# Past-paper walk-through

Stellar radii ▪ 25.2

eXercise

# Questions in this set

- 9702/41 J25 Q10 ▪ 10 marks
- 9702/43 J25 Q10 ▪ 10 marks

# Reading the mark scheme

- **B1** a mark that stands on its own – the point is either made or not.
- **M1** a *method* mark: the right approach, even if the number is wrong.
- **A1** an *answer* mark, and it usually needs its M mark first.
- **C1** a working mark on the way to the answer.
- // separates answers the examiner accepts equally.
- **ecf** = error carried forward: a later part is marked on your own earlier answer.
- **owtte** = "or words to that effect" – the wording need not match.

# Question 10

9702/41 J25 ▪ Q10 ▪ 10 marks

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

**(b)(i)** Explain why the observed wavelength and the emitted wavelength have different values. **[2]**

**(b)(ii)** Calculate the speed of the star relative to the Earth. **[2]**

**(b)(iii)** The wavelength of maximum intensity of emission is used to determine a value for the surface temperature of the star.

Explain how the temperature determined using the observed wavelength compares with the true value of temperature determined using the emitted wavelength. **[2]**

**(c)** A value for the Hubble constant is $2.3 \times 10^{-18}$ s$^{-1}$.

Use your answer in **(b)(ii)** to determine the distance of the star in **(b)** from the Earth. **[2]**

# Solution 10

## (a)

### Mark scheme

- speed is (directly) proportional to distance **M1**
- speed is speed of recession of galaxy from an observer, and distance is the distance of the galaxy from the observer **A1**

# Solution 10

## (b)(i)

**Mark scheme**

- galaxy is receding from the Earth **B1**
- observed wavelength is redshifted from emitted wavelength **B1**

# Solution 10

## (b)(ii) Worked steps

Redshift relates the **fractional** change in wavelength to the speed as a fraction of the speed of light.

- $\dfrac{\Delta\lambda}{\lambda} = \dfrac{v}{c}$
- $\Delta\lambda = 4.91 - 4.62 = 0.29$ (in whatever unit the two are quoted — the ratio is what matters, so no conversion is needed)
- $\dfrac{0.29}{4.62} = \dfrac{v}{3.00 \times 10^8}$
- $v = 1.9 \times 10^7\ \mathrm{m\,s^{-1}}$

# Solution 10

Divide by the **emitted** wavelength, not the observed one: $\lambda$ in the formula is the laboratory value the shift is measured from. The difference is small here, but it is the difference between a method mark and none.

## Mark scheme

- $\Delta\lambda$ / $\lambda$ = v / c
- (4.91 – 4.62) / 4.62 = v / (3.00 × 108) **C1**
- v = 1.9 × 107 m s–1 **A1**

# Solution 10

## (b)(iii) Worked steps

Wien's displacement law makes this a one-step comparison.

- $\lambda_{\max} T =$ constant, so $\lambda_{\max} \propto \dfrac{1}{T}$ — the peak wavelength and the temperature are **inversely** proportional.
- The star is receding, so the observed peak wavelength is **longer** than the emitted one.
- A longer wavelength substituted into Wien's law gives a **lower** temperature.

So the temperature found from the observed wavelength is **too low** compared with the true value.

# Solution 10

Both marks are for the reasoning, not the conclusion: state the inverse proportionality, then say which way the wavelength moved. A bare "too low" earns one mark at most.

**Mark scheme**

- wavelength (of maximum intensity) is inversely proportional to temperature **B1**
- observed wavelength too high, so determined temperature too low **B1**

# Solution 10

## (c) Worked steps

Hubble's law connects recession speed to distance directly.

- $v = H_0 d$, so $d = \dfrac{v}{H_0}$
- $d = \dfrac{1.9 \times 10^{7}}{2.3 \times 10^{-18}}$
- $d = 8.3 \times 10^{24}$ m

# Solution 10

The Hubble constant is given in $s^{-1}$, so the answer comes out in metres with no conversion — which is why the question quotes it that way rather than in $km\,s^{-1}\,Mpc^{-1}$.
Use your own speed from (b)(ii); the mark is for the method.

**Mark scheme**

- v = H0d **C1**
- d = (1.9 × 107) / (2.3 × 10–18)
- = 8.3 × 1024 m **A1**

# Question 10

9702/43 J25 ▪ Q10 ▪ 10 marks

**10** **(a)** State Hubble's law.

# Question 10

**(b)** A star in a distant galaxy emits radiation that has a maximum intensity of emission at a wavelength of $4.62 \times 10^{-7}$ m.

Observations of the galaxy made on the Earth detect the maximum intensity of emission from the star at a wavelength of $4.91 \times 10^{-7}$ m.

**(i)** Explain why the observed wavelength and the emitted wavelength have different values.

# Question 10

**(ii)** Calculate the speed of the star relative to the Earth.

# Question 10

**(iii)** The wavelength of maximum intensity of emission is used to determine a value for the surface temperature of the star.

Explain how the temperature determined using the observed wavelength compares with the true value of temperature determined using the emitted wavelength.

# Question 10

**(c)** A value for the Hubble constant is $2.3 \times 10^{-18}\,s^{-1}$.

Use your answer in **(b)(ii)** to determine the distance of the star in **(b)** from the Earth.

# Question 10

[Total: 10]

# Solution 10

## (a)

**Mark scheme**

- speed is (directly) proportional to distance
- speed is speed of recession of galaxy from an observer, and distance is the distance of the galaxy from the observer

# Solution 10

## (b)(i)

**Mark scheme**

- galaxy is receding from the Earth
- observed wavelength is redshifted from emitted wavelength

# Solution 10

## (b)(ii) Worked steps

Redshift relates the **fractional** change in wavelength to the speed as a fraction of $c$.

- $\dfrac{\Delta\lambda}{\lambda} = \dfrac{v}{c}$
- $\Delta\lambda = 4.91 - 4.62 = 0.29$; the two wavelengths are in the same unit, so the ratio needs no conversion.
- $\dfrac{0.29}{4.62} = \dfrac{v}{3.00 \times 10^8}$
- $v = 1.9 \times 10^7$ m s$^{-1}$

# Solution 10

Divide by the **emitted** wavelength, not the observed one — $\lambda$ in the formula is the laboratory value the shift is measured from.

## Mark scheme

- $\Delta\lambda / \lambda = \mathrm{v} / \mathrm{c}$
- $(4.91 - 4.62) / 4.62 = \mathrm{v} / (3.00 \times 108)$
- $\mathrm{v} = 1.9 \times 107$ m s–1

# Solution 10

**(b)(iii)**

**Mark scheme**

- wavelength (of maximum intensity) is inversely proportional to temperature
- observed wavelength too high, so determined temperature too low

# Solution 10

## (c) Worked steps

Hubble's law connects that recession speed to distance in one step.

- $v = H_0 d$, so $d = \dfrac{v}{H_0} = \dfrac{1.9 \times 10^{7}}{2.3 \times 10^{-18}}$
- $d = 8.3 \times 10^{24}$ m

# Solution 10

The Hubble constant is quoted in $s^{-1}$, so the answer comes out in metres with no conversion — which is exactly why the question gives it that way rather than in $\mathrm{km\,s^{-1}\,Mpc^{-1}}$. Use your own speed from (b)(ii); the mark is for the method.

**Mark scheme**

- $v = H0d$
- $d = (1.9 \times 107) / (2.3 \times 10–18)$
- $= 8.3 \times 1024\,\mathrm{m}$