# Redshift calculations and expansion

Student activity • observation and reasoning

YEAR 11 / LESSON 111 / PHYSICS ONLY

## The question

**How does a measured fractional wavelength shift connect to a low-redshift speed estimate?**

Calculate original low-redshift examples and use an expanding-coordinate model to explain the distance trend.

## Equipment

- Booklet, graph paper, ruler and calculator

Paper calculations only. No balloons, stretched elastic, discharge tubes or optical viewing of the Sun.

Course coverage: Physics only: 8.1, 8.16P–8.18P. Fractional wavelength shift, approximate recession speed and expansion evidence.

## Plan, model or apparatus sketch

**Draw a labelled expansion or evidence diagram and identify what it does not represent.**

# Method and reasoning

Read the whole sequence before starting

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**1.** Define $\Delta\lambda$ = observed wavelength − reference wavelength and $z = \Delta\lambda/\lambda_{reference}$. Keep both wavelength values in the same units.

**2.** Use invented pairs 500→505 nm, 600→612 nm and 400→412 nm. Calculate z for each and use the low-redshift approximation $v/c \approx z$ with $c = 3.0 \times 10^8$ m $s^{-1}$.

**3.** Convert each speed to km $s^{-1}$. State that this simple velocity interpretation is a low-redshift approximation; do not apply it unchanged to very distant high-redshift galaxies.

**4.** Draw a one-dimensional paper model with points at 0, 2, 4 and 6 cm, then multiply every coordinate by 1.5. Calculate changes in separation from the point at 0.

**5.** Repeat the separation comparison using the point originally at 2 cm as observer. Explain how proportional expansion can give more separation change for more distant points without selecting one privileged central observer within the model.

**6.** Connect the broad galaxy redshift–distance trend to cosmic expansion. State that nearby peculiar motions can modify the trend and that the paper model is not a measured galaxy dataset.

## Cleanup

- Retain the calculated spectra and coordinate diagrams.

# Record your evidence

Blank spaces are for your own work

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## Reference and task data

Practice z values are 0.010, 0.020 and 0.030; approximate speeds are 3.0, 6.0 and 9.0 × $10^6$ m $s^{-1}$, or 3000, 6000 and 9000 km $s^{-1}$. Cosmological redshift arises as light is stretched by expansion; zc is not a universal exact recession speed.

| Reference / nm | Observed / nm | z | Approx. v / km $s^{-1}$ |
|---|---|---|---|
| 500 | 505 | | |
| 600 | 612 | | |
| 400 | 412 | | |

**Show your calculations, labelled model or correction here.**

# Explain and evaluate

Use evidence and show calculation steps where relevant

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**1.** Find z for 500→505 nm.

**2.** Find the first approximate speed in m $s^{-1}$.

**3.** Convert it to km $s^{-1}$.

**4.** Which wavelength belongs in the denominator?

**5.** Is v = zc exact at arbitrary redshift?

**6.** Does the paper expansion require a privileged observer among its marked points?