity on the Moon, so \_\_\_\_\_

\_\_\_\_\_







	Letter on the Map
Aristotle was from Greece	
al-Khwarizmi was from Persia	
Copernicus was from Poland	
Kepler was from Germany	
Galileo was from Italy	
Newton was from Britain	