



Give the marks for the points in the marking scheme; an answer in other words that says the same is right.

1 Key words

1. universe
2. galaxy
3. Milky Way
4. light-year
5. cosmology
6. Big Bang theory
7. critical density
8. Big Crunch

K • 4

Each carries 0.5 mark.

2 Label the diagram

1. accelerating: what is actually measured
2. closed
3. time since the Big Bang

4. open: expands forever, slowing down
5. flat: slows down, never quite stops
6. Big Crunch

K • 3

Each carries 0.5 mark.

3 Multiple choice

- i. **b. the gravitational force**

K • 1

Gravitation acts between all masses over huge distances and never cancels out, so it rules the motion of planets, stars and galaxies. Nuclear forces act only inside atoms' nuclei; magnetic and electric forces cancel out over large distances because matter has equal positive and negative charges.

- ii. **a. from the sudden expansion of an extremely hot, dense state**

K • 1

The universe began with the sudden expansion, the "explosion", of an extremely hot, dense state smaller than an atom: an expansion of space itself. (Some books word this option as "the explosion of an atom".) Stars and nebulae came much later.

- iii. **a. The farther away galaxies are, the faster they move away.**

U • 1

Hubble's law, $v = Hd$: speed is proportional to distance.

- iv. **b. when the average density is less than the critical density**

U • 1

With less than the critical density, gravity is too weak to stop the expansion, and the universe expands forever: an open universe.

- v. **b. distance**

K • 1

It is the **distance** light travels in one year, about 9.46×10^{12} km. The word "year" in it tricks many people into thinking it is a time.

4 Very short answers

- a. **MARKING SCHEME**

K • 1

✓ About 13.8 billion years.

- b. **MARKING SCHEME**

K • 1

✓ Edwin Hubble.

- c. **MARKING SCHEME**

K • 1

✓ Gravitational, electromagnetic, strong nuclear and weak nuclear forces (all four).



5 Short answers

a. MARKING SCHEME

U • 2

- ✓ Each body is pulled by the gravity of the bigger body it orbits.
- ✓ It also moves sideways along its orbit at high speed, so gravity bends its path into a curve around that body instead of pulling it in.

b. MARKING SCHEME

U • 2

- ✓ The universe is expanding: the space between galaxies stretches everywhere at the same rate.
- ✓ Galaxies far apart have more stretching space between them, so the distance between them grows faster (Hubble's law, $v = Hd$), like dots on a balloon being blown up.

c. MARKING SCHEME

U • 2

- ✓ Any one difference, e.g. in a closed universe the average density is greater than the critical density; in an open universe it is less.
- ✓ Any second difference, e.g. a closed universe stops expanding and collapses in a Big Crunch; an open universe expands forever.

6 Long answer

ANSWER

A • 4

- The speed is proportional to the distance: twice as far, twice as fast (Hubble's law, $v = Hd$).
- $H = v \div d = 7,300 \text{ km/s} \div 100 \text{ Mpc} = 73 \text{ km/s per Mpc}$.
- $v = Hd = 73 \times 300 = 21,900 \text{ km/s}$.
- All the galaxies are moving apart, so the universe is expanding; long ago they must have been together, in the hot, dense state from which the Big Bang began.

MARKING SCHEME

- ✓ i. Speed is proportional to distance ($v = Hd$).
- ✓ ii. $H = 7,300 \div 100 = 73 \text{ km/s per Mpc}$.
- ✓ iii. $v = 73 \times 300 = 21,900 \text{ km/s}$.
- ✓ iv. The galaxies are moving apart, so the universe is expanding and was once together in one hot, dense state.

7 Numerical problems

a. ANSWER

A • 2

Distance = speed $\times$ time = $300,000 \text{ km/s} \times 500 \text{ s} = 150,000,000 \text{ km}$ ($1.5 \times 10^8 \text{ km}$).

MARKING SCHEME

- ✓ Distance = speed $\times$ time = $300,000 \times 500$.
- ✓ $1.5 \times 10^8 \text{ km}$ (150 million km).

b. ANSWER

A • 2

$d = v \div H = 14,600 \div 73 = 200 \text{ Mpc}$.

MARKING SCHEME

- ✓ $d = v \div H = 14,600 \div 73$.
- ✓ $d = 200 \text{ Mpc}$.



8 Think

ANSWER

HA · 2

Most likely it will expand forever. The Big Bang's afterglow shows the universe is flat, but most of its density is dark energy, which pushes space apart: since 1998 measurements of distant supernovae show the expansion is speeding up, so there will be no Big Crunch. (Any future with good reasons can earn marks.)

MARKING SCHEME

- ✓ A future (open, flat or closed) chosen, linked to the density of the universe compared with the critical density.
- ✓ A reason from the evidence, e.g. the expansion is speeding up because of dark energy (since 1998), so it will most likely expand forever.

9 Activity: A balloon universe

(not marked)

WHAT STUDENTS SHOULD FIND

Every dot moves away from A, and from every other dot. The dots that were farther from A moved away by more: the distances all grow by about the same fraction, so a dot twice as far moves away twice as much, as in Hubble's law. No dot is the center, and the dots don't crawl across the rubber: the rubber between them stretches, as space does between galaxies.

Marks by level	Knowledge	Understanding	Application	Higher ability	Total
Marks	13	8	8	2	31

