

25.3 Hubble's law and the Big Bang theory

Name: _____ Class: _____ Date: _____

Total: 13 marks

Objective

Build the skills to answer exam questions on **redshift**, **Hubble's law** and the **Big Bang**.

You must be able to:

- use the **redshift** $\frac{\Delta\lambda}{\lambda} \approx \frac{v}{c}$
- use **Hubble's law** $v \approx H_0 d$
- explain how redshift and Hubble's law support the **Big Bang**

1 Worked examples

Study these first. Each one shows the method for a question type used later —follow the steps and you can do the Practice and Exam-style questions yourself.

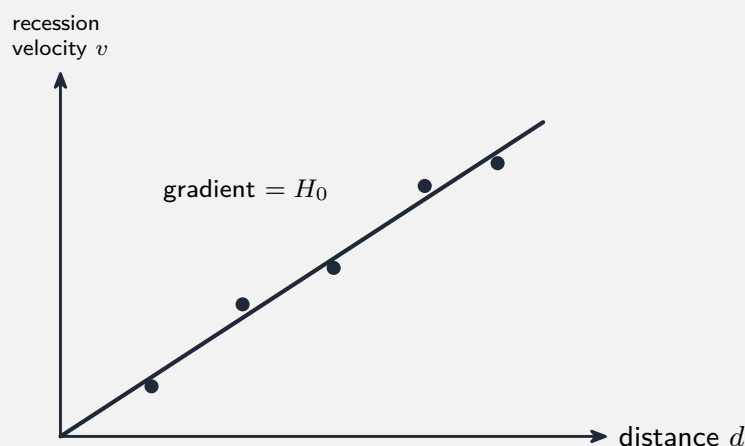
■ Redshift

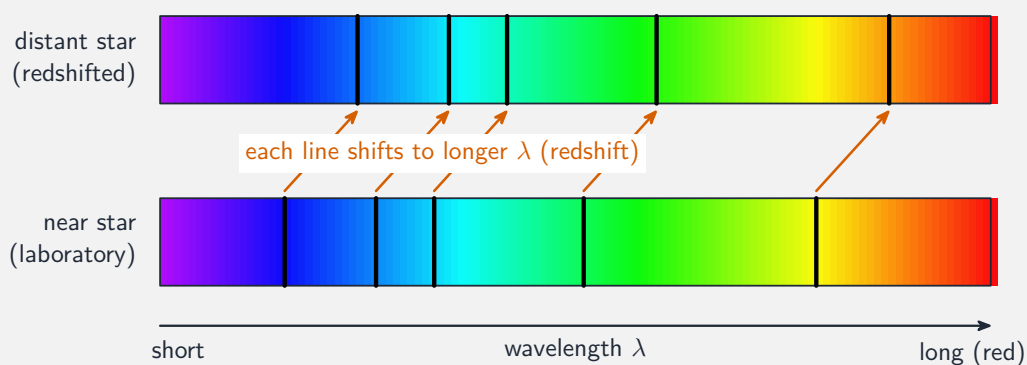
The spectral lines of distant galaxies are at **longer** wavelengths than in the lab —a **redshift**, showing the galaxy is moving **away**. For $v \ll c$:

$$\frac{\Delta\lambda}{\lambda} \approx \frac{v}{c}, \quad \Delta\lambda = \lambda_{\text{observed}} - \lambda_{\text{emitted}}.$$

■ Hubble's law

The recession speed is **proportional to distance**:





Redshift in a galaxy spectrum

$$v \approx H_0 d.$$

Every galaxy moving away (faster if further) means the Universe is **expanding** —so in the past it was smaller and denser, leading to the idea that it began from a single point: the **Big Bang**.

2 Practice

Now apply the methods above.

2.1 State what is meant by **redshift**. [1]

2.2 Write the **redshift** equation linking $\Delta\lambda$, λ and v . [1]

2.3 Write **Hubble's law**. [1]

2.4 State what the redshift of distant galaxies tells us about the Universe. [1]

3 Exam-style questions

3.1 The redshift of distant galaxies is evidence that: [1]

- **A** the Universe is static
- **B** the Universe is expanding
- **C** galaxies are approaching us

- D light slows down over distance
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3.2 A spectral line emitted at 4.62×10^{-7} m is observed at 4.91×10^{-7} m. Calculate the **recession velocity** of the source. [3]

3.3 A galaxy recedes at 2.0×10^7 m s⁻¹. Taking $H_0 = 2.2 \times 10^{-18}$ s⁻¹, calculate its **distance**. [2]

3.4 Explain how **Hubble's law** leads to the **Big Bang** theory. [3]

4 Go further

You are now ready for the real exam questions on this subtopic. Open the **25.3 Hubble's law and the Big Bang theory** past-paper sheet in the Library, or try these in **Practice mode**:

- 9702/41 J25 —Q10 (redshift and recession velocity)
- 9702/43 J25 —Q10 (Hubble's law)
- 9702/42 M25 —Q10 (redshift and the expanding Universe)

Solutions

2.1 The **increase in wavelength** of light from a source moving **away** from the observer.

2.2 $\frac{\Delta\lambda}{\lambda} \approx \frac{v}{c}$.

2.3 $v \approx H_0 d$.

2.4 It is **expanding** (galaxies are moving apart).

3.1 B —the Universe is expanding.

3.2 $\Delta\lambda = 4.91 \times 10^{-7} - 4.62 \times 10^{-7} = 0.29 \times 10^{-7} \text{ m}$; $v = \frac{\Delta\lambda}{\lambda} c = \frac{0.29 \times 10^{-7}}{4.62 \times 10^{-7}} (3.0 \times 10^8)$
 $= 1.9 \times 10^7 \text{ m s}^{-1}$.

3.3 $d = \frac{v}{H_0} = \frac{2.0 \times 10^7}{2.2 \times 10^{-18}} = 9.1 \times 10^{24} \text{ m}$.

3.4 All galaxies are moving **away**, faster the further they are, so the Universe is **expanding** —in the past it was smaller and denser; extrapolating back, everything began from a single point/event —the **Big Bang**.