

Exercise walk-through

15.1

Spectral shifts: a low-speed astronomical estimate

International Baccalaureate · IB Diploma · Physics · HL

15.1 Spectral shifts: a low-speed astronomical estimate

Name: _____ Class: _____ Date: _____ **Total: 10 marks**

KEY WORDS redshift • rest wavelength

Objective

Spectral shifts: a low-speed astronomical estimate. Original classroom practice for IB HL; not an official IB paper.

1 Key knowledge and worked examples

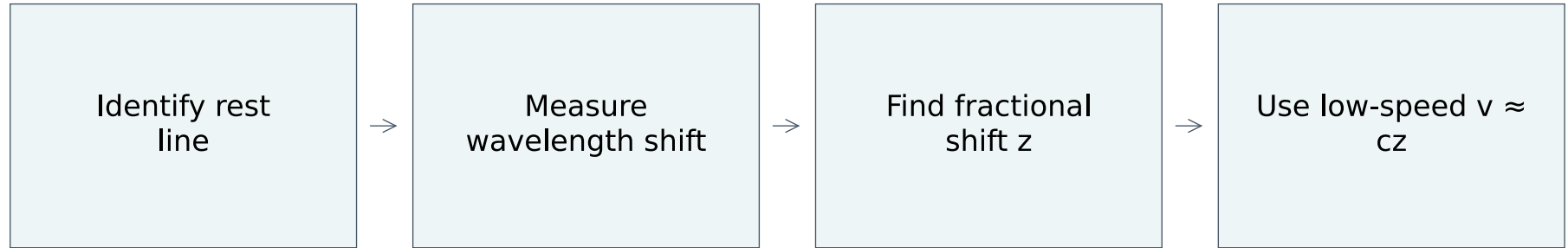
- What would explain this observation?
 - A recognizable spectral line appears at a longer wavelength in a distant source. Its shift can provide evidence of recession along the line of sight.

■ Build the model

- Relative source-observer motion changes observed frequency or wavelength.
- For light at a relative speed much smaller than c , the magnitude of the fractional wavelength shift is approximately v/c .
- Recession corresponds to longer wavelength, and approach to shorter wavelength.
- **redshift** : Shift of an identified line toward longer wavelength.

- **rest wavelength**
motion.

: Wavelength of the line measured with no relative source



■ Choose evidence that can test it

- Compare a identified line with its laboratory rest wavelength.
- Use $z = (\text{observed} - \text{rest}) / \text{rest}$, then v approximately cz in the stated low-speed model.
- Do not apply this approximation without checking the regime or treating a cosmological redshift as a simple exact velocity.

In the lab: Use attributed spectra with calibration and line identification. Compare several lines for a consistent shift. State uncertainty and distinguish relative line-of-sight motion from an unmeasured transverse component.

■ **Work from known quantities**

- Known: a 500 nm rest line is observed at 501 nm. $z = (501-500)/500 = 0.002$.
- With $c=3.0\times10^8$ m/s, v approximately 6.0×10^5 m/s away.
- The sound-source denominator formula is not the required SL light approximation.

Your turn: A 600 nm rest line is observed at 601.2 nm. Find $z=(\text{observed}-\text{rest})/\text{rest}$.

■ **Check the conclusion and its limits**

- The approximate shift relation does not show that light travels faster from an approaching source.
- A single unidentified line cannot safely establish a redshift.

Not true: An observed redshift means light speed increased. Light speed in vacuum is the same for all observers. Redshift is a change in observed wavelength from relative motion (or expanding space), not light travelling faster or slower.

Key:

- Relative source-observer motion changes observed frequency or wavelength.
- Compare a identified line with its laboratory rest wavelength.
- Watch for: the approximate shift relation does not show that light travels faster from an approaching source.

■ **Write from a redshift of 0.004**

- A 400 nm rest line is observed at 401.6 nm.

- Find z . Redshift does not mean the speed of light increased.
-

Exercises 2.1·2.2

2.1 What does an identified line shifting to a longer wavelength suggest in the stated model? Choose one answer.

- **A** Recession along the line of sight
- **B** The source frequency must be zero
- **C** Light speed increased

[1]

2.2 A 600 nm rest line is observed at 601.2 nm. Find $z = (\text{observed} - \text{rest}) / \text{rest}$. Show the relation, substitution and units.

[2]

Exercises 2.1·2.2

2.1 What does an identified line shifting to a longer wavelength suggest in the stated model? Choose one answer.

- **A** Recession along the line of sight
- **B** The source frequency must be zero
- **C** Light speed increased

[1]

2.1 A A known line found at a longer wavelength is redshifted, which in this model means the source is receding along the line of sight. The speed of light is constant, and a shifted line still has a nonzero frequency.

2.2 A 600 nm rest line is observed at 601.2 nm. Find $z=(\text{observed}-\text{rest})/\text{rest}$. Show the relation, substitution and units.

[2]

2.2 $z=(601.2-600)/600=0.002$.

Exercises 2.3-3.1

2.3 Decide whether this claim is true and justify: An observed redshift means light speed increased. [2]

2.4 Shift of an identified line toward longer wavelength: write the technical term. [1]

3.1 A 500 nm rest line is observed at 499 nm. Find z and low-speed radial velocity using $c=3\times 10^8$ m/s. Explain sign and limit. [4]

Exercises 2.3-3.1

2.3 Decide whether this claim is true and justify: An observed redshift means light speed increased. [2]

2.3 False. Light speed in vacuum is the same for all observers. Redshift is a change in observed wavelength from relative motion (or expanding space), not light travelling faster or slower.

2.4 Shift of an identified line toward longer wavelength: write the technical term. [1]

2.4 redshift. redshift means Shift of an identified line toward longer wavelength.

3.1 A 500 nm rest line is observed at 499 nm. Find z and low-speed radial velocity using $c=3\times 10^8$ m/s. Explain sign and limit. [4]

3.1 $z=-0.002$; $v\approx cz=-6\times 10^5$ m/s, approaching under the positive-away convention. This small- $|z|$ kinematic approximation does not cover every origin of redshift.