8.2 Red shift and the Big Bang (P)

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

KEY WORDS red shift • Big Bang

Objective

Build the skills to answer exam questions on **red shift and the Big Bang** : the Doppler effect, red shift in the light from galaxies, the expanding universe, and the cosmic microwave background radiation.

You must be able to:

- describe the Doppler effect for a moving source of waves
- explain red shift in the spectra of galaxies
- explain how red shift shows that the universe is expanding
- explain how red shift and the cosmic microwave background support the Big Bang theory

1 Key knowledge and worked examples

Red shift and the Big Bang

idea	equation or rule
Doppler effect	a source moving away: the waves are stretched, so the wavelength is longer and the frequency lower; moving towards: shorter wavelength, higher frequency
red shift	dark lines in the spectrum of a galaxy are moved towards the red end (longer wavelength): the galaxy is moving away
distance	the further away a galaxy is, the bigger its red shift, so the faster it is moving away
expanding universe	galaxies in every direction are moving away from us, so space itself is expanding
Big Bang	the universe began about 14 thousand million years ago from a very small, very hot, very dense region
CMBR	cosmic microwave background radiation: microwaves from every direction, left over from the hot early universe and stretched as it expanded

Worked example 1: the size of a shift. A dark line is at 486 nm in the laboratory and at 496 nm in the light from a galaxy. Find the shift and say what it shows.

1. Known: $\lambda_{\text{lab}} = 486$ nm, $\lambda_{\text{galaxy}} = 496$ nm.
2. Rule: shift = observed − laboratory; a longer wavelength is red shift.
3. Numbers: $496 - 486$.
4. Result: 10 **nm towards red: the galaxy is moving away**.

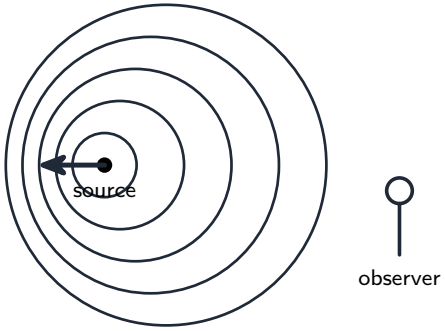
Worked example 2: comparing galaxies. Galaxy M has a shift of 4 nm; galaxy N has a shift of 12 nm for the same line. Which is further away?

1. Known: N has the bigger red shift.
2. Rule: bigger red shift means faster and further away.
3. Numbers: $12 \div 4 = 3$.
4. Result: **N, about** 3 **times as far away**.

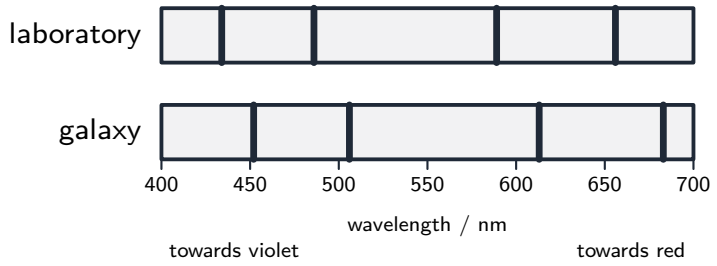
Answer shapes: say which way the lines move (towards red) and what it means (moving away); link the CMBR to the hot early universe.

2 Practice

2.1 A source of sound waves is moving away from the observer. What happens to the wavelength and the frequency that the observer measures? [2]

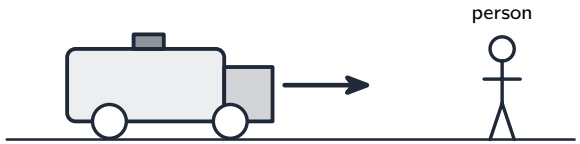


2.2 The spectra show the same dark lines from a laboratory source and from a galaxy. Is the galaxy moving towards us or away from us? Give a reason. [2]

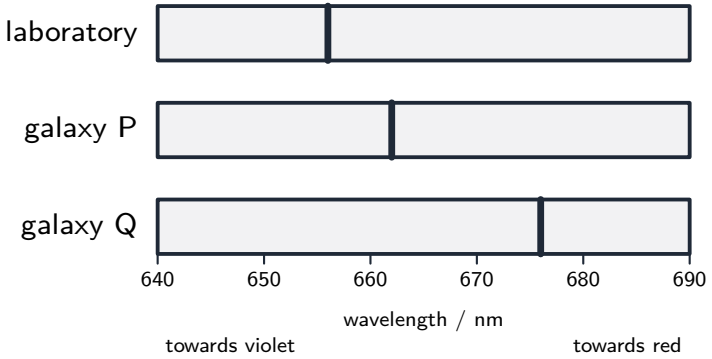


3 Exam-style questions

3.1 An ambulance with its siren on drives past a person standing by the road. Describe and explain how the sound she hears changes as the ambulance passes her. [3]



3.2 The diagram shows one dark line in the spectra of a laboratory source and of two galaxies, P and Q. In the laboratory the line is at 656 nm.



(a) Describe how the spectrum of galaxy P is different from the laboratory spectrum. Explain what this tells us. [3]

(b) The line is at 662 nm for galaxy P and 676 nm for galaxy Q. Calculate the shift for each galaxy. How many times bigger is the shift for Q? [3]

(c) What does your answer to (b) tell us about galaxy Q compared with galaxy P? [2]

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

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 increases (gets longer); the frequency decreases

2.2

- **away** from us; the lines are shifted towards the red end (longer wavelength)

3.1

- as it comes towards her the waves are squashed: shorter wavelength, higher frequency, higher pitch
- as it moves away the waves are stretched: longer wavelength, lower frequency
- so the pitch drops suddenly as the ambulance passes

3.2

(a) the line is in the same pattern but moved towards the red end, to a longer wavelength; this is red shift; galaxy P is moving away from us

(b) P: $662 - 656 = 6$ nm; Q: $676 - 656 = 20$ nm; $20 \div 6 =$ about **3.3** times

(c) Q is moving away faster; so Q is further away, about 3.3 times as far

(d) points to include:

- light from distant galaxies is red-shifted, so they are moving away from us
- the further away a galaxy is, the bigger the red shift, so the universe is expanding
- going back in time, everything was once in a very small, hot, dense region: the Big Bang
- the CMBR comes from every direction and was given out when the universe was very hot
- the expansion has stretched it into microwaves; the Big Bang theory predicts it, which is why scientists accept the theory

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.

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