

# Solar System

What are the planets in the solar system?

What would happen if the Earth stops rotating?

Are there other planets that can support life the way the Earth can?

Sun

Mercury

Venus

Earth

Mars

## Let's Understand:

- Solar system

## Science Blog

### The discovery of a new planet

In early 2016, astronomers found a new planet in our solar system. Astronomers refer to this planet as the 9<sup>th</sup> planet that could have a mass about 10 times that of the Earth. However, this discovery is still in its research stage. Please visit the following website for additional information.



The Discovery of a New Planet  
<https://solarsystem.nasa.gov/planets/planetx>

Info



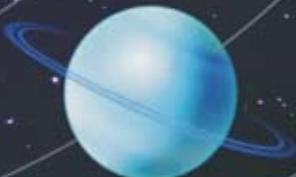
Saturn



Jupiter



Neptune



Uranus

### Keywords

- ▶ Solar system
- ▶ Astronomical unit
- ▶ Light years
- ▶ Amplitude
- ▶ Planets
- ▶ Ecological footprint

You have studied the solar system and planets in the solar system in primary school. Scan the following AR to see a 3D animation of the solar system.

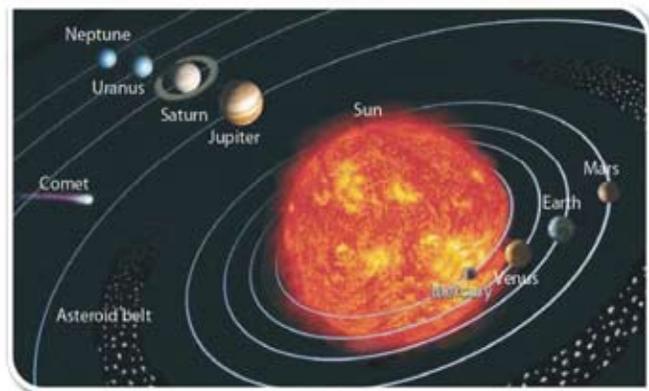


Figure 12.1 Solar system (Not to scale)



In 2006, Pluto was no longer recognised as a planet in the solar system. Instead it is known as a dwarf planet.



Animation of the Solar System



How is the distance between the planets and the Sun determined?

The distance between the planets and the Sun is very great. Therefore, astronomical unit and light years are used to measure the relative distances between the planets and the Sun.



### Comparison of Planet Distances in the Solar System from the Sun

#### • Astronomical Unit (A.U.)

Astronomical unit (A.U.) is the average distance between the Earth and the Sun, which is approximately 93 million miles or 150 million kilometres (Figure 12.2).

$$1 \text{ A.U.} = 1.5 \times 10^8 \text{ km}$$

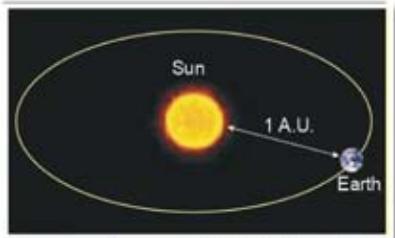


Figure 12.2 Distance of the Earth from the Sun

#### • Light Years (ly)

Light years refers to the distance travelled by light in one year. Light moves at a velocity of 300 000 km every second. Therefore, light can move as far as  $9.5 \times 10^{12}$  km in a year.

$$1 \text{ light year} = 9.5 \times 10^{12} \text{ km}$$

## Converting Units between Astronomical Unit, Light Years and Kilometres

To convert units between astronomical unit (A.U.) and km:

$$\text{Distance in A.U.} = \frac{\text{Distance in km}}{1.5 \times 10^8 \text{ km}}$$

To convert units between light years (ly) and km:

$$\text{Distance in ly} = \frac{\text{Distance in km}}{9.5 \times 10^{12} \text{ km}}$$

**Example 1:** Determine the distance of the Earth from the Sun in A.U. and ly.

**Solution:**

$$\text{Distance of Earth from Sun in km} = 1.5 \times 10^8 \text{ km}$$

$$\begin{aligned} \text{Distance of Earth from Sun in A.U.} &= \frac{1.5 \times 10^8 \text{ km}}{1.5 \times 10^8 \text{ km}} \\ &= 1.0 \text{ A.U.} \end{aligned}$$

$$\begin{aligned} \text{Distance of Earth from Sun in ly} &= \frac{1.5 \times 10^8 \text{ km}}{9.5 \times 10^{12} \text{ km}} \\ &= 1.58 \times 10^{-5} \text{ ly} \end{aligned}$$

**Example 2:** Saturn is the 6<sup>th</sup> planet in the solar system which is  $1.43 \times 10^9$  km from the Sun.

- (a) Calculate its distance in A.U.  
(b) Calculate its distance in ly.

**Solution:**

(a) Distance =  $1.43 \times 10^9$  km

$$\begin{aligned} \text{Distance in A.U.} &= \frac{1.43 \times 10^9 \text{ km}}{1.5 \times 10^8 \text{ km}} \\ &= 9.5 \text{ A.U.} \end{aligned}$$

(b) Distance =  $1.43 \times 10^9$  km

$$\begin{aligned} \text{Distance in ly} &= \frac{1.43 \times 10^9 \text{ km}}{9.5 \times 10^{12} \text{ km}} \\ &= 1.51 \times 10^{-4} \text{ ly} \end{aligned}$$

### Activity 12.1

**Aim:** Calculate the distance between the planets and the Sun in A.U. and ly.

#### Instruction

Complete the table below.

**Table 12.1** Distance of planets from the Sun in A.U. and ly

Planet	Distance from Sun (km)	Distance from Sun (A.U.)	Distance from Sun (ly)
Mercury	$5.79 \times 10^7$	0.39	
Venus	$1.08 \times 10^8$	0.72	
Earth	$1.50 \times 10^8$	1.0	$1.58 \times 10^{-5}$
Mars	$2.28 \times 10^8$		
Jupiter	$7.78 \times 10^8$		
Saturn	$1.43 \times 10^9$	9.5	$1.51 \times 10^{-4}$
Uranus	$2.87 \times 10^9$		
Neptune	$4.5 \times 10^9$	30	

## Planets in the Solar System

### Mercury



- The closest planet to the Sun, approximately 57.9 million kilometres.
- It is the smallest planet in the solar system. The diameter of Mercury is 40% smaller than the diameter of the Earth, and 40% bigger than the moon. In fact, it is smaller than Jupiter's moon, Ganymede; and Saturn's moon, Titan.
- The surface of Mercury is similar to the surface of the moon, with asteroid craters and cliffs which are tens of kilometres high. However, because of the absence of atmosphere, light cannot be scattered. As a result, the sky appears dark in outer space.

### Venus



- The second closest planet to the Sun.
- Venus is known as the 'greenhouse' planet because of the high content of carbon dioxide in its atmosphere.
- Venus also rotates from east to west, which differs from the Earth and other planets which rotate from west to east. This means that on Venus, the Sun rises from the west.
- The size and age of Venus is the same as the Earth, but its climate is far more challenging, with a temperature of approximately 460°C.

### Earth



- The third planet from the Sun.
- The only place in the universe that is inhabited by living things.
- Earth has a layer of air known as the atmosphere, which protects the surface of the Earth from solar wind, harmful ultraviolet rays and radiation from outer space.
- More than 71% of the Earth is covered in water and 29% land.

### Mars



- The fourth planet from the Sun and is also known as the 'Red Planet'.
- Mars has two moons, Phobos and Demos.
- Mars has a surface area that is only 25% that of the Earth and its mass is 10% that of the Earth.
- If observed from Earth, the atmosphere of Mars can be divided into two different areas. The brighter area is covered in dust and reddish sand, while the poles contain frozen water and carbon dioxide.



### Jupiter

- The fifth planet from the Sun and also the largest planet of all eight planets in the solar system.
- Its mass is almost 320 times that of the Earth, and is twice the amount of all the planets in the solar system.
- Jupiter is said to be the protector of the Earth, as it is able to deflect huge objects from hitting Earth with its strong gravity.



### Saturn

- The sixth planet from the Sun and the second largest planet in the solar system.
- Saturn is classified as a 'giant gas' planet.
- It has a ring system which mostly comprises of ice with a small amount of rocky material and dust.
- To date, 62 moons have been found to orbit this planet. The size of Titan, Saturn's biggest moon (after Ganymede) is bigger than Mercury.



### Uranus

- The seventh planet from the Sun.
- The first elements in the interior of Uranus are ice and rock. Uranus is the third biggest planet in the solar system. Astronomers often refer to it as a 'giant gas' planet.
- Uranus has a ring system similar to Saturn, but it is thinner and darker.
- It has many moons.
- Uranus is a unique planet because its axis of rotation is tilted, almost parallel to its orbit around the Sun.
- Uranus takes 84 years (time on Earth) to orbit the Sun.



### Neptune

- The eighth planet from the Sun.
- Also classified as a 'giant gas' planet.
- Takes almost 165 years (time on Earth) to orbit the Sun.



Video of the Solar system  
<http://bukateksksm.my/Science/Video6.mp4>

Video

Photograph 12.1 Planets in the solar system

**Table 12.2** General characteristics of planets in the solar system

Planet	Mercury	Venus	Earth	Mars
				
Distance from Sun (million km)	57.9	108.2	149.6	227.9
Relative mass (x Earth)	0.055	0.815	1	0.107
Diameter (km)	4 879	12 104	12 756	6 794
Density ( $\text{g cm}^{-3}$ )	5.4	5.2	5.5	3.9
Gravitational pull ( $\text{m s}^{-2}$ )	3.7	8.87	9.8	3.71
Average surface temperature ( $^{\circ}\text{C}$ )	167	457	14	-55
Time taken to orbit Sun (time on Earth)	88 days	224.7 days	365 days	687 days
Time taken for one complete rotation on its axis (time on Earth)	59 days	243 days	24 hours	25 hours
Velocity of rotation on axis (km/h)	10.89	6.52	1 674.4	868.2
Number of natural satellites or moons	0	0	1	2
Main atmospheric content	None (no atmosphere)	96.5% carbon dioxide; 3.4% nitrogen; 0.1% argon, helium, sulphur dioxide, water vapour	78% nitrogen; 21% oxygen; 0.97% inert gases and other substances; 0.03% carbon dioxide	96% carbon dioxide; 1.9% nitrogen; 1.9% argon; 0.2% oxygen, carbon monoxide
Condition of planet's surface	No colour, craters covered in fine dust, has plains, mountains and valleys	Orange, sandy and rocky, has big plains, volcanoes and wide craters.	More than 71% of its surface is water and 29% land (plains, mountains and volcanoes)	Red, sandy and rocky, has big plains, volcanoes and wide craters

Jupiter	Saturn	Uranus	Neptune
			
778.3	1429	2871	4504
317.8	95.159	14.536	17.147
142984	120536	51118	49528
13	0.7	1.27	1.6
24.79	10.44	8.69	11.15
-153	-185	-214	-225
11.9 years	29.5 years	84 years	164.8 years
10 hours	11 hours	17 hours	16 hours
45300	35500	9320	9660
67	62	27	14
89.6% hydrogen; 10.1% helium; 0.3% methane, ammonia, ethane, water	96% hydrogen; 3% helium; 0.4% methane, ammonia, ethane, water	83.3% hydrogen; 15.5% helium; 2.4% methane	80% hydrogen; 19% helium; 0.1% methane, ethane
No hard surface. Only covered in gas.			

**Aim:** To plan a vacation to explore outer space

**Instruction**

1. Work in groups.
2. Choose a planet as a holiday destination.
3. Collect the features of the planet and create a tourism poster or advertisement brochure to attract the interest of other classmates to visit that planet.
4. Present the product.

## Relationship between Temperature of a Planet and the Sun

Theoretically, planets that are closer to the Sun would receive more heat from it as compared to planets which are further from the Sun. However, the situation in reality is rather complex. Let us refer to the table below to understand better.

**Table 12.3** Distance of planet from the Sun and the surface temperature of each planet

Planet	Mercury	Venus	Earth	Mars	Jupiter	Saturn	Uranus	Neptune
Distance from the Sun (million km)	57.9	108.2	149.6	227.9	778.3	1427	2871	4497
Surface temperature (°C)	-173 to 427	462	-89.2 to 56.7	-143 to 35	-108	-139	-197.2	-201

### For planets that do not have an atmosphere

Mercury : sunlight that directly reaches its surface will cause the area that faces the Sun to be extremely hot, **more than 427°C**. The darker area is extremely cold, and its temperatures can drop to **-173°C**.

### For planets that have an atmosphere

- (a) Earth : has clouds that reflect sunlight back into outer space but the atmosphere traps some of the heat, which causes the greenhouse effect.
- (b) Venus : has thick clouds that can reflect sunlight back into outer space, but the atmospheric layers consist of mostly carbon dioxide which causes the greenhouse effect. Therefore, more heat is trapped and the surface temperature can reach up to **462°C**.
- (c) Mars : although it has an atmosphere, the surface pressure is extremely low compared to that of the Earth (less than  $\frac{1}{100}$  of Earth's pressure), causing minimal effect on the surface temperature. The surface temperature fluctuates between **-143°C to 35°C**.

### For giant planets

Jupiter, Saturn, Uranus and Neptune – the surface of these planets are covered in gas. These planets receive very little sunlight, therefore their surface temperatures are extremely low.

## The Relationship between Density and Gravitational Pull of the Planets

The gravity on the surface of a planet depends on its mass and density.

**Table 12.4** Relative mass, diameter, density and gravity of the planets

Planet	Mercury	Venus	Earth	Mars	Jupiter	Saturn	Uranus	Neptune
Relative mass (x Earth)	0.055	0.815	1	0.107	317.8	95.159	14.536	17.147
Diameter (km)	4 879	12 104	12 756	6 794	142 984	120 536	51 118	49 528
Density ( $\text{g cm}^{-3}$ )	5.4	5.2	5.5	3.9	1.3	0.7	1.27	1.6
Gravity ( $\text{m s}^{-2}$ )	3.7	8.87	9.8	3.71	24.79	10.44	8.69	11.15

### The gravity of the Earth

The gravity of the Earth is  $9.8 \text{ m s}^{-2}$ . This means that if we release an object from a certain height, the object will fall at an acceleration of 9.8 metres per second per second.

- The gravity of Mercury and Mars is lower than the Earth because their masses are lower than the Earth.
- The gravity of Venus is almost the same as the Earth's because its mass is almost the same as the mass of the Earth.
- The gravity of Jupiter is much higher compared to the Earth because its mass is extremely high although it has a low density.
- Although Saturn, Uranus and Neptune have very high mass, their gravity is not as high as the gravity of the Earth because these 'giant gas' planets have low density.

## The Relationship between Distance, Time and Speed

**Table 12.5** Distance from the Sun and time taken for each planet to orbit the Sun

Planet	Mercury	Venus	Earth	Mars	Jupiter	Saturn	Uranus	Neptune
Distance from Sun (million km)	57.9	108.2	149.6	227.9	778.3	1 427	2 871	4 497
Time taken to orbit the Sun (time on Earth)	88 days	224.7 days	365 days	687 days	11.9 years	29.5 years	84 years	164.8 years

- The further a planet is from the Sun, the more time it needs to orbit the Sun.

For example, Mercury is the closest planet to the Sun. It takes only 88 days to orbit the Sun. Neptune is the furthest planet from the Sun and it takes 164.8 years to complete its orbit around the Sun.

## Rotational direction of the planets

All planets in the solar system rotate on their axis at different angles (Figure 12.3). All these planets rotate from **west to east** except Venus and Uranus. Venus rotates from **east to west** while Uranus rotates on its side. Why do these two planets have different rotational direction as compared to the other planets?

**My Science World**

The Earth rotates from west to east, and therefore we see the Sun rising in the east and setting in the west.

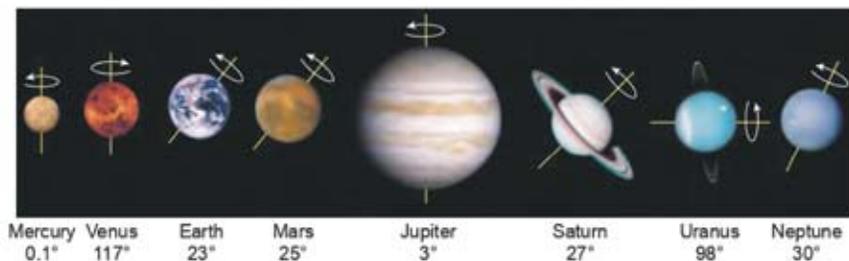


Figure 12.3 Rotational angle and direction of the planets in the solar system

## Hypothetical Situation related to the Solar System

What happens if the rotation of the Earth slows down or stops completely?

We know that the rotation of the Earth on its axis is the reason for several phenomena such as day and night, tides and many more.

What would happen if the Earth rotates slower or stops rotating?

Longer day and night duration in two different parts of the Earth

More desert areas in parts of the Earth that faces the Sun

Change in high and low tides

Temperature will drop in areas of the Earth that do not receive sunlight

Figure 12.4 Effects that take place if the Earth rotates slower or stops rotating

### What are natural satellites?

Natural satellites are objects that move around planets on their own orbit. The moon is the only natural satellite of the Earth (Figure 12.5).



Figure 12.5 The Earth orbits the Sun, while the Moon orbits the Earth

### How would the condition and appearance of the Earth be from the Moon?

Just like the Earth, the Moon also rotates on its own axis. At the same time, the Moon also moves around the Earth on its orbit. The duration taken for the Moon to rotate on its axis and orbit the Earth is about the same, which is 27 days. Therefore, the same surface of the Moon would be facing the Earth at all times. The Earth is four times bigger than the Moon. How would the Earth appear from the Moon?



Photograph 12.2 Appearance of the Earth from the Moon

## The Earth as a Planet for Living Things



Figure 12.6 The Earth

The Earth is the only planet that has life. The Earth can support life because of a few factors such as the presence of water, minerals, its temperature and atmospheric content. Discuss the characteristics of the Earth as a planet most suitable for life. Are there other planets that are suitable for life if the resources on the Earth are fully exhausted or the Earth is destroyed by natural disasters and pollution? What is the role of each individual to preserve the Earth?



Figure 12.7 Characteristics of the Earth as the most suitable planet for life

 **My Malaysia!**



Datuk Dr. Mazlan Othman is well known in the field of research and development of astronomy in Malaysia. She has not only received recognition at national level but is also admired in the international arena.



### Activity 12.3

**STEM**
**21**  
Century

**Aim:** To look for new ideas of the possibility of other planets to replace the Earth if the natural resources on the Earth are depleted.

#### Instruction

1. Work in groups.
2. Use your creativity or imagination to think about the possibility of a planet to support life if the natural resources on the Earth are depleted. Collect information from the Internet or the library.
3. Present ideas using a multimedia presentation.

#### Career in STEM

Astronomers are scientists who study objects in outer space such as planets, stars and galaxies. They are looking at the possibilities of other planets to replace the Earth.

## Love Our Earth

Human life relies heavily on resources from water and earth, including to get food, manufacturing materials and to generate energy. The increase in human population has caused rapid exploration of the seas and land. Are the Earth's natural resources able to sustain the increasing needs and wants of humans?

- **Ecological footprint** is the measure of the ability of water and land to provide the basic needs of humans (food, water, shelter and others) as well as the ability of the Earth to absorb all human wastes and reproduce resources after they have been used by humans.
- Ecological footprint is the ratio measurement for six areas, which are **carbon dioxide waste treatment areas, construction areas, forests, agricultural areas, farming areas** and **fishing areas** using the shape of a human foot.
- If the ecological footprint exceeds the ability of the Earth to renew its resources, the Earth will be depleted of all its resources.
- Ecological footprint is different between countries.

## Ecological Footprint

To measure the rate of human use of the resources of the Earth and the rate of human waste production.

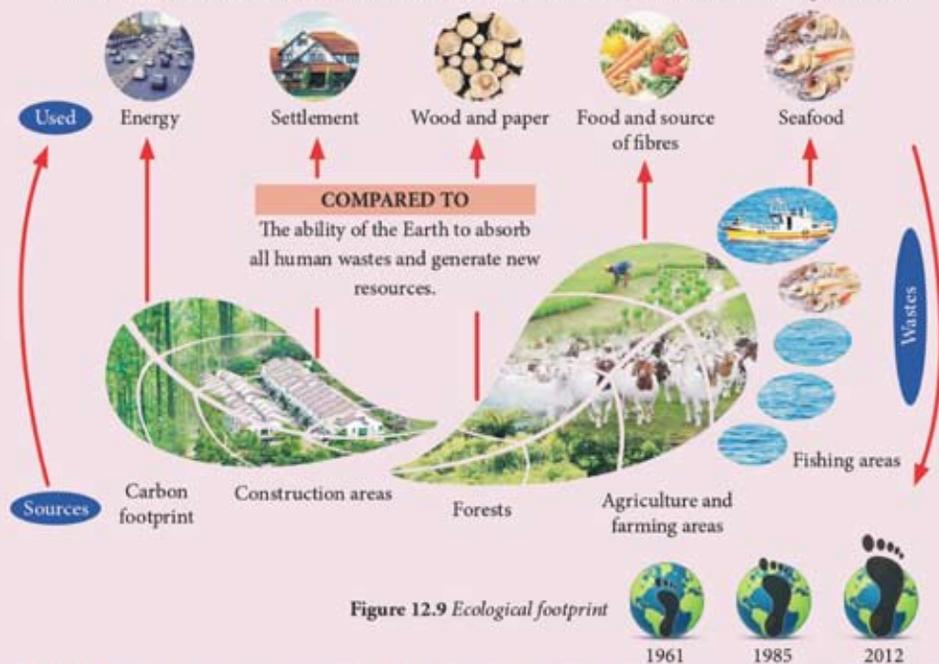


Figure 12.9 Ecological footprint

## Activity 12.4

**Aim:** To discuss the steps and importance of reducing our ecological footprint.

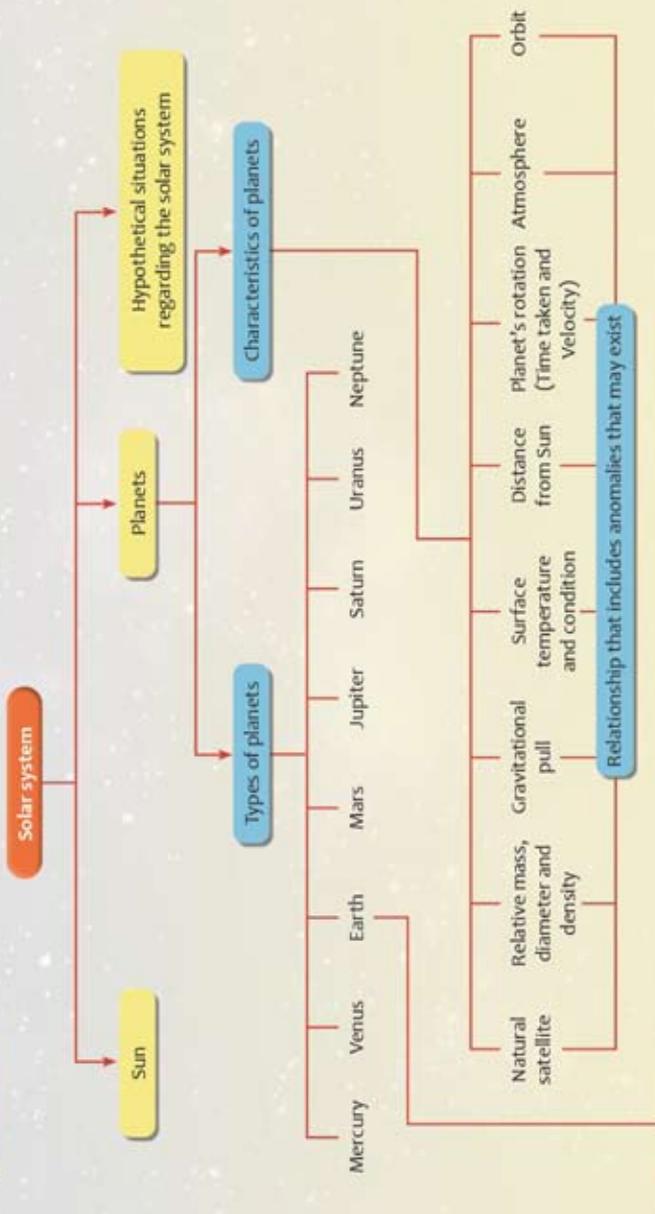
**Instruction**

1. Work in groups.
2. Each group is assigned with collecting information on ecological footprint.
3. Discuss:
  - (a) the steps we can take as consumers to reduce our ecological footprint
  - (b) the importance of reducing our ecological footprint.
4. Present the results in the form of a multimedia presentation.

## Formative Practice 12.1

1. Why are A.U. and ly used to determine the distance between planets and the Sun in the solar system?
2. Which planet is closest to the Sun?
3. What is the relationship between the surface temperature of a planet and its distance from the Sun?

# Summary



Earth is the most suitable planet for living things



Interactive Quiz 12

Quiz



## SELF-REFLECTION

After learning this chapter, you are able to:

### 12.1 Solar System

- Compare the distance between the Sun and the planets in the solar system using astronomical unit (A.U.) and light years (ly).
- Construct a table to compare and contrast the planets in the solar system and the Earth.
- Explore the possible relationship based on the characteristics of the planets and explain the relationship including anomalies that may arise.
- Reasoning and making analogies in hypothetical situations related to the solar system.
- Justify why the Earth is the most ideal planet for life based on data collected.

## Summative Practice 12

- Figure 1 shows the solar system.
  - State the number of planets that are in the solar system.
  - State the planet that is the nearest to and furthest from the Sun.
  - Why does Mercury orbit the Sun faster than the Earth?
- Figure 2 shows phenomena that happen on the Earth.



Figure 1



Sun rises in the East



Sun sets in the West

Figure 2

- Which characteristic of the Earth causes such phenomena?
- Venus has a different rotational direction compared to the Earth. Predict the phenomena of the sun rising and setting that can be seen on Venus.
- Predict two possibilities that might take place if the Earth stops rotating. 🧠

3. A star is 4.37 light years away from the Sun.

- Calculate its distance in km.
- Calculate its distance in A.U.

4. The natural resources of the Earth such as wood and fossil fuels are decreasing.

One way to overcome this issue is to recycle materials. Design a new product that uses waste materials.

5. The information below shows the distance of planet *P*, *Q* and *R* in the solar system from the Sun.

*P*: 108.2 million km  
*Q*: 2 871 million km  
*R*: 778.3 million km

- Based on the information above, which planet is the hottest and the coldest? Give reasons for your answers.
- Which planet takes the longest time to orbit the Sun? Give reasons for your answers.

## HOTS Mastery 12

6. (a) Venus is considered as a twin planet to the Earth because its size, volume and density are similar to that of the Earth. Why doesn't this planet have any living things compared to the Earth?
- (b) Two students were having a conversation about Mercury and Venus.

Aisyah : Mercury is the closest to the Earth, and therefore is the hottest planet in the solar system.  
 Pei Lui : No. Venus is the hottest planet in the solar system.

In your opinion, who is correct? Give reasons for your answers.

7. Europa is a natural satellite of Jupiter (Figure 3) which is very unique as there is a possibility of seawater below the surface of the ice. In your opinion, why do scientists have an assumption that there is life on Europa?

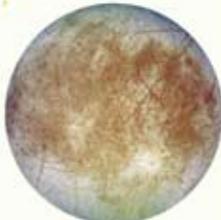


Figure 3