25.2 Stellar radii

Name: ______________ Class: __________ Date: ____________ **Total: 13 marks**

Objective

Build the skills to answer exam questions on **stellar temperature and radius**.

You must be able to:

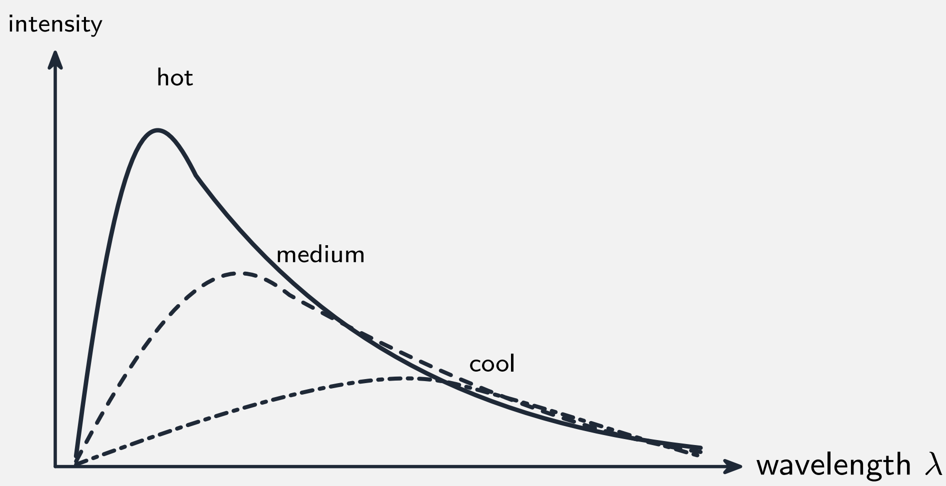
- use **Wien's law** $\lambda_{\max}T = \text{constant}$
- use the **Stefan–Boltzmann law** $L = 4\pi\sigma r^2 T^4$
- combine them to estimate a star's **radius**

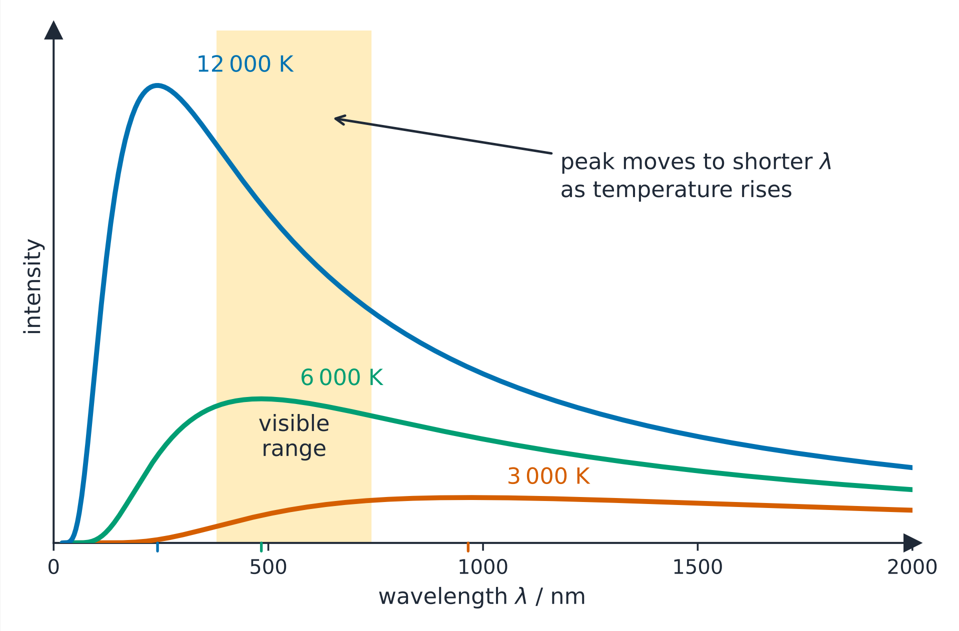
1 Worked examples

Study these first. Each one shows the method for a question type used later —follow the steps and you can do the Practice and Exam-style questions yourself.

Wien's law

A star radiates a **black-body** spectrum; a **hotter** star radiates more and peaks at a **shorter** wavelength:





A blackbody curve and Wien law

$$\lambda_{\max} T = b, \qquad b = 2.90 \times 10^{-3}\ \text{m K}.$$

■ **Stefan–Boltzmann law and radius**

$$L = 4\pi\sigma r^2 T^4, \qquad \sigma = 5.67 \times 10^{-8}\ \text{W m}^{-2}\,\text{K}^{-4}.$$

Find T from Wien's law, then $r = \sqrt{\dfrac{L}{4\pi\sigma T^4}}$.

Worked example. $\lambda_{\max} = 500$ nm: $T = \dfrac{2.90 \times 10^{-3}}{500 \times 10^{-9}} = 5800$ K.

2 Practice

Now apply the methods above.

2.1 Write **Wien's displacement law**. [1]

2.2 A star's spectrum peaks at 500 nm. Find its surface **temperature**. [2]

2.3 Write the **Stefan–Boltzmann law**. [1]

2.4 State how λ_{max} changes for a **hotter** star. [1]

3 Exam-style questions

3.1 A **hotter** star has its peak emission at a: [1]

- **A** longer wavelength
- **B** shorter wavelength
- **C** the same wavelength
- **D** no peak

3.2 A star's black-body spectrum peaks at 290 nm. Calculate its surface **temperature**. [2]

3.3 A star has a surface temperature of 6000 K and luminosity 4.0×10^{26} W. Calculate its **radius**. ($\sigma = 5.67 \times 10^{-8}$.) [3]

3.4 Outline how a star's **radius** can be estimated from its spectrum. [2]

4 Go further

You are now ready for the real exam questions on this subtopic. Open the **25.2 Stellar radii** past-paper sheet in the Library, or try these in **Practice mode**:

- 9702/41 J25 —Q10 (Wien's law and Stefan–Boltzmann)
- 9702/43 J25 —Q10 (stellar radius)
- 9702/44 J25 —Q11 (black-body radiation)

- 9702/42 M25 —Q10 (temperature and radius)

Solutions

2.1 $\lambda_{\max}T = \text{constant}$ (or $\lambda_{\max} \propto 1/T$).

2.2 $T = \dfrac{b}{\lambda_{\max}} = \dfrac{2.90 \times 10^{-3}}{500 \times 10^{-9}} = 5800$ K.

2.3 $L = 4\pi\sigma r^2 T^4$.

2.4 It is **shorter** ($\lambda_{\max} \propto 1/T$).

3.1 **B** —shorter wavelength.

3.2 $T = \dfrac{2.90 \times 10^{-3}}{290 \times 10^{-9}} = 1.0 \times 10^4$ K.

3.3 $r = \sqrt{\dfrac{L}{4\pi\sigma T^4}} = \sqrt{\dfrac{4.0 \times 10^{26}}{4\pi(5.67 \times 10^{-8})(6000)^4}} = 6.6 \times 10^8$ m.

3.4 Find T from $\lambda_{\max}$ (Wien's law) and measure L; then use the Stefan–Boltzmann law $L = 4\pi\sigma r^2 T^4$ to solve for r.