A-LEVEL PHYSICS • EXERCISE SHEET

25.3 Hubble's law and the Big Bang theory

Name: _____ Class: _____ Date: _____ **Total: 25 marks**

KEY WORDS redshift 红移 • hubble's law 哈勃定律 • big bang 大爆炸 • recession 退行 • spectral lines 谱线

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** $\dfrac{\Delta\lambda}{\lambda} \approx \dfrac{v}{c}$
- 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.

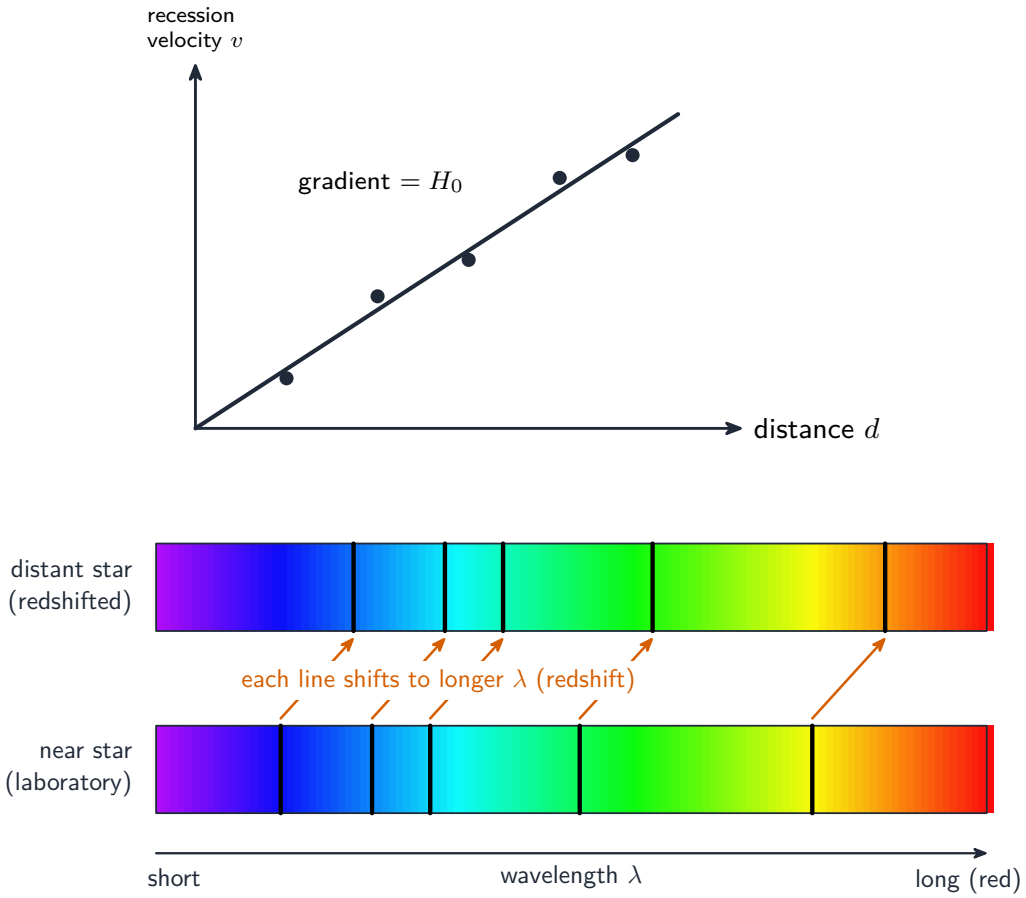
■ Redshift

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

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

■ 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	B
C	D

A the Universe is static
B the Universe is expanding
C galaxies are approaching us
D light slows down over distance

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]

3.5 A spectral line emitted at 486.1 nm in the laboratory is observed at 492.6 nm in the light from a distant galaxy. Take $c = 3.00 \times 10^8$ m s^{-1} and the Hubble constant as 2.3×10^{-18} s^{-1}.

(a) **State** Hubble's law. [2]

(b) **Explain** why the observed and emitted wavelengths differ. [2]

(c) **Determine** the speed of the galaxy relative to the Earth, and state whether it is approaching or receding. [3]

(d) **Determine** the distance of the galaxy from the Earth. [2]

(e) **Suggest** why an estimate of the age of the Universe can be made from the Hubble constant, and **state** one assumption that estimate depends on. [3]