# 8.2 Cosmology and red-shift (P)

Name: _____ Class: _____ Date: _____ **Total: 21 marks**

## Objective

Build the skills to answer exam questions on **cosmology** : red-shift, the expanding Universe, the Big Bang theory and the cosmic microwave background radiation.

**You must be able to:**

- describe red-shift and what it tells us about galaxies
- use $\Delta\lambda/\lambda_0 = v/c$
- explain the evidence for the Big Bang theory
- describe the cosmic microwave background radiation

## 1 Key knowledge and worked examples

### The expanding Universe

| idea | equation or rule |
|---|---|
| red-shift | light from a galaxy moving away has longer wavelengths than light from a lab source |
| size of red-shift | $\Delta\lambda \div \lambda_0 = v \div c$, with $c = 3.0 \times 10^8$ m/s |
| further galaxies | have bigger red-shifts, so they move away faster |
| Big Bang | the Universe began from a very small, very hot, dense point and has been expanding ever since |
| CMB radiation | microwave radiation from every direction; it is light from the early Universe, stretched by the expansion |

**Worked example 1: red-shift.** A line at $\lambda_0 = 500$ nm is seen at 510 nm. Find the galaxy's speed.

1. Known: $\Delta\lambda = 10$ nm; $\lambda_0 = 500$ nm.
2. Rule: $v = c \times \Delta\lambda \div \lambda_0$.
3. Numbers: $3.0 \times 10^8 \times 10 \div 500$.
4. Result: $6.0 \times 10^6$ **m/s**.

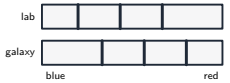
**Worked example 2: wavelength shift.** A galaxy moves away at $1.5 \times 10^7$ m/s. A line has $\lambda_0 = 600$ nm. Find $\Delta\lambda$.

1. Known: $v = 1.5 \times 10^7$ m/s; $\lambda_0 = 600$ nm.
2. Rule: $\Delta\lambda = \lambda_0 \times v \div c$.
3. Numbers: $600 \times 1.5 \times 10^7 \div 3.0 \times 10^8$.
4. Result: 30 **nm**, so it is seen at 630 nm.

**Answer shapes:** red-shift shows motion away; the pattern of lines stays the same but moves towards red.

## 2 Practice

**2.1** What is meant by red-shift? [2]




**2.2** Name the radiation that is evidence for the Big Bang and reaches us from space, and give **one** feature of it. [2]



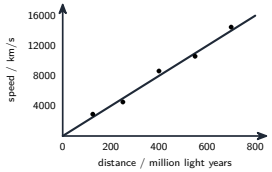
## 3 Exam-style questions

**3.1** Galaxy P has a red-shift of 0.010 and galaxy Q a red-shift of 0.030. Calculate the speed of galaxy Q, and say which galaxy is further away. [3]



**3.2** Astronomers measure the red-shift and distance of several galaxies. The graph shows their results.

(a) Describe the pattern in the graph. [2]




(b) A galaxy is 400 million light years away. Use the graph to find its speed, and calculate the change in wavelength of a line with $\lambda_0 = 656$ nm. [3]

(c) Explain why this pattern shows that the Universe is expanding. [3]

(d) Explain how red-shift and the cosmic microwave background radiation support the Big Bang theory. [6]

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## Solutions

Marking: **M1** a correct method, **A1** the correct answer, **B1** an independent mark.

Each answer shows the steps, then the **result**.

**2.1**

- the wavelength of light from a galaxy is longer than measured in the lab
- because the galaxy is moving away from us

**2.2**

- cosmic microwave background (CMB) radiation
- it comes from every direction, and is almost the same in every direction

**3.1**

- $v = 0.030 \times 3.0 \times 10^8$
- $\mathbf{9.0 \times 10^6}$ m/s
- Q is further away, because it has the bigger red-shift

**3.2**

(a) further galaxies move away faster; speed is proportional to distance (straight line through the origin)

(b) speed read from graph = 8000 km/s = $8.0 \times 10^6$ m/s; $\Delta\lambda = 656 \times 8.0 \times 10^6 \div 3.0 \times 10^8$ = **17.5** nm

(c) almost all galaxies are moving away from us; the further away, the faster; this is what happens if all of space is stretching, so the Universe is expanding

(d) points to include:

- distant galaxies show red-shift, so they are moving away (K)
- more distant galaxies move faster, so space is expanding (K)
- running the expansion backwards, everything started at one very small, hot, dense point (An)
- CMB radiation comes from all directions and is almost the same everywhere (K)
- it is radiation from the hot early Universe (K)
- the expansion has stretched its wavelength into the microwave region; the Big Bang predicts this (An)

Levels: **5**–**6** a full, logical answer with correct physics and correct terms; **3**–**4** several correct points, partly linked; **1**–**2** one or two relevant points.