

# SPACE

AQA GCSE Physics | Topic 8

**TEACHER EDITION**

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Name: \_\_\_\_\_

Teacher: \_\_\_\_\_

# Space Facts Quiz

Cover the answer column and test your recall. Use these for quick retrieval practice.

#	Question	Answer
1	How many planets are there in our solar system?	<i>There are eight planets and one dwarf planet (Pluto).</i>
2	Write the planets in the solar system in order.	<i>Mercury, Venus, Earth, Mars, Jupiter, Saturn, Uranus, Neptune.</i>
3	What is a satellite? What are the two types of satellite?	<i>A satellite is something in orbit around a planet. A satellite can be natural (like the Moon) or artificial (like communications or weather satellites).</i>
4	What galaxy is the solar system a part of?	<i>The solar system is part of the Milky Way galaxy.</i>
5	What is a nebula?	<i>A nebula is a cloud of dust and gas.</i>
6	How is a star formed?	<i>A nebula gets pulled together under gravity. Friction heats hydrogen until the nebula is hot enough for nuclear fusion to happen.</i>
7	Once a star is formed, how does it reach equilibrium?	<i>When a star is formed it is stable because the forces within it are balanced. Gravity acts inwards. This is balanced by the outward force of radiation from nuclear fusion trying to make the star expand.</i>
8	What are the stages in the life cycle of a star of similar size to the Sun?	<i>Nebula → Protostar → Main sequence star → Red giant → White dwarf → Black dwarf.</i>
9	What are the stages in the life cycle of a star much more massive than the Sun?	<i>Nebula → Protostar → Main sequence star → Red supergiant → Supernova → Neutron star / Black hole.</i>
10	How are elements heavier than iron produced?	<i>In the explosion of a massive star (supernova) elements heavier than iron are spread throughout the universe.</i>
11	What provides the force that allows planets and satellites to maintain their circular orbits?	<i>Gravity.</i>
12	How can the force of gravity lead to changing velocity but unchanged speed?	<i>Velocity is a vector, whereas speed is a scalar. As an object orbits, its direction changes. Therefore the velocity changes even if speed does not.</i>
13	What happens to the radius of an orbit if the speed increases?	<i>If the speed increases, then the radius of an orbit decreases.</i>
14	What evidence do we have for the Big Bang?	<i>There is an observed increase in the wavelength of light from most distant galaxies. The further away the galaxies, the faster they are moving and the bigger the observed increase in wavelength. This effect is called the red-shift. Cosmic microwave background radiation (CMBR) is another piece of evidence.</i>
15	What does the red shift tell us about the universe?	<i>The red shift tells us that the universe is expanding and that it began from a very small region that was extremely hot and dense.</i>
16	What happens to the wavelength of a wave if the source is moving towards us?	<i>The wavelength decreases as the source moves towards us (the Doppler effect). The opposite happens if the source is moving away from us.</i>

#	Question	Answer
17	What have observations of recent supernovae suggested?	<i>Observations of supernovae suggest that distant galaxies are receding even faster.</i>

## LESSON 1

# Our Solar System

## Do Now

1. Name as many planets in our Solar System as you can.

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2. Name the force that causes objects to fall to the ground.

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3. Name three different forces.

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4. What is the difference between **mass** and **weight**?

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## Part 1 of 3 | The Sun and the Planets

### Key Information

Our <b>Solar System</b> is made of one star (the <b>Sun</b> ) and eight planets that orbit around it.	1
The eight planets, in order from the Sun: <b>Mercury, Venus, Earth, Mars, Jupiter, Saturn, Uranus, Neptune.</b>	2
A useful mnemonic: <i>My Very Easy Method Just Speeds Up Naming Planets.</i>	3
The first four planets (Mercury, Venus, Earth, Mars) are <b>terrestrial planets</b> — small, rocky.	4
Jupiter, Saturn, Uranus, Neptune are <b>gas giants</b> (Uranus and Neptune are sometimes called ice giants).	5
Pluto is now classified as a <b>dwarf planet</b> , not a planet, because it has not cleared its orbit of other objects.	6
Other objects in the solar system include moons, comets, asteroids and dwarf planets.	7

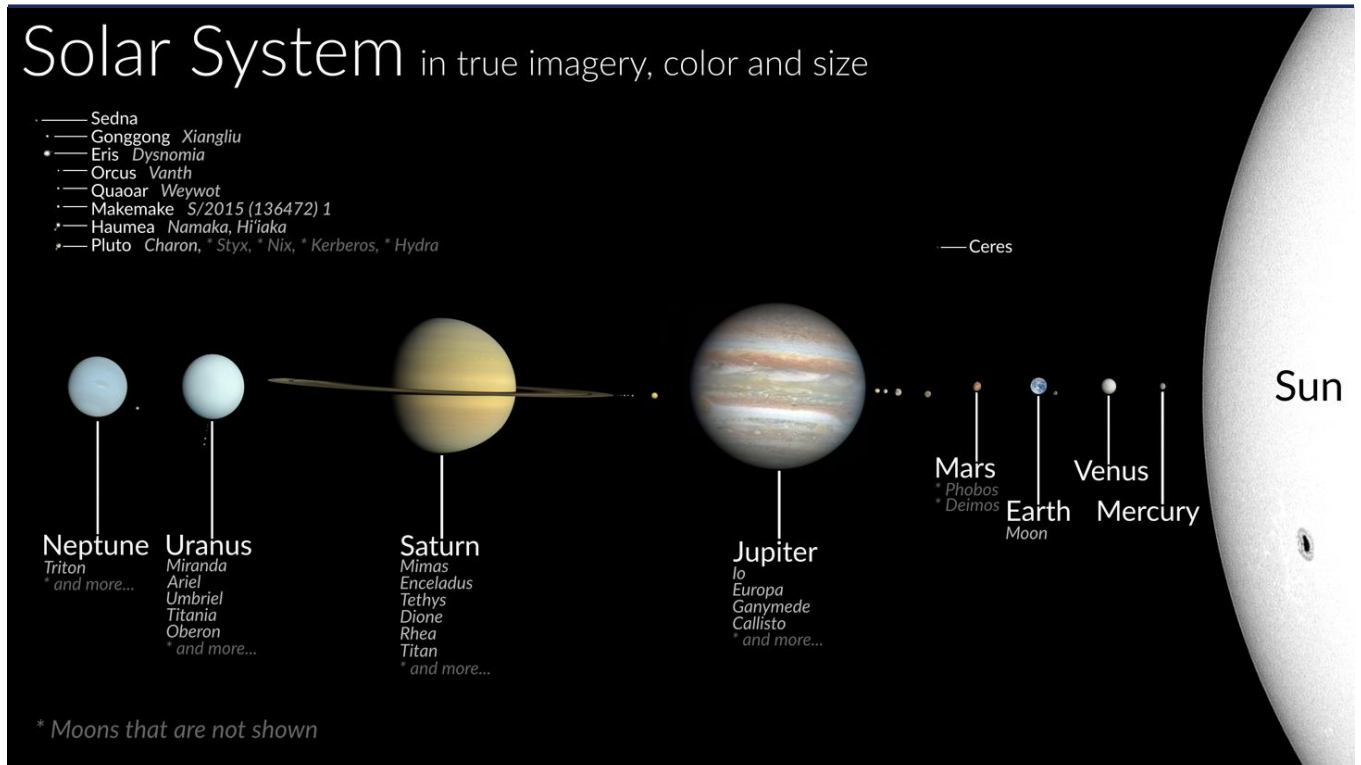


Fig 1.1 — The eight planets of the Solar System in true colour and size

**Questions**

- Name the star at the centre of our Solar System. (1 mark)

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- List the eight planets of the Solar System in order, starting from the Sun. (4 marks)

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- State which type of object Pluto is now classified as. Explain why it is not classed as a planet. (2 marks)

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- Name two terrestrial planets and two gas giants. (2 marks)

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- Other than planets, name three other types of object that orbit the Sun. (3 marks)

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**Answers**

- The Sun.
- Mercury, Venus, Earth, Mars, Jupiter, Saturn, Uranus, Neptune. (1 mark for first four in correct order; 1 mark for last four in correct order; 2 marks if all correct.)
- Pluto is a dwarf planet (1). It has not cleared its orbit of other objects, so it does not meet the full definition of a planet (1).
- Any two terrestrial: Mercury / Venus / Earth / Mars (1). Any two gas giants: Jupiter / Saturn / Uranus / Neptune (1).
- Any three from: moons, comets, asteroids, dwarf planets, meteoroids.

## Part 2 of 3 | Galaxies and the Universe

## Key Information

A <b>galaxy</b> is a huge collection of billions of stars, held together by gravity.	1
Our Solar System is part of the <b>Milky Way</b> galaxy.	2
There are billions of galaxies in the observable <b>Universe</b> .	3
A <b>star</b> is a giant ball of plasma (mostly hydrogen and helium) that emits light and heat from <b>nuclear fusion</b> .	4
Stars are very far away — distances are often measured in <b>light-years</b> (the distance light travels in one year).	5
The order of size, smallest to largest: planet < star < solar system < galaxy < Universe.	6



Fig 1.2 — A nebula: a cloud of dust and gas from which stars form



Fig 1.3 — Our Sun, a main sequence star

## Questions

6. State which galaxy our Solar System belongs to.

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(1 mark)

7. Define what is meant by a **galaxy**.

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(2 marks)

8. Explain the difference between a **star** and a **planet**.

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(2 marks)

9. Place these in order of size, smallest first: galaxy, planet, Universe, star, solar system.

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(2 marks)

10. State **one** reason why distances in space are usually measured in light-years rather than kilometres.

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(1 mark)

**Answers**

6. The Milky Way.
7. A huge collection of billions of stars (1) held together by gravity (1).
8. A star produces its own light and heat from nuclear fusion (1). A planet does not produce light; it orbits a star (1).
9. Planet, star, solar system, galaxy, Universe. (1 mark for first three correct; 2 marks if fully correct.)
10. Distances in space are so large that kilometre values would be inconveniently huge / impractical to write or compare.

**Part 3 of 3 | Exam-Style Questions****EXAM QUESTION — Q1: Our Solar System (8 marks)**

Mark allocations shown as (n) following AQA convention.

(a) There are eight planets in orbit around the Sun. Which other type of object also orbits the Sun? Tick **one** box: Dwarf planet  Galaxy  Moon  Star

\_\_\_\_\_ (1)

(b) Complete the sentences. Choose the answers from the box: *hydrogen, dwarf planets, Milky Way, nebula, fusion, friction*.

There are eight planets in orbit around the Sun, along with some \_\_\_\_\_ like Pluto. The Solar System is part of the galaxy which is called the \_\_\_\_\_.

\_\_\_\_\_  
\_\_\_\_\_ (2)

(c) Name the galaxy our Solar System belongs to and state approximately how many stars it contains.

\_\_\_\_\_  
\_\_\_\_\_ (2)

(d) Distances between stars are measured in light-years. Define what is meant by a **light-year**.

\_\_\_\_\_ (1)

(e) State **two** ways in which a star differs from a planet.

\_\_\_\_\_  
\_\_\_\_\_ (2)

**Answers**

- (a) Dwarf planet. (1)
- (b) dwarf planets; Milky Way. (1 mark each)
- (c) The Milky Way (1). It contains around 100–400 billion stars (accept any value of order  $10^{11}$ ) (1).
- (d) The distance light travels in one year.
- (e) Any two from: a star produces its own light/heat by nuclear fusion, a planet does not (1); a star is much larger than a planet (1); a planet orbits a star (1); stars are made mainly of hot plasma, planets are made of rock/gas (1).

## LESSON 2

## Star Formation

## Do Now

1. Which galaxy is our Solar System part of?

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2. What force pulls dust and gas together in space?

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3. Name the lightest element in the Universe.

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4. Roughly what temperature does the centre of the Sun reach? (Order of magnitude.)

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## Part 1 of 3 | Nebulae and Protostars

## Key Information

A **nebula** is a cloud of dust and gas in space, mostly **hydrogen** and helium. 1

Gravity pulls the gas and dust in a nebula closer together. 2

As the particles collide more frequently, **friction** heats up the gas. 3

When enough mass has gathered together, the cloud becomes a **protostar**. 4

A protostar continues to contract and heat up until the core temperature reaches over **10 million °C**. 5

At this temperature, **nuclear fusion** can begin and a **main sequence star** is born. 6

## Questions

1. Define what is meant by a **nebula**.

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(2 marks)

2. State the force that pulls the dust and gas in a nebula together.

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(1 mark)

3. Explain how friction in a nebula causes its temperature to rise.

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(2 marks)

4. Define what is meant by a **protostar**.

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(1 mark)

5. State the approximate temperature required at the core of a protostar for nuclear fusion to begin.

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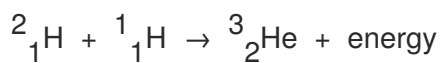
(1 mark)

**Answers**

1. A cloud of dust and gas (1), mostly hydrogen and helium (1).
2. Gravity.
3. As particles are pulled together by gravity (1) they collide more often, and friction between them transfers their kinetic energy into thermal energy (1).
4. A protostar is the early stage of a star formed when a nebula has been pulled together by gravity but nuclear fusion has not yet begun.
5. Around 10 million °C (accept > 10<sup>7</sup> K).

**Part 2 of 3 | Nuclear Fusion****Key Information**

<b>Nuclear fusion</b> is the joining of two small (light) atomic nuclei to form a heavier nucleus.	1
Fusion releases a huge amount of energy, which keeps the star hot and shining.	2
In a star like the Sun, fusion combines isotopes of <b>hydrogen</b> to form <b>helium</b> .	3
Mass is converted into energy ( $E = mc^2$ ): a tiny loss of mass produces enormous energy because $c$ is so large.	4
Once fusion starts, the energy released maintains the high temperature, and fusion continues until the fuel runs out.	5
A star in this stable, fusion-powered phase is called a <b>main sequence star</b> . Our Sun is currently a main sequence star.	6

**Questions**

6. Define **nuclear fusion**.

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(2 marks)

7. State which two elements are mainly involved in fusion in the Sun.

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(2 marks)

8. Explain why nuclear fusion releases so much energy.

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(2 marks)

9. Name the stage of a star's life cycle in which it is steadily fusing hydrogen into helium.

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(1 mark)

10. State **one** reason why a star remains stable during the main sequence phase.

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(2 marks)

**Answers**

6. The joining (1) of two small/light atomic nuclei to form a heavier nucleus (1).  
 7. Hydrogen (1) and helium (1).  
 8. A small amount of mass is converted into energy (1). Because the speed of light  $c$  is so large, the energy released ( $E = mc^2$ ) is enormous (1).  
 9. Main sequence.  
 10. The inward force of gravity is balanced (1) by the outward force from the radiation produced in nuclear fusion (1).

**Part 3 of 3 | Exam-Style Questions****EXAM QUESTION — Q2: Star Formation (7 marks)**

Mark allocations shown as (n) following AQA convention.

(a) Use the correct answer from the box to complete the sentence. *black hole gravity friction nebula protostar upthrust*

The Sun was formed when a \_\_\_\_\_ in space was pulled together by \_\_\_\_\_.

\_\_\_\_\_

(2)

(b) Describe how a protostar becomes a main sequence star.

\_\_\_\_\_

\_\_\_\_\_

(3)

(c) State the name of the process by which energy is released in stars.

\_\_\_\_\_

(1)

(d) Explain why a main sequence star is described as **stable**.

\_\_\_\_\_

(1)

**Answers**

(a) *nebula; gravity. (1 mark each)*

(b) *Gravity continues to pull material together (1). The temperature and pressure in the core rise (1) until they are high enough for nuclear fusion of hydrogen to start, forming a main sequence star (1).*

(c) *(Nuclear) fusion.*

(d) *The forces inside it are balanced — gravity acting inwards equals the radiation force from fusion acting outwards.*

## LESSON 3

# Life Cycle of a Sun-like Star

## Do Now

1. How is a protostar formed from a nebula?

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2. What temperature must be reached for nuclear fusion to begin?

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3. Name the two elements involved in fusion in the Sun.

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4. What stage in its life cycle is the Sun in **now**?

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## Part 1 of 3 | Stable Equilibrium

### Key Information

While a star is on the main sequence, it is in a **stable equilibrium**: the inward force of gravity is balanced by the outward force from radiation produced by nuclear fusion. 1

If gravity were larger, the star would collapse; if radiation pressure were larger, it would expand. 2

The Sun has been a main sequence star for about 4.6 billion years. 3

The Sun is expected to remain a main sequence star for about another 5 billion years. 4

While stable, the star's size, brightness and surface temperature stay roughly constant. 5

## Forces Inside a Star

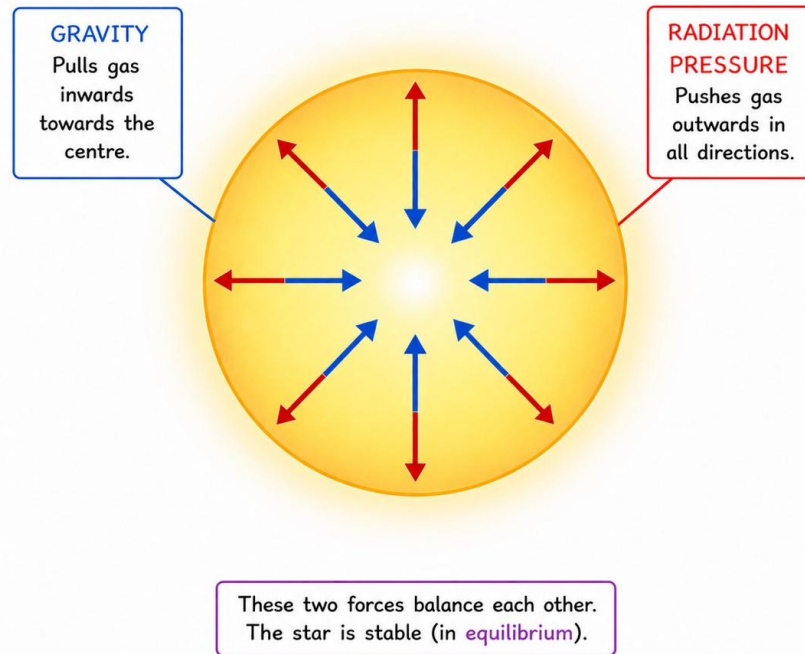


Fig 3.1 — Balanced forces inside a stable main sequence star

### Questions

1. Name the **two** forces that are balanced in a stable main sequence star.

\_\_\_\_\_

(2 marks)

2. State the direction in which each of those two forces acts.

\_\_\_\_\_

(2 marks)

3. Explain what would happen to a star if the inward force were greater than the outward force.

\_\_\_\_\_

(2 marks)

4. Approximately how long has the Sun been a main sequence star, and how much longer is it expected to remain one?

\_\_\_\_\_

(2 marks)

### Answers

1. Gravity (1) and the radiation pressure from nuclear fusion (1).
2. Gravity acts inwards / towards the centre (1); radiation pressure acts outwards (1).
3. The star would contract / collapse (1) because the unbalanced inward force would pull material towards the centre (1).
4. About 4.6 billion years (1) and about another 5 billion years (1).

**Part 2 of 3 | After the Main Sequence**

**Key Information**

When the hydrogen in the core runs out, the force from fusion decreases and the star contracts under gravity.	1
The contraction increases the core temperature until <b>helium</b> can fuse into heavier elements.	2
This new fusion releases more radiation, and the outer layers expand and cool: the star becomes a <b>red giant</b> .	3
After helium runs out, the outer layers drift away as a <b>planetary nebula</b> .	4
What remains at the centre is a small, hot, dense core called a <b>white dwarf</b> .	5
Over a very long time, the white dwarf cools and stops emitting light, becoming a <b>black dwarf</b> .	6
Life cycle (Sun-like): nebula → protostar → main sequence → red giant → white dwarf → black dwarf.	7

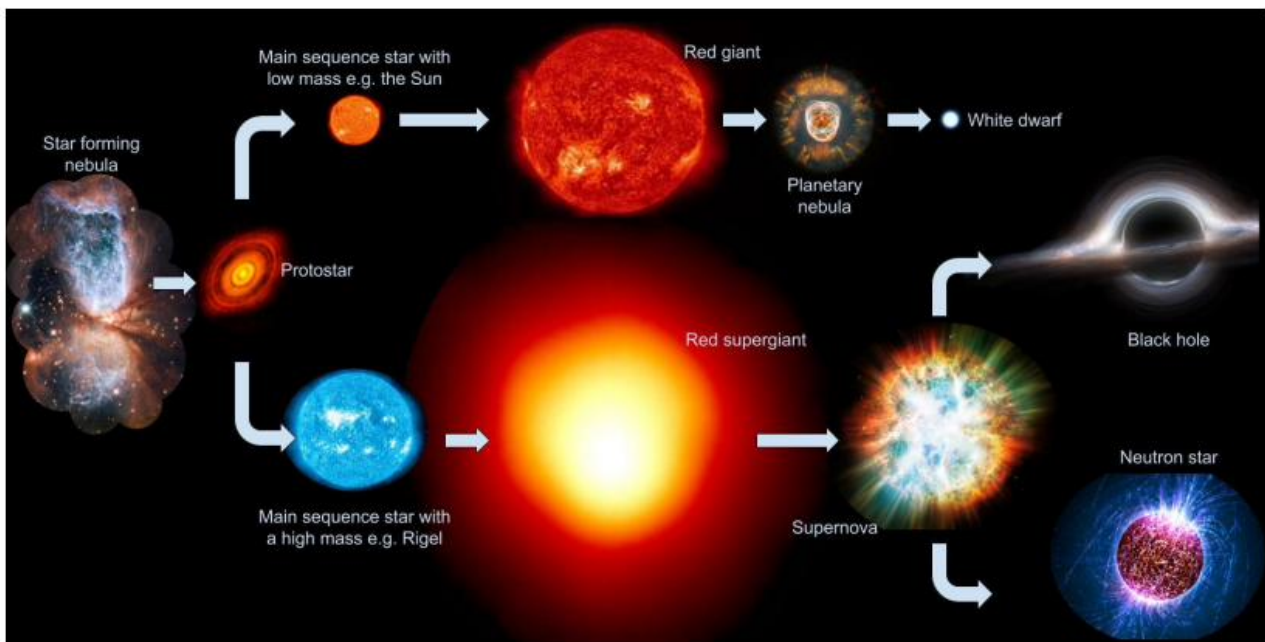


Fig 3.2 — The life cycle of stars of different masses

**Questions**

- Describe what happens when the hydrogen in the core of a Sun-like star runs out.  
 \_\_\_\_\_  
 \_\_\_\_\_  
 (2 marks)
- State why the star expands to become a red giant.  
 \_\_\_\_\_  
 \_\_\_\_\_  
 (2 marks)
- Name the stage in which the outer layers of a Sun-like star drift away into space.  
 \_\_\_\_\_  
 (1 mark)
- State the name of the small, hot, dense remnant left behind after a Sun-like star sheds its outer layers.  
 \_\_\_\_\_  
 (1 mark)

9. List the stages of the life cycle of a Sun-like star, in order, starting from **nebula**.

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(4 marks)

**Answers**

- 5. The fusion force decreases (1) so gravity is no longer balanced and the core contracts and heats up (1).
- 6. The hotter core can fuse helium (1), releasing more radiation; the increased outward pressure pushes the outer layers outwards, so the star expands and cools at the surface (1).
- 7. Planetary nebula.
- 8. White dwarf.
- 9. Nebula → protostar → main sequence star → red giant → white dwarf → black dwarf. (1 mark for each correct stage in correct position, max 4)

**Part 3 of 3 | Exam-Style Questions**

**EXAM QUESTION — Q3: Life Cycle of a Sun-like Star (8 marks)**

Mark allocations shown as (n) following AQA convention.

(a) State why a star is stable during the main sequence period of its life cycle.

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(2)

(b) The life cycle of a star after the main sequence depends on its mass. A particular star is the same size as the Sun. State the stages, in order, after the main sequence in the life cycle of this star.

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(3)

(c) Use the correct answer from the box to complete the sentence. *decay fission fusion*  
 Energy is released in stars by the process of nuclear \_\_\_\_\_.

---

(1)

(d) State the name of the cloud of gas and dust expelled by a Sun-like star late in its life.

---

(1)

(e) Explain why a white dwarf eventually becomes a black dwarf.

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(1)

**Answers**

- (a) The forces inside it are balanced (1) — gravity inwards equals radiation pressure outwards from nuclear fusion (1).
- (b) Red giant (1) → white dwarf (1) → black dwarf (1).
- (c) fusion.
- (d) Planetary nebula.
- (e) The white dwarf cools down over a very long time, and eventually stops emitting visible light.

## LESSON 4

# Massive Stars and the Origin of the Elements

## Do Now

1. What is the final stage of a Sun-like star's life cycle?

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2. Name the force that acts inwards in a stable star.

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3. Name the process that produces the outward force in a stable star.

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4. Name **two** elements lighter than iron and **one** element heavier than iron.

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## Part 1 of 3 | Red Supergiants and Supernovae

### Key Information

A star much more massive than the Sun follows a different path after the main sequence.	1
It expands into a <b>red supergiant</b> rather than a red giant.	2
Inside a red supergiant, fusion creates progressively heavier elements: helium, carbon, oxygen, ..., up to <b>iron</b> .	3
Iron is the heaviest element that can be produced by fusion in a star's core, because fusing iron <b>absorbs</b> energy rather than releasing it.	4
When fusion stops, gravity is no longer balanced and the core collapses.	5
The collapse causes a massive explosion called a <b>supernova</b> .	6
The supernova produces and ejects elements <b>heavier than iron</b> (e.g. gold, lead, uranium) throughout the Universe.	7

### Questions

1. Name the type of star formed when a star much more massive than the Sun expands.

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(1 mark)

2. State the name given to the explosion at the end of a massive star's life.

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(1 mark)

3. Explain why iron is the heaviest element that can be made by fusion in a star's core.

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(2 marks)

4. Describe how elements heavier than iron, such as gold, are formed.

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(2 marks)

5. State why the heavy elements in your body could only have come from a supernova.

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(2 marks)

**Answers**

1. Red supergiant.
2. Supernova.
3. Fusing iron does not release energy / actually absorbs energy (1), so it cannot maintain the star against gravitational collapse (1).
4. They are produced in the explosion of a supernova (1) and then spread out across the Universe (1).
5. Elements heavier than iron can only be produced in supernovae (1); these elements were ejected and later became part of the matter that formed the Earth and living things (1).

**Part 2 of 3 | Neutron Stars and Black Holes**

**Key Information**

What remains after a supernova depends on the mass of the original star.	1
If the original star was massive, a small, very dense object called a <b>neutron star</b> is left behind.	2
If the original star was extremely massive, the core collapses to a single point and a <b>black hole</b> is formed.	3
A black hole has a gravitational field so strong that not even light can escape from it.	4
Life cycle (massive): nebula → protostar → main sequence → red supergiant → supernova → neutron star or black hole.	5

**Questions**

6. State **two** things that can be left after a supernova.

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(2 marks)

7. State which of these is formed from the most massive stars.

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(1 mark)

8. Define what is meant by a **black hole**.

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(2 marks)

9. List the stages of the life cycle of a very massive star, in order, starting from nebula.

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(4 marks)

10. Compare the life cycle of a massive star with that of a Sun-like star — identify **one** similarity and **one** difference.

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(2 marks)

**Answers**

- 6. A neutron star (1) and a black hole (1).
- 7. A black hole.
- 8. An object whose gravitational field is so strong (1) that not even light can escape from it (1).
- 9. Nebula → protostar → main sequence → red supergiant → supernova → neutron star / black hole. (1 mark per correct stage, max 4)
- 10. Similarity: both begin as a nebula and pass through the main sequence (1). Difference: only the massive star explodes as a supernova (and forms a neutron star or black hole), whereas the Sun-like star ends as a black dwarf (1).

**Part 3 of 3 | Exam-Style Questions**

**EXAM QUESTION — Q4: Massive Stars and Heavy Elements (7 marks)**

Mark allocations shown as (n) following AQA convention.

(a) Use the correct answer from the box to complete the sentence. *hydrogen iron uranium*

The early Universe contained only \_\_\_\_\_.

\_\_\_\_\_ (1)

(b) Use the correct answer from the box to complete the sentence. *main sequence star protostar supernova*

The heaviest elements are formed only in a \_\_\_\_\_.

\_\_\_\_\_ (1)

(c) Use the correct answer from the box to complete the sentence. *red giant red supergiant white dwarf*

Only a star much bigger than the Sun can become a \_\_\_\_\_.

\_\_\_\_\_ (1)

(d) The Universe now contains a large variety of different elements. Describe how this happened.

\_\_\_\_\_  
 \_\_\_\_\_  
 \_\_\_\_\_  
 \_\_\_\_\_ (4)

**Answers**

- (a) *hydrogen.*
- (b) *supernova.*
- (c) *red supergiant.*
- (d) *Stars fuse hydrogen into helium and progressively heavier elements up to iron in their cores (1). Massive stars eventually explode as supernovae (1). The supernova produces elements heavier than iron (1) and spreads all of these elements across the Universe, where they form the basis of new stars, planets and living things (1).*

## LESSON 5

# Orbits, Gravity and Circular Motion

## Do Now

1. Define **gravity**.

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2. What is the difference between a **scalar** and a **vector**?

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3. State whether **speed** is a scalar or a vector. Repeat for **velocity**.

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4. Name **one** natural object that orbits the Earth.

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## Part 1 of 3 | Centripetal Force and Gravity

### Key Information

An object moving in a <b>circular orbit</b> is constantly changing direction.	1
Because direction is changing, the <b>velocity</b> is changing, even if the speed is constant.	2
A change in velocity means the object is <b>accelerating</b> , which requires a <b>resultant force</b> .	3
For a planet, moon or satellite, this resultant force is the force of <b>gravity</b> .	4
This inward force, towards the centre of the orbit, is called the <b>centripetal force</b> .	5
Without gravity, the orbiting object would travel in a straight line (Newton's First Law).	6

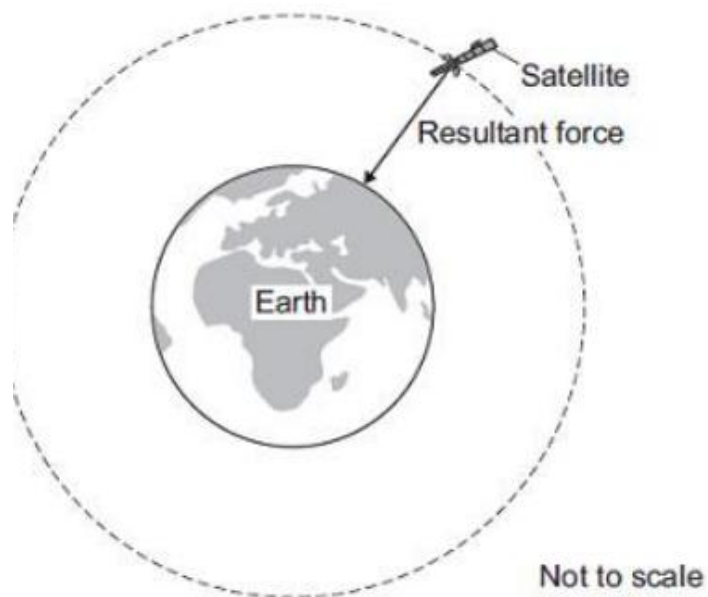


Fig 5.1 — Gravity provides the centripetal force on an orbiting satellite

## Questions

1. State the name of the force that keeps planets in orbit around the Sun.  
\_\_\_\_\_  
(1 mark)
2. Define **centripetal force**.  
\_\_\_\_\_  
\_\_\_\_\_  
(2 marks)
3. Explain why an object moving in a circle at constant speed is still accelerating.  
\_\_\_\_\_  
\_\_\_\_\_  
(2 marks)
4. State the direction in which the centripetal force acts on an orbiting satellite.  
\_\_\_\_\_  
(1 mark)
5. State **two** factors that determine the size of the gravitational force on a satellite orbiting Earth.  
\_\_\_\_\_  
\_\_\_\_\_  
(2 marks)

## Answers

1. Gravity (the gravitational force).
2. The resultant force on an object moving in a circle (1), directed towards the centre of the circle (1).
3. Velocity is a vector and includes direction (1); the direction is constantly changing, so velocity is changing — this is acceleration (1).
4. Towards the centre of the orbit (towards the Earth).
5. Any two from: the mass of the satellite (1); the mass of the Earth (1); the distance between the satellite and the centre of the Earth / the radius of the orbit (1).

## Part 2 of 3 | Speed, Velocity and the Orbit Radius

## Key Information

In a stable circular orbit, an object travels at a constant <b>speed</b> .	1
Its <b>velocity</b> is not constant, because direction is constantly changing.	2
An orbit closer to a planet (smaller radius) requires a higher orbital speed.	3
An orbit further from a planet (larger radius) has a lower orbital speed and a longer orbital time.	4
If a satellite is moved to a faster orbit, the radius decreases; if it is slowed, the radius increases.	5
Orbital speed: $v = (2\pi r) / T$ , where $r$ = orbital radius (m) and $T$ = time for one orbit (s).	6

$$v = \frac{2\pi r}{T}$$

## Questions

6. Explain why a satellite in a circular orbit has a changing velocity but a constant speed.  
\_\_\_\_\_  
\_\_\_\_\_  
(2 marks)

7. State what happens to the orbital speed if the orbit radius decreases.

\_\_\_\_\_

(1 mark)

8. Calculate the orbital speed of a satellite that orbits at a radius of 7 000 km in 92 minutes. (Convert km to m and minutes to s.) Give your answer in m/s.

\_\_\_\_\_  
\_\_\_\_\_

(3 marks)

9. The Moon orbits Earth at a radius of 384 000 km, taking 28 days. Calculate the speed of the Moon, in m/s. (1 day = 86 400 s.)

\_\_\_\_\_  
\_\_\_\_\_

(3 marks)

10. Light from the Sun takes 3 minutes to reach Mercury and 8 minutes to reach Earth. Mercury orbits the Sun in 3 months and Jupiter in about 11 years. Which of Mercury and Jupiter is travelling faster? Justify your answer.

\_\_\_\_\_  
\_\_\_\_\_

(3 marks)

### Answers

6. Speed has only magnitude (1). Velocity is a vector and changes whenever direction changes — the satellite is constantly changing direction in its circular orbit (1).

7. Orbital speed increases.

8. Circumference =  $2\pi r = 2 \times \pi \times 7\,000\,000 = 4.40 \times 10^7 \text{ m}$  (1).  $T = 92 \times 60 = 5520 \text{ s}$  (1).  $v = 4.40 \times 10^7 / 5520 \approx 7965 \text{ m/s} \approx 7.97 \text{ km/s}$  (1).

9. Circumference =  $2 \times \pi \times 384\,000\,000 = 2.413 \times 10^9 \text{ m}$  (1).  $T = 28 \times 86\,400 = 2.42 \times 10^6 \text{ s}$  (1).  $v = 2.413 \times 10^9 / 2.42 \times 10^6 \approx 998 \text{ m/s} \approx 1 \text{ km/s}$  (1).

10. Mercury is travelling faster (1). Mercury is closer to the Sun (light reaches it in 3 minutes vs 8 for Earth) (1) and a smaller orbit radius means a faster orbital speed; also Mercury completes a full orbit in only 3 months versus 11 years for Jupiter (1).

## Part 3 of 3 | Exam-Style Questions

### EXAM QUESTION — Q5: Orbital Motion (7 marks)

Mark allocations shown as (n) following AQA convention.

(a) Man-made satellites orbit the Earth. The satellite experiences a resultant force directed towards the centre of the orbit. State the name given to this resultant force.

\_\_\_\_\_

(1)

(b) State what provides the centripetal force on the satellite.

\_\_\_\_\_

(1)

(c) State **two** factors that determine the size of the centripetal force on the satellite.

\_\_\_\_\_

(2)

(d) When in stable orbit, a satellite travels at a constant speed but its velocity is constantly changing. Explain why.

\_\_\_\_\_

\_\_\_\_\_

(3)

**Answers**

(a) Centripetal force.

(b) The gravitational force (gravity) between the Earth and the satellite.

(c) Any two from: mass of the satellite (1); mass of the Earth (1); distance from the centre of the Earth / orbit radius (1).

(d) Velocity is a vector quantity (1) and includes direction (1). In a circular orbit the direction is constantly changing, so the velocity changes even though the magnitude (speed) stays the same (1).

## LESSON 6

## Satellites

## Do Now

1. What force keeps a satellite in orbit?

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2. Name **one** natural satellite of the Earth.

---

3. What does it mean to be “in orbit” around a planet?

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4. For a satellite in circular orbit at constant speed, what changes? What stays the same?

---

## Part 1 of 3 | Natural and Artificial Satellites

## Key Information

A <b>satellite</b> is an object in orbit around a planet (or another body).	1
A <b>natural satellite</b> is one that occurs in nature, such as the Moon orbiting the Earth.	2
An <b>artificial satellite</b> is one launched by humans, e.g. for communications, weather, GPS or science.	3
Artificial satellites generally fall into two main categories: <b>geostationary</b> and <b>low orbit (monitoring)</b> .	4
<b>Geostationary satellites</b> orbit the Earth once every <b>24 hours</b> , staying above the same point above the equator. They are used mainly for <b>communications</b> (TV, phone).	5
<b>Low orbit / monitoring satellites</b> orbit much closer to Earth and take only 90 min – 3 hours per orbit. They are used for weather monitoring, mapping and Earth observation.	6
The first artificial satellite, <b>Sputnik 1</b> , was launched in 1957.	7

## Two main types of artificial satellite:

**Geostationary** — ~36 000 km above Earth, 24-hour orbital period, stays fixed above the equator. Used for TV, phone, internet.

**Low Earth Orbit (LEO)** — 200–2 000 km, ~90-minute period. Used for weather monitoring, GPS, Earth observation.



Fig 6.1 — An artificial satellite orbiting the Earth

## Questions

1. Define what is meant by a **satellite**.

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(1 mark)

2. State the difference between a **natural** and an **artificial** satellite. Give one example of each.

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(4 marks)

3. Name the two main types of artificial satellite that orbit the Earth.

---

(2 marks)

4. State the time taken for a geostationary satellite to complete one orbit and give one common use for it.

---

(2 marks)

5. State **one** reason why a weather (monitoring) satellite is placed in a low orbit.

---

(1 mark)

### Answers

1. An object in orbit around a planet (or other large body).
2. Natural: occurs in nature, e.g. the Moon (2). Artificial: human-made, e.g. communications, weather or GPS satellites (2).
3. Geostationary (1) and low orbit / monitoring (1).
4. 24 hours (1). Communications such as TV, phone or internet relay (1).
5. Lower orbit means closer to Earth's surface, giving more detailed observations / a faster orbit which lets it scan the whole globe quickly. (1 mark for any reasonable answer.)

## Part 2 of 3 | Calculating Orbital Speed and Period

### Key Information

Distance travelled in one orbit = circumference of the orbit = $2\pi r$ .	1
$r$ is the radius from the <b>centre</b> of the planet, not the height above the surface.	2
Speed of an orbiting satellite: $v = 2\pi r / T$ , where $T$ is the orbital period in seconds.	3
Closer satellites have higher speed and shorter period; further satellites have lower speed and longer period.	4
Mass of the satellite does <b>not</b> affect orbital speed at a given radius.	5

$$v = \frac{2\pi r}{T}$$

$$r = r_{\text{Earth}} + \text{height above surface}$$

### Questions

6. A satellite orbits at an average distance from the centre of the Earth of 6 700 km, taking 92 minutes. Calculate its speed in m/s.

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(3 marks)

7. A geostationary satellite orbits 36 000 km above the Earth's surface. The radius of the Earth is 6 371 km. Calculate the radius of the orbit.

(1 mark)

8. Use your answer from Q2 (and  $T = 24$  hours) to calculate the orbital speed of the geostationary satellite, in m/s.

(3 marks)

9. State **one** factor that does **not** affect the orbital speed of a satellite at a given radius.

(1 mark)

10. State the relationship between orbit height and orbital period (time to complete one orbit).

(1 mark)

### Answers

6. Circumference =  $2\pi r = 2 \times \pi \times 6\,700\,000 = 4.21 \times 10^7 \text{ m}$  (1).  $T = 92 \times 60 = 5520 \text{ s}$  (1).  $v = 4.21 \times 10^7 / 5520 \approx 7625 \text{ m/s} \approx 7.6 \text{ km/s}$  (1).

7.  $r = 6\,371 + 36\,000 = 42\,371 \text{ km}$  ( $= 4.24 \times 10^7 \text{ m}$ ).

8. Circumference =  $2 \times \pi \times 4.24 \times 10^7 = 2.66 \times 10^8 \text{ m}$  (1).  $T = 24 \times 60 \times 60 = 86\,400 \text{ s}$  (1).  $v = 2.66 \times 10^8 / 86\,400 \approx 3\,080 \text{ m/s} \approx 3.1 \text{ km/s}$  (1).

9. The mass of the satellite (does not affect orbital speed at a given radius).

10. The greater the orbit height, the longer the orbital period (the slower the satellite moves).

## Part 3 of 3 | Exam-Style Questions

### EXAM QUESTION — Q6: Satellites (8 marks)

Mark allocations shown as (n) following AQA convention.

(a) Describe the orbit of an artificial satellite around the Earth.

(1)

(b) State what provides the force needed to keep a satellite in its orbit.

(1)

(c) The table below gives data for five satellites orbiting the Earth. Satellite A: 370 km, 93 min. Satellite B: 697 km, 99 min. Satellite C: 827 km, 103 min. Satellite D: 5 900 km, 228 min. Satellite E: 35 800 km, 1440 min. State the relationship between the height of the satellite above the Earth's surface and the time taken for it to orbit the Earth once.

(1)

(d) Using the data in (c), state the relationship (if any) between the orbital period and the mass of the satellite. Justify your answer.

(2)

(e) A satellite is moved to a lower orbit. Describe and explain what happens to its orbital speed and orbital period.

(3)

**Answers**

- (a) The satellite orbits in a (near-)circular path around the Earth.
- (b) The gravitational force (gravity) between the satellite and the Earth.
- (c) As the height above Earth increases, the time taken to orbit (the period) increases.
- (d) There is no relationship (1). The data shows that satellites with very different masses can orbit at the same height with the same period; the mass of a satellite does not affect its orbital period (1).
- (e) Orbital speed increases (1). Orbital period decreases (1). At a smaller radius, gravity provides a stronger centripetal force, so the satellite must travel faster, and a smaller circumference + higher speed both reduce the time per orbit (1).

## LESSON 7

## Red-shift and the Big Bang

## Do Now

1. Define **wavelength**.

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2. Write down the colours of the visible spectrum, from longest to shortest wavelength.

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3. Write the planets in the Solar System in order.

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4. What is a **satellite**? What are the two types of satellite?

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5. What galaxy is the Solar System a part of?

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6. What is a **nebula**?

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## Part 1 of 3 | The Doppler Effect and Red-shift

## Key Information

The <b>Doppler effect</b> is the change in wavelength (and frequency) of a wave when the source is moving relative to the observer.	1
If the source is moving <b>towards</b> us: wavelength decreases, frequency increases (e.g. siren sounds higher pitched).	2
If the source is moving <b>away</b> from us: wavelength increases, frequency decreases (e.g. siren sounds lower pitched).	3
The same effect happens with light: if a galaxy is moving away from us, its light is shifted to longer (redder) wavelengths — this is <b>red-shift</b> .	4
If a galaxy is moving towards us, its light is shifted to shorter (bluer) wavelengths — this is <b>blue-shift</b> .	5
Red-shift is observed in the absorption lines (dark lines) in the spectrum of light from distant galaxies.	6
The greater the red-shift, the faster the galaxy is moving away.	7

The Doppler Effect for a Moving Sound Source

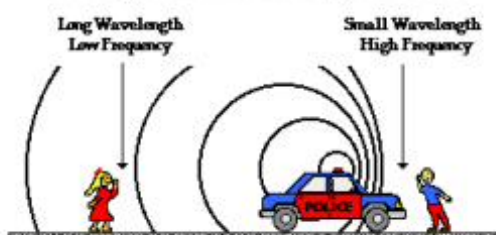


Fig 7.1 — Doppler effect: a moving source shifts wave frequency

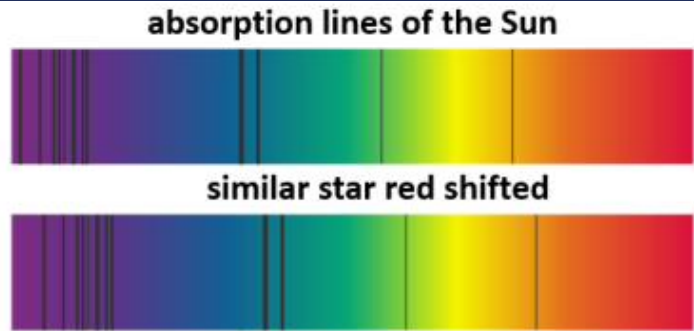


Fig 7.2 — Absorption lines shifted to the red for a receding galaxy

### Questions

1. Define the **Doppler effect**.

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(2 marks)

2. State what happens to the wavelength of light if a galaxy is moving towards Earth.

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(1 mark)

3. State what is meant by **red-shift**.

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(2 marks)

4. Galaxy X has a larger red-shift than galaxy Y. State which galaxy is moving away from Earth faster, and which is closer to Earth.

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(2 marks)

5. Explain why scientists look at the dark absorption lines in a galaxy's spectrum, rather than just its overall colour, to detect red-shift.

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(2 marks)

### Answers

1. The change in wavelength (and frequency) of a wave (1) caused by the source moving relative to the observer (1).
2. The wavelength decreases (light is blue-shifted).
3. The increase in wavelength (1) of light from galaxies that are moving away from Earth (1).
4. Galaxy X is moving away faster (1) and Galaxy Y is closer to Earth (1).
5. The absorption lines occur at known, specific wavelengths (1). Comparing how far they have shifted from these known wavelengths gives a precise measure of the change in wavelength and so the speed (1).

**Part 2 of 3 | The Big Bang and Evidence**

**Key Information**

Almost all distant galaxies show <b>red-shift</b> : they are moving away from us.	1
The further away a galaxy is, the greater its red-shift — so the faster it is moving away.	2
This is evidence that the <b>Universe is expanding</b> .	3
Working backwards in time, the Universe must once have been very small, hot and dense.	4
The <b>Big Bang theory</b> states that the Universe began about 13.8 billion years ago from a single, very small, very hot, very dense region.	5
Two main pieces of evidence: (1) red-shift of distant galaxies; (2) <b>cosmic microwave background radiation (CMBR)</b> — faint microwave radiation coming from all directions, predicted by the Big Bang theory.	6
Recent observations of distant <b>supernovae</b> show that the most distant galaxies are receding even <b>faster</b> than expected — the expansion of the Universe is <b>accelerating</b> . Scientists are still trying to explain this (“dark energy”).	7

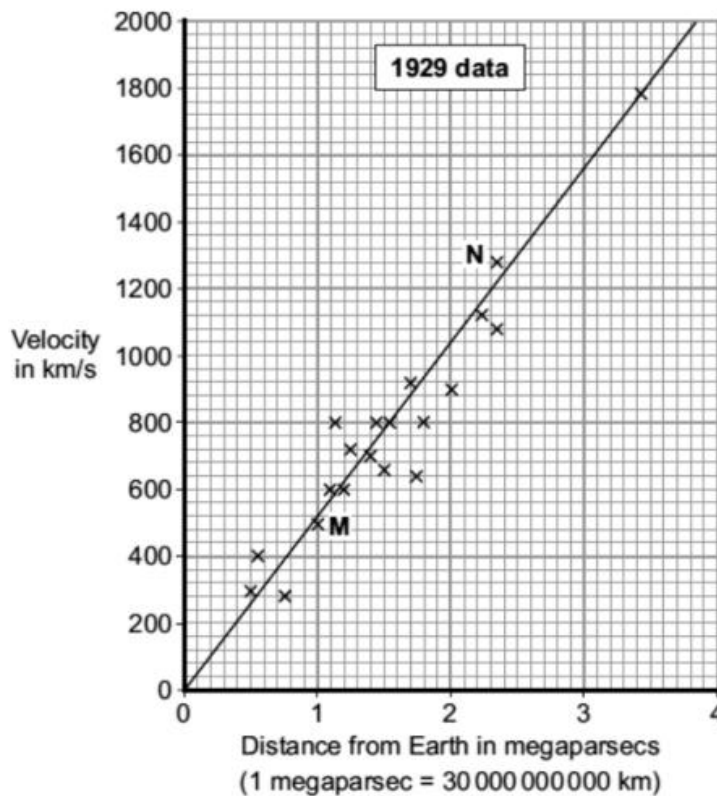


Fig 7.3 — Hubble's 1929 data: galaxy recession velocity vs distance — evidence the Universe is expanding

**Questions**

6. State **two** pieces of evidence that support the Big Bang theory.

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(2 marks)

7. Describe what the Big Bang theory states.

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(3 marks)

8. Explain how red-shift gives evidence that the Universe is expanding.

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(3 marks)

9. State what observations of distant supernovae have suggested about the expansion of the Universe.

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(1 mark)

10. Suggest **one** reason why scientists currently accept the Big Bang theory rather than other explanations.

---

(1 mark)

### Answers

6. Red-shift of distant galaxies (1) and cosmic microwave background radiation (CMBR) (1).

7. The Universe began from a very small, very hot, very dense point/region (1) about 13.8 billion years ago (1) and has been expanding ever since (1).

8. Light from almost all distant galaxies is red-shifted, showing they are moving away from us (1). The further away the galaxy, the greater the red-shift, so the faster it is moving (1). This pattern is exactly what would be observed if space itself is expanding in all directions (1).

9. The expansion of the Universe is accelerating — distant galaxies are receding faster than expected.

10. It is currently the best explanation that fits all the available observational evidence (red-shift and CMBR).

### Part 3 of 3 | Exam-Style Questions

#### EXAM QUESTION — Q7: Red-shift and the Big Bang (9 marks)

Mark allocations shown as (n) following AQA convention.

(a) Compared to the light from the Sun, the light from a distant galaxy has moved towards the red end of the spectrum. State the name given to this effect.

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(1)

(b) Complete the sentence by choosing the correct ending. *The fact that light from a distant galaxy seems to move towards the red end of the spectrum gives scientists evidence that ... (galaxies are shrinking / galaxies are changing colour / the Universe is expanding)*

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(1)

(c) Scientists have a theory that the Universe began from a very small point and then expanded outwards. State the name given to this theory.

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(1)

(d) Which statement gives a reason why scientists think that the Universe began with an explosion? Tick **one**: At the moment it is the best way of explaining our scientific knowledge  It can be proved using equations  People felt the explosion

---

(1)

(e) Light from a distant galaxy seems to move towards the red end of the spectrum. Compared to a light wave from the Sun, state how the wavelength and frequency have changed.

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(2)

(f) Star B has a smaller red-shift than star D. State which star is moving away faster.

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(1)

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(g) State **one** piece of evidence, other than red-shift, that supports the Big Bang theory.

---

(1)

(h) State what observations of distant supernovae suggest about the rate at which the Universe is expanding.

---

(1)

**Answers**

(a) *Red-shift.*

(b) *The Universe is expanding.*

(c) *The Big Bang theory.*

(d) *At the moment it is the best way of explaining our scientific knowledge.*

(e) *Wavelength has increased (1); frequency has decreased (1).*

(f) *Star D.*

(g) *Cosmic microwave background radiation (CMBR).*

(h) *The expansion of the Universe is speeding up / accelerating.*