

Space Physics

Earth - Rotation & orbit

Earth: rocky planet that rotates in a near circular orbit around the Sun.

Earth's rotation

- Earth rotates on its axis, which is tilted, once every 24 hours.
- This is used to explain observations of the apparent daily motion of the Sun and the periodic cycle of day and night

Axis: imaginary line between the Earth's North & South poles

Earth's orbit

- Earth orbits the Sun once every 365 days
- This is used to explain the periodic nature of the seasons

Orbit: path of an object as it moves around a larger object.

NOTE: Reason for seasons is the earth's tilt, NOT the distance of earth from the sun.

Moon

- Natural satellite that orbits the Earth
- Moon rotates on its axis, once every 28 days.
- It takes approximately one month (28 days) for the Moon to orbit the Earth.
- This is used to explain the periodic nature of the Moon's periodic cycle of phases

NOTE: We see only one side of the moon because it takes 28 days to complete 1 rotation, as well as 28 days to complete one orbit around the earth.

In the New Moon phase:

- Moon is between Earth and Sun
- Sunlight is only on the opposite side of the moon, which does not face the earth
- So Moon is not visible from earth

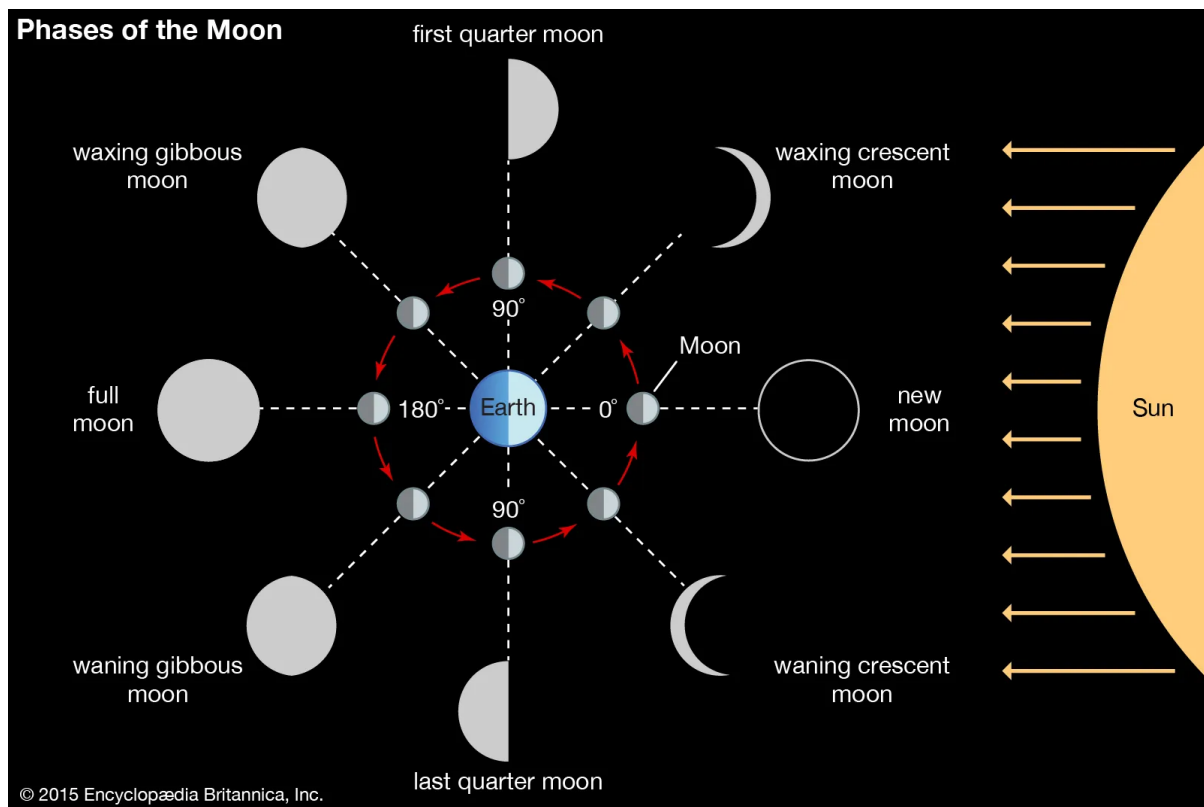
At the Full Moon phase:

- Earth is between Moon and Sun
- Sunlight is on the side of the moon that faces the earth
- So moon is fully lit/visible from Earth

Each quarter = 7 days

New moon to full moon = 2 quarters = 14 days

- Waxing: the bright part is getting bigger
- Crescent: moon is less than half-lit
- Gibbous: moon is more than half-lit
- Waning: the bright part is getting smaller



The Solar System

It consists of:

1. One star - The Sun
2. Eight planets that orbit the sun
3. Minor planets (dwarf planets + asteroids) that orbit the sun
4. Moons that orbit planets
5. Smaller Solar System bodies (comets + natural satellites)

The Sun

- Lies at the centre of the Solar System
- A star that makes up over 99% of the mass of the solar system

The eight planets

- Orbit the sun
- Large enough to form a spherical shape

- The gravitational field around planets is strong enough to have pulled in all nearby objects with the exception of natural satellites
- **Inner planets**
 - Small and rocky
 - High density
 - Mercury, venus, earth, mars
- **Outer planets**
 - Large and cold
 - Made of low density gases
 - Jupiter, saturn, uranus, neptune

The dwarf planets

- There are unknown number of them orbiting the sun
- Large enough to form a spherical shape
- The gravitational field around a dwarf planet is not strong enough to have pulled in nearby objects
- Eg. Pluto

Satellites

Orbit around a planet

2 types of satellite:

- Natural (eg. moons that orbit some planets)
- Artificial (man-made and can orbit any object in space)

Asteroids

- A small rocky object which orbits the Sun
- Location: The asteroid belt which lies between Mars and Jupiter
- Orbit shape: circular orbit around the sun
- Have similar density to the inner planets

Comets

- Made from: ice and dust
- The ice melts when the comet approaches the Sun and forms the comet's tail.
- Location: beyond Neptune
- Orbit shape: highly elliptical orbit around the sun
- Have similar density to the outer planets

Planet	Dwarf planet	Minor planet (eg. asteroid)
Orbits the sun	Orbits the sun	Orbits the sun

Spherical	Spherical	Not spherical
Can clear small objects from their path	Cannot clear small objects from their path	

NOTE: planets, minor planets and comets have elliptical orbits; Sun is not at the centre of the elliptical orbit, except when the orbit is approximately circular.

Formation of the solar system - The Accretion Model

Accretion: the process by which small particles gather together to form larger bodies, under the influence of gravity

Requirements for accretion model

1. Gravity
 2. A nebula: the presence of many elements in interstellar clouds of gas and dust
 3. A spinning accretion disc: the rotation of material in the cloud forms an accretion disc
- **Supernova:** an explosion that takes place at the end of a star's life
 - **Nebula:** cloud of dust & gas (mostly hydrogen); After supernova explosion, leftover dust & gas drifted into space to form nebulae.
 - Gravitational forces caused the cloud (nebula) to collapse
 - As it collapsed, it spun faster to form a rotating accretion disc
 - Sun formed at the centre of the accretion disc as gravity pulled matter (dust & gas) together
 - The outer regions of the nebula that were not pulled into the sun became planets

Properties of inner planets in terms of accretion model

Rocky	Inner planets were formed in hotter regions of the cloud, where only heavy elements with high m.p. (like rock), were solid. *Elements have to be solid for accretion to take place
Small	Concentration of heavy elements was low
High density	Made of heavy elements that tightly clumped together

Properties of outer planets in terms of accretion model

Icy & gaseous	Outer planets were formed in colder regions of the cloud, where light elements with low m.p. were frozen solid.
Large	Concentration of light elements was very high Strong gravitational attraction due to their size, which pulls in more

	elements (like hydrogen & helium), further increasing the size
Low density	Made of light elements

Orbital speed

The time taken for an object to complete one orbit.

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

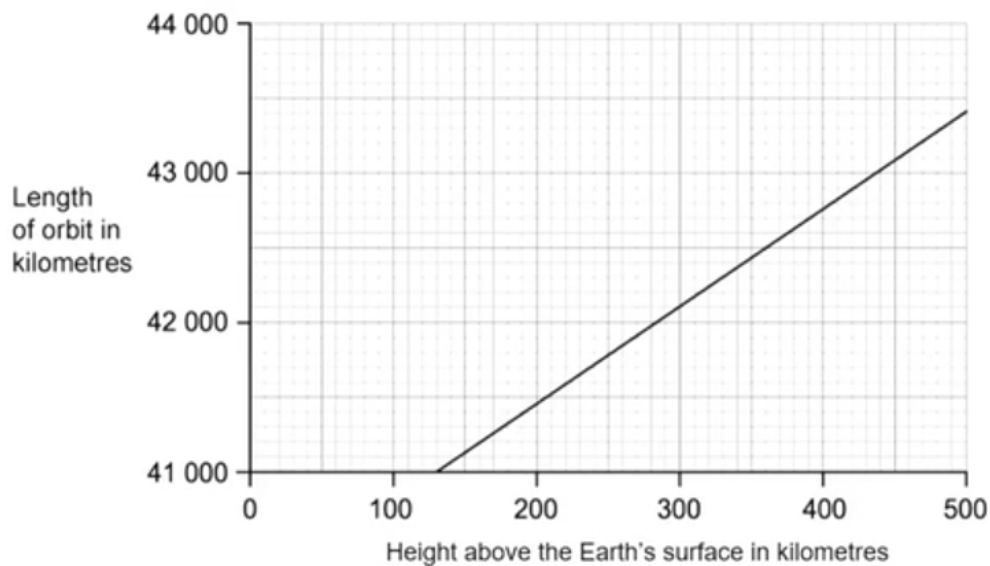
NOTE: Orbital radius r is always taken from the centre of the object being orbited to the object orbiting.

Orbital radius: the average distance of the planet from the sun

Orbital period: the time taken for a planet to complete one full orbit of the sun

1.

The graph shows how the length of an orbit depends on the height above the Earth's surface.



A satellite orbits 250 km above the Earth's surface at a speed of 7.8 km/s.

Calculate how many complete orbits of the Earth the satellite will make in 24 hours.

- Looking at the graph, height of 250km means length of orbit = 41800km
- Time = distance / speed = $41800 / 7.8$ s
- Number of orbits in 24 hours = $(24 \times 3600) \div (41800 / 7.8) = 16$

2.

A satellite orbits the Earth once every 230 minutes at a speed of 3.1 km/s.

Calculate the height, in km, of the satellite above the Earth's surface.

Radius of the Earth = 6370 km

- Distance = $2\pi r = 230 \times 60 \times 3.1$
- $r = 6808$ km
- Height above earth's surface = $6808 - 6370 = 440$ km

Gravitational effects on orbits

- Strength of gravitational field at the surface of a planet depends on mass of the planet
- Strength of gravitational field around planet decreases as distance from planet increases

Gravitational field of the sun

- Sun contains most of the mass of the Solar System and this is why planets orbit the Sun
- Force that keeps objects in orbit around the Sun is the gravitational attraction of the Sun
- Strength of Sun's gravitational field decreases as distance from sun increases
- As a result, orbital speeds of the planets decrease as the distance from the Sun increases; planets closer to sun travel faster than planets further away

Elliptical orbits

- An object in elliptical orbit around the Sun travels at a different speed depending on its distance from the Sun
- As the object approaches the Sun:
 - The radius of the orbit decreases
 - The orbital speed increases due to the Sun's strong gravitational pull
- As the object travels further away from the Sun
 - The radius of the orbit increases
 - The orbital speed decreases due to a weaker gravitational pull from the Sun

NOTE: comets have the most elliptical orbits around the sun.

Conservation of Energy

- Although an object in elliptical orbit continually changes speed, its energy is conserved
- Gravitational potential energy & kinetic energy of object changes throughout the orbit
- As the object approaches the Sun:
 - It loses gravitational potential energy and gains kinetic energy
 - This causes the object to speed up
 - This increase in speed causes a slingshot effect, and the body will be flung back out into space again, having passed around the Sun
- As the object moves away from the Sun:

- It gains gravitational potential energy and loses kinetic energy
- This causes it to slow down
- Eventually, it falls back towards the Sun once more
- In this way, a stable orbit is formed

Why an orbit is elliptical

During formation of Solar System:

- an object moves past the sun at high speed, carried along by its own momentum from the explosion
- As it passes near the sun, gravitational force of the sun acts on the object & pulls it towards the sun
- Gravitational force also causes object to accelerate; it speeds up and its high kinetic energy carries it to the furthest point of the orbit
- The object then slows down and is pulled back towards the sun

Astronomical distances

- Measured in light-years
- One light-year is the distance travelled in the vacuum of space by light in one year
- 1 light-year = 9.5×10^{15} m

NOTE: light from sun takes 8 minutes to reach the earth

1. How long does it take light to reach the Earth from a galaxy which is located 15 billion light-years away?

- A** 15 years
- B** 300 years
- C** 30 million years
- D** 15 billion years

Answer: D

Stars & the Universe

The Sun

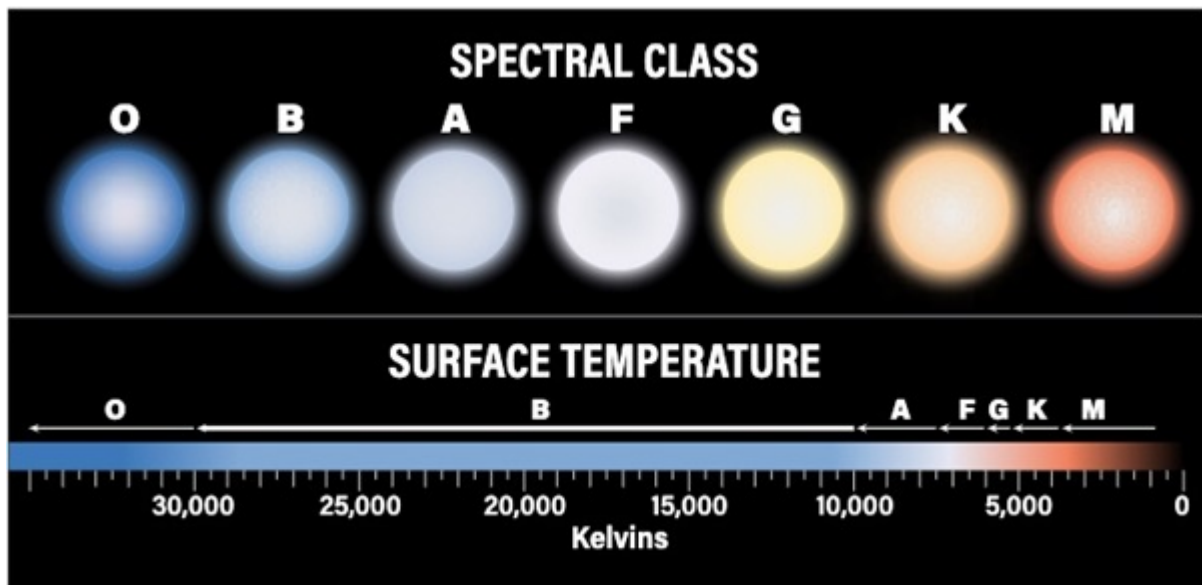
- Medium-sized star consisting of mainly hydrogen and helium
- Lies at the centre of the Solar System (99% of the mass of the solar system)
- Radiates most of its energy in the infrared, visible and ultraviolet regions of the electromagnetic spectrum

The Stars

The colour of stars

- Warm objects emit infrared & extremely hot objects emit visible light as well
- Therefore, the colour of a star depends on how hot it is

- A star's colour is related to its surface temperature

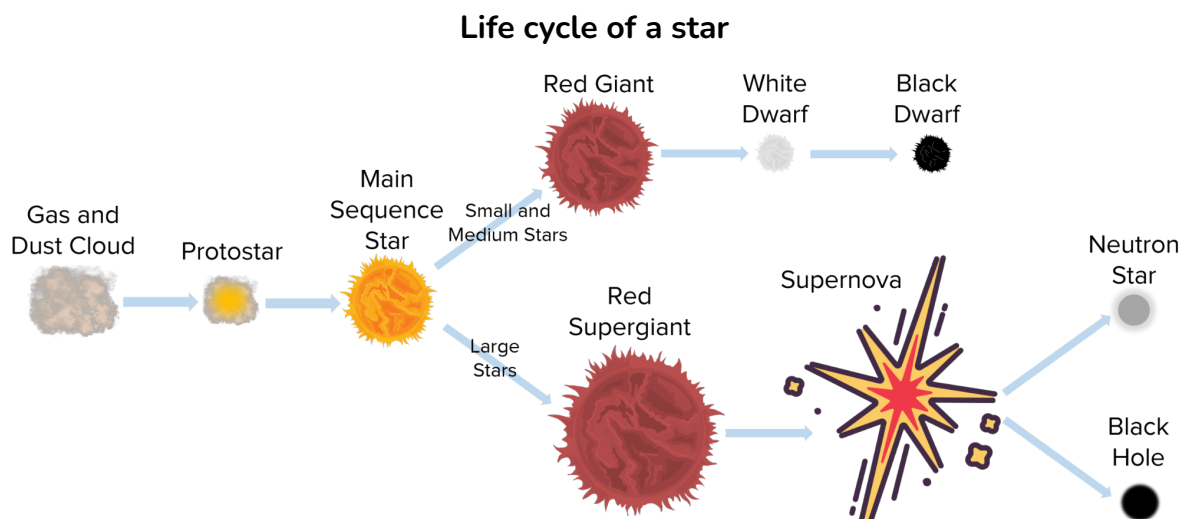
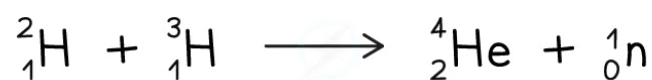


Nuclear reactions in stars

- Stars are powered by nuclear reactions that release energy
- Stable stars (like the sun) are powered by nuclear reactions that involve the fusion of hydrogen into helium

Nuclear fusion

- In the centre of a stable star, hydrogen atoms undergo nuclear fusion to form helium
- A huge amount of energy is released in the reaction
- This provides a pressure that prevents the star from collapsing under its gravity
- The process of nuclear fusion makes the sun shine



1. Nebula (cloud of dust & gas)

- Star is formed from interstellar clouds of gas & dust that contain hydrogen (& helium)
- Gravitational attraction pulls the dust and gas together.

2. Protostar:

- Interstellar cloud of dust & gas collapses as internal gravitational attraction increases
- As it collapses, the internal temperature of the cloud increases
- As mass of protostar increases, so does inward force due to gravitational attraction.

3. Main sequence star (stable star)

- When the temperature and pressure get high enough, nuclear fusion can start.
- High temperatures created by fusion produce an outward force/ outward radiation pressure.
- Protostar becomes a stable star when the inward force of gravitational attraction is balanced by the outward force / outward radiation pressure due to high temperature caused by nuclear fusion.

Once a protostar is formed, its life cycle will depend on its mass

Life-cycle of low-mass stars (fewer than 8 solar masses - like the sun)

4. Red giant

- All stars eventually run out of hydrogen as fuel for the nuclear reaction (all the hydrogen eventually fuses into helium).
- Without fusion, outward radiation pressure decreases and gravitational attraction takes over, causing the star to collapse/contract.
- As the star collapses, helium nuclei are pushed closer together, increasing number of collisions, and thus raising the temperature.
- Temperature and pressure are high enough for nuclear fusion of helium.
- High temperature/ heating causes outer layers of the star to expand & later cool down, appearing redder; **red giant**.

5. Planetary nebula

- During nuclear fusion of helium, the star becomes stable once more
- Once helium eventually runs out, nuclear fusion stops & outward pressure reduces; gravitational attraction takes over and star contracts
- The outer layers drift outward, and form a **planetary nebula**

6. White dwarf: Small, dense, white core that remains at the centre of planetary nebula.

7. Black dwarf: White dwarf cools down & emits less energy; its light fades away.

Life-cycle of high-mass stars (exceeding 8 solar masses)

4. Red supergiant

- All stars eventually run out of hydrogen as fuel for the nuclear reaction (all the hydrogen eventually fuses into helium).
- Without fusion, outward radiation pressure decreases and gravitational attraction takes over, causing the star to collapse/contract.
- As the star collapses, helium nuclei are pushed closer together, increasing number of collisions, and thus raising the temperature.
- Temperature and pressure are high enough for nuclear fusion of helium.
- High temperature/ heating causes outer layers of the star to expand & later cool down, appearing redder; **red supergiant**.

5. Supernova

- During nuclear fusion of helium, the star becomes stable.
- Once helium runs out, nuclear fusion doesn't stop; the star will contract & expand
- This causes nuclear fusion to continue until heavy elements like iron.
- Fusion cannot continue once an iron core forms.
- Once fusion reactions cannot continue, the core of the star will collapse, resulting in a shockwave explosion; **supernova**.

6. Neutron star/ Black hole

- Outer layers of supernova ejected into space, forming clouds of dust & gas (nebula).
 - The nebula contains hydrogen and heavier elements, which new planets/ stars are created from.
 - Small, dense core remains at the centre of the explosion, and could either turn into:
 - a. **Neutron star** (small & dense) - if the initial mass of star was not that massive.
 - b. **Black hole** (smaller & denser; densest object in the universe, even light cannot escape) - if mass of initial star was very massive.
-
- **Interstellar cloud**: a cloud of gas and dust that occupies the space between stars.
 - **Molecular cloud**: a cloud of interstellar gas that consists mostly of molecular hydrogen; it is cold & dense enough to collapse to form stars.
 - **Protostar**: a very young star that is still gathering mass from its parent molecular cloud.
 - **Radiation pressure**: the outward force due to the high temperature of a star.
 - **Stable star**: a star that is not collapsing/expanding because the inward force of gravity is balanced by radiation pressure, which pushes outwards.
 - **Main sequence**: a stable star that is burning hydrogen in its core.
 - **Red giant**: a star that began with fewer than 8 solar masses and is burning helium in its core; its shell of hydrogen has expanded and cooled.

- **White dwarf**: the final stage of a star that has started with fewer than 8 solar masses after all its fuel has been used up.
- **Planetary nebula**: a bubble of gas surrounding a white dwarf star that used to be the outer shell of a red giant which has collapsed.
- **Red supergiant**: a star that began with at least 8 solar masses and is burning helium in its core; its shell of hydrogen has expanded and cooled.
- **Supernova**: an exploding star that started with at least 8 solar masses after all its fuel has been used up.
- **Neutron star**: a collapsed star composed almost entirely of neutrons, which forms when a star with over 8 solar masses reaches the end of its lifecycle
- **Black hole**: the final stage of a star that has started with more than 8 solar masses; a point with very high gravity that even light can't escape.

Differences between protostar and main sequence star

- A protostar is much cooler / lower temperature / does not emit as much radiation/energy/heat/light
- Because nuclear fusion reactions have not yet started

How stars like the sun were formed [2 marks]

- From a giant cloud of dust and gas/ nebula
- Which was pulled together by gravitational attraction/ forces

The Universe

Universe: a large collection of galaxies

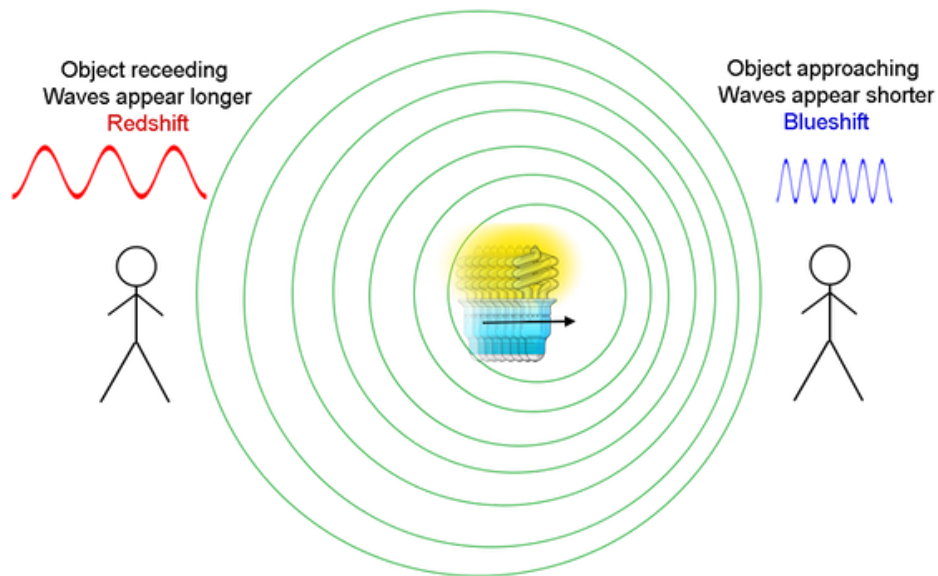
Galaxy: a large collection of stars

The Milky Way

- One of many billions of galaxies making up the Universe
- Diameter of the Milky Way = approximately 100000 light-years

Doppler effect

- Can be observed in all types of moving waves (including light & sound).
- Usually, when an object emits waves, the wavefronts spread out symmetrically
- If the wave source moves, the waves can become squashed together or stretched out



Example: doppler shift of sound

- When sound waves move towards an observer:
 - Wavelength decreases
 - Frequency/ pitch increases
- When sound waves move away from an observer:
 - Wavelength increases
 - Frequency/ pitch decreases

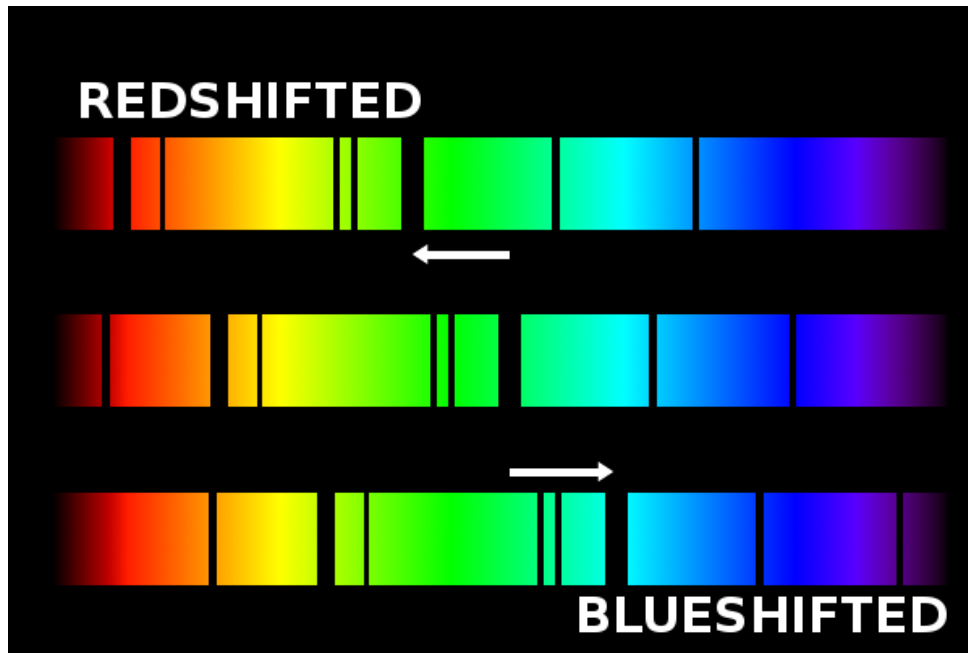
Example: doppler shift of light

- When light moves towards an observer:
 - Wavelength decreases
 - Light appears bluer; wavelength shifts towards the blue end of light spectrum
- When light moves away from an observer:
 - Wavelength increases
 - Light appears redder; wavelength shifts towards the red end of light spectrum

Galactic Redshift

Redshift: An increase in the observed wavelength of electromagnetic radiation emitted from receding stars and galaxies.

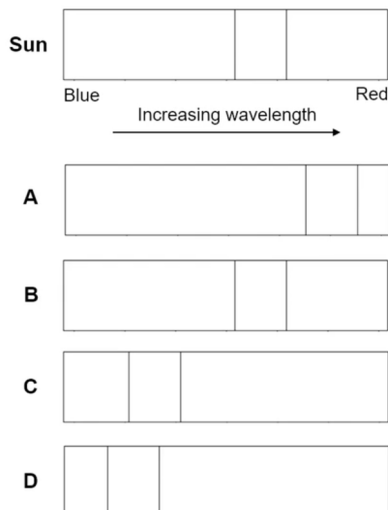
- Light emitted from distant galaxies appears redshifted in comparison with light emitted on Earth.
- This indicates that galaxies are moving away from us, and that the universe is expanding.
- Redshift in the light from distant galaxies is evidence that the Universe is expanding and it supports the **Big Bang Theory**.



NOTE: Further away a galaxy:

- The greater the redshift observed
- The faster it is moving away from us.

The diagram shows the visible light spectrum from the Sun and four other stars.



(a) Which of the stars **A**, **B**, **C** or **D**, is moving away from the Earth? (1)

(b) State and explain how the speed of star **C** compares with the speed of star **D**. (2)

a) Answer: A

b) - speed of star C is less than that of star D

- because light from D shows a greater blueshift/ change in wavelength

Big Bang Theory

The Universe (space, time, matter, energy) began from a single point (13.8 billion years ago) and has been expanding and cooling ever since.

- Universe began from a single point
- Was initially very hot and dense
- Universe is expanding rapidly from the single point

NOTE: rather than an explosion, the Big Bang was a rapid expansion

Evidence that supports the Big Bang Theory

1. Galactic redshift of light from distant galaxies
2. Cosmic microwave background radiation (CMBR)

Evidence from galactic redshift

- Observation: if galaxies are moving further away, it should mean that they were closer together in the past

Evidence: the Universe began from a single point

- Observation: light from the most distant galaxies are the most red shifted, which means that the most distant galaxies are moving away at the fastest speeds

Evidence: the Universe is expanding rapidly from the single point

Observations from Earth show there is an increase in the wavelength of light from distant galaxies.

Explain how this observation supports the Big Bang theory of the formation of the Universe.

(5)

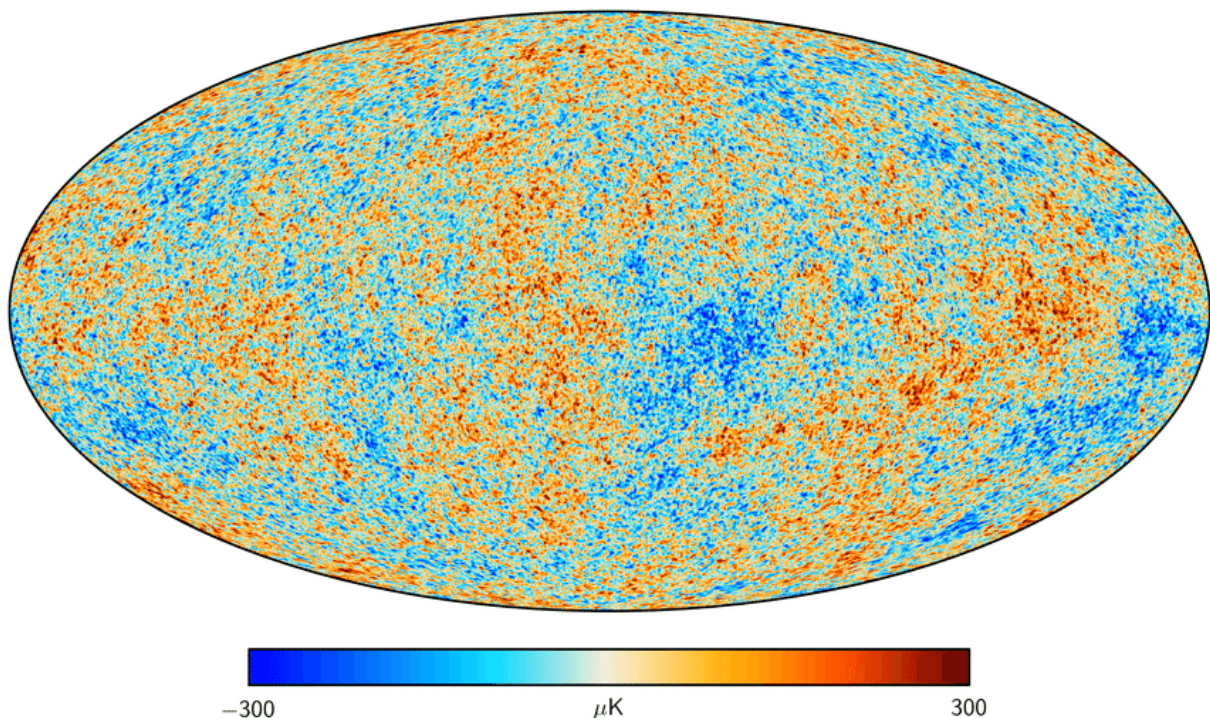
- This observation shows that galaxies are moving away from the earth
- The more distant galaxies show greater redshift/ increase in wavelength
- This means that the more distant galaxies are moving away faster
- Therefore, the universe is expanding
- Therefore, galaxies must have been closer together in the past // Universe must have started from a single point

Cosmic Microwave Background Radiation (CMBR)

Microwave radiation of a specific frequency is observed at all points in space around us and is known as **cosmic microwave background radiation (CMBR)**:

- An electromagnetic wave: microwave
- Found everywhere in space
- Extremely uniform temperature (2.7K)
- CMBR was produced shortly after the Universe was formed
- This radiation has been expanded into the microwave region of the electromagnetic spectrum as the Universe expanded

- In 1964, Astronomers discovered radiation in the microwave region of the electromagnetic spectrum coming from all directions, at a uniform temperature of 2.73 K.
- They were unable to do this earlier since microwaves are absorbed by the atmosphere.
- Around this time, space flight was developed which enabled astronomers to send telescopes into orbit above the atmosphere.
- According to Big Bang theory, early Universe was an extremely hot & dense environment
- As a result of this, it must have emitted thermal radiation.
- Initially, this would have been high energy radiation (towards gamma end of spectrum).
- The radiation is now in the microwave region.
- This is because over the past 14 billion years, the radiation from the Big Bang has become redshifted as the Universe has expanded.
- As the Universe expanded, the wavelength of the radiation increased, that it is now in the microwave region of the spectrum.
- The CMB radiation is very uniform and has the exact profile expected to be emitted from a hot body that has cooled down over a very long time.
- The temperature of the CMB radiation is mostly uniform, which implies that all objects in the Universe are more or less uniformly spread out.



The CMB map with areas of higher and lower temperature.

- Red / orange / brown regions represent warmer temperature = higher density of galaxies
- Blue regions represent cooler temperature = lower density of galaxies

Other than redshift, describe and explain another piece of evidence that supports the Big Bang theory of the formation of the Universe. (4)

- CMBR is observed uniformly/ at all points throughout the Universe
- It was emitted when the Universe was formed/ at the time of the Big Bang

EITHER

- The wavelength of the radiation has increased/ been stretched/ redshifted
- This is due to expansion of the Universe (thus supports Big Bang Theory)

OR

- The temperature of the radiation has decreased/ cooled over time
- This is because Universe started with a hot explosion (supports Big Bang Theory)

Measuring Galactic Speed & Distance

Using Redshift Observations to Measure the Universe

Speed (v) at which a galaxy is moving away from the Earth can be found from the change in wavelength of the galaxy's starlight due to redshift.

$$\frac{\text{difference between actual wavelength and expected wavelength}}{\text{actual wavelength}} = \frac{\text{speed of the galaxy}}{\text{speed of light}}$$

Measuring Distance Using Supernovae

Distance (d) of far galaxy can be determined using brightness of a supernova in that galaxy.

- Supernovae are exploding stars.
- Type 1a supernovae always have the same luminosity (output power), so they act as a 'standard candle'; they are so bright that they can be seen clearly even though they may be deep inside their parent galaxy.
- This allows the distance to the galaxy to be calculated.
- Type 1a supernovae in distant galaxy suggests that expansion of Universe is accelerating

Hubble's Law

Hubble's Law: Recessional velocity v of a galaxy is proportional to its distance from Earth.

*recessional velocity: the velocity of an object moving away from an observer.

$$H_0 = \frac{v}{d}$$

Therefore, the graph of recession velocity against distance will have a constant gradient.

Hubble constant (H_0): the ratio of the speed at which the galaxy is moving away from the Earth to its distance from the Earth

$$H_0 = \frac{v}{d}$$

- Current estimate for $H_0 = 2.2 \times 10^{-18}$ per second

NOTE: Hubble constant = gradient of v-d graph

Age of the Universe

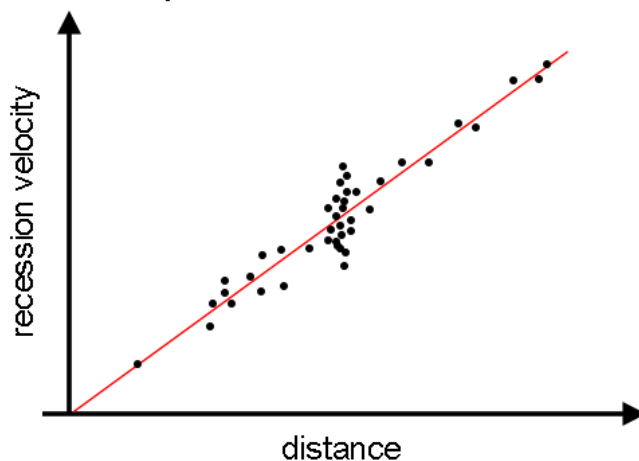
$$H_0 = \frac{v}{d}$$

therefore:

$$\frac{1}{H_0} = \frac{d}{v}$$

- This equation represents an estimate for the age of the Universe.
- This is evidence for the idea that all the matter in Universe was present at a single point.

NOTE: The reciprocal/inverse of H_0 is called Hubble time.



- The gradient of this graph can be used to find the Age of the Universe
- When the distance equals zero, this represents all the matter in the Universe being at a single point
- This is the *singularity* that occurred at the moment of the Big Bang
- The units of the gradient are per second = Hubble Constant
- By taking the reciprocal of H_0 the units will become seconds

- Therefore the reciprocal of the gradient represents time and gives the amount of time which the Universe has been expanding for (around 13.7 billion years)

Questions

1.

Which line in the table best describes the angle of the Earth's axis from the vertical, and the effect of this tilt?

	Angle of tilt	Effect of tilt
A	23.4°	Rising and setting of the Sun
B	23.4°	Changing of the seasons
C	66.6°	Rising and setting of the Sun
D	66.6°	Changing of the seasons

Answer: B

2.

The orbit of the Earth around the Sun can be thought of as following a circular path with a circumference of 942×10^6 km. What is the approximate orbital speed of the Earth?

- A. 10 000 km /h
- B. 100 000 km /h
- C. 2.5×10^6 km /h
- D. 50×10^6 km /h

Answer: B

3.

Comets travel faster within the Solar System than they do when they are outside it. Which is the correct reason for this?

- A. A comet near to the Sun has more gravitational potential energy.
- B. Comets closer to the Sun transfer gravitational potential energy to kinetic energy due to conservation of energy.
- C. A comet which is outside the Solar System has less energy than one which is passing through it.
- D. Comets closer to the Sun transfer kinetic energy to gravitational potential energy due to conservation of energy.

Answer: B

4.

Select the combination which best defines and describes an accretion disk.

1. Gases rotating around a star
2. Ring of rocky material
3. Leads to formation of orbiting planets
4. Explains the range of elements in rocky planets
5. Explains the range of elements in the parent star

A. 1, 3 and 5

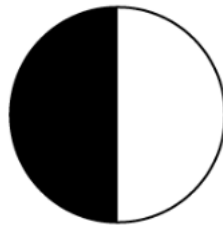
B. 2, 3 and 5

C. 1, 3 and 4

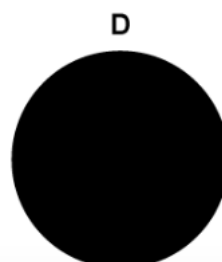
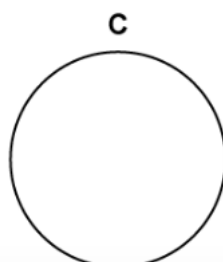
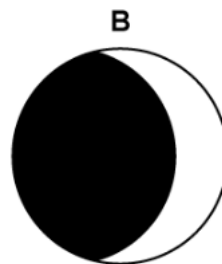
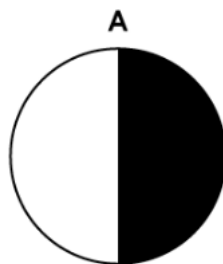
D. 2, 3 and 4

Answer: C

The diagram shows a phase of the Moon.



Which of the four options shows the Moon 7 days later?



5.

Answer: C

The question shows the Moon in its first quarter

This is the phase seen a quarter of a lunar month (7 days) after the New Moon

Seven days after the first quarter the Moon will be full, as shown in Option C

NOTE: the periodic nature of seasons is created by a combination of the orbiting of the earth around the sun and the earth's tilting axis.

6. State the similarities and differences between the orbits of the planets

Similarities

- They are all elliptical/ nearly circular
- They are in the same direction (around the sun)
- They are in the same plane

Differences

- They are at different distances from the sun/ have different radii
- They have different orbital speeds
- They have different orbital periods

7. State the source of the heavier elements that make up the inner planets:

supernova (explosion)

8. Explain the process that formed the inner planets

- Name of process: accretion model of the solar system
- Dust / a disc cloud of matter (left from the formation of the Sun)
- Contained elements created in a supernova
- Gravity caused the disc to spin / rotate around the Sun
- Gravitational attraction / gravity caused dust / (small) particles to join / clump together
- Forming an accretion disc
- Near the Sun the temperature was high
- Therefore inner planets are made of materials with high melting points (eg. metals)

1.

Pluto is a dwarf planet. Fig. 10.1 shows the direction of motion of Pluto as it follows its elliptical orbit around the Sun.

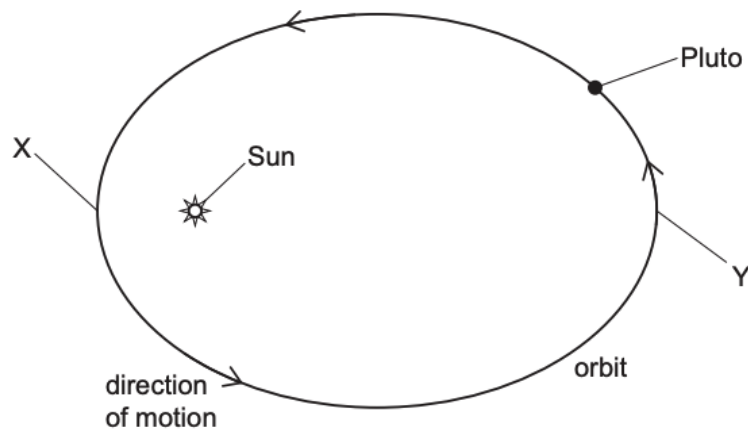


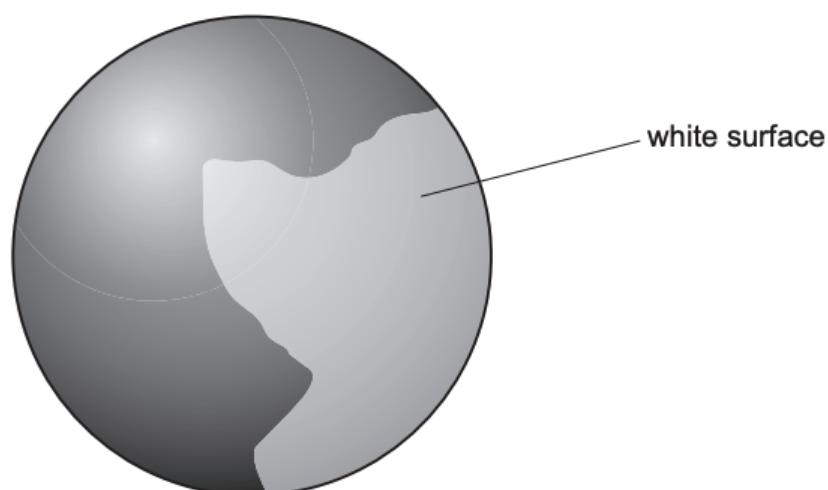
Fig. 10.1 (not to scale)

Explain in terms of energy transfers, why the speed of Pluto varies

- gravitational (potential) energy (GPE) transfers to kinetic energy (KE) or vice versa
- KE transfers to GPE from X to Y AND GPE transfers to KE from Y to X
- speed decreases as KE decreases / ORA
- most GPE at Y OR least GPE at X
- total (of GPE + KE) energy is constant

2.

Pluto has a white surface, as shown in Fig. 10.2. As Pluto rotates, the white surface alternately faces towards and away from the Sun.



Explain how this affects the temperature of Pluto as it rotates on its own axis

- (white surface) is a poor absorber / good reflector / poor emitter of IR / radiation OR black / other surface is a good absorber / poor reflector / good emitter of IR / radiation

any one from:

- (the white surface) increases in temperature less when facing the Sun
- (the white surface) decreases in temperature less when facing away (from Sun)
- the black / other surfaces increases in temperature more when facing the Sun
- the black / other surface decreases in temperature more when facing away (from Sun)
- less variation in temperature on white surface (during one whole rotation)

3. Redshift

- wavelength of light from distant galaxies increases
- occurs when galaxies are moving away from Earth

4. What redshift is used to calculate

speed / velocity (that galaxy is moving away from Earth)

5. Describe what happens in the core of stable star to release energy which is eventually transferred into space

- hydrogen nuclei fuse to become helium nuclei
- nuclear reactions OR (nuclear) fusion
- hydrogen fuses into helium

6. State the quantity that astronomers use to determine the speed at which a galaxy is moving away

Change in wavelength of starlight due to redshift