

Exercise walk-through

5.8

Stellar radiation, distances and evolution (161–168)

Pearson Edexcel · International A-Level · Physics

CP15: attenuation is a thickness law

Action	Why it matters
Fix geometry and count time	Source contribution must be comparable across thicknesses.
Measure and subtract background	Background does not follow the absorber transmission law.
Repeat; plot log corrected rate versus lead thickness	Test exponential attenuation. Avoid near-background readings with large relative uncertainty.

Use the evidence

Three half-value thicknesses transmit $1/8$. Follow supervised source handling and shielding.

Your turn: from colour to received intensity

Follow energy from the star to the observer

The wavelength spectrum peaks at 580 nm. Stellar radius is 7.0×10^8 m; observer distance is 1.5×10^{11} m.

Use $b = 2.898 \times 10^{-3}$ m K and $\sigma = 5.67 \times 10^{-8}$ W m⁻² K⁻⁴.

Find temperature, luminosity and received intensity. Name the two different spherical areas.

Use the documents in their learning order

Reference: learn the complete knowledge, methods and assumptions.



Skill sheet: supported practice → reduced support → exam-style demands.



Authentic set: transfer to original wording; correct with reasons.



Return to the reference for a diagnosed gap; reattempt before using reserved assessment questions.

Exercise 2.1

2.1 A star's wavelength spectrum peaks at 500 nm. Find surface temperature using $\lambda_{max}T = 2.898 \times 10^{-3} \text{ m K}$. Explain the effect of higher temperature on peak wavelength and emitted power per unit area. [4]

$$\lambda_{max} = 500 \text{ nm}$$



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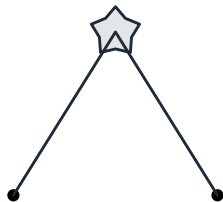
2.1 Use Wien's wavelength law, converting nm to m.

$$T = \frac{2.898 \times 10^{-3} \text{ m K}}{\lambda_{max}} = \frac{2.898 \times 10^{-3} \text{ m K}}{500 \times 10^{-9} \text{ m}} = 5796 \text{ K}$$

Temperature. Higher T moves the wavelength peak shorter and increases total emitted power per area as T^4 for a black body.

Exercise 2.2

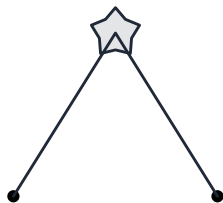
2.2 A nearby star shows total angular shift 0.10 arcsecond between observations six months apart. Calculate distance in parsecs and explain why half the total shift is used. [3]



six months; full shift 0.10 arcsec

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2.2 Parallax is half the full six-month shift, 0.050 arcsecond.

$$d_{pc} = \frac{1}{p_{arcsec}} = \frac{1}{0.050} = 20 \text{ pc}$$

Distance. The full baseline is two Earth-orbit radii, while parallax uses one radius.

Exercise 2.3

2.3 A standard candle has luminosity $8.0 \times 10^{28} \text{ W}$ and received intensity $4.0 \times 10^{-12} \text{ W m}^{-2}$. Find distance and state one limitation of the isotropic, transparent-space model. [4]

$$L = 8.0 \times 10^{28} \text{ W}$$
$$I = 4.0 \times 10^{-12} \text{ W/m}^2$$



3 Exam-style questions

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2.3 Rearrange the inverse-square intensity relation.

$$d = \sqrt{\frac{L}{4\pi I}} = \sqrt{\frac{8.0 \times 10^{28} \text{ W}}{4\pi(4.0 \times 10^{-12} \text{ W m}^{-2})}} = 3.99 \times 10^{19} \text{ m}$$

Substitution and value. Absorption by dust or anisotropic emission can invalidate the assumed relation.

Exercise 3.1

3.1 A spherical black-body star has radius 6.0×10^8 m, surface temperature 6000 K and an orbiting planet at 2.0×10^{11} m. Calculate stellar luminosity and intensity at the planet using $\sigma = 5.67 \times 10^{-8} \text{ W m}^{-2} \text{ K}^{-4}$. Explain why the two areas differ. [6]

$$R = 6.0 \times 10^8 \text{ m}; T = 6000 \text{ K}$$

$$d = 2.0 \times 10^{11} \text{ m}$$



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3.1 Use the emitting surface for luminosity.

$$L = 4\pi R^2 \sigma T^4 = 4\pi (6.0 \times 10^8 \text{ m})^2 (5.67 \times 10^{-8} \text{ W m}^{-2} \text{ K}^{-4}) (6000 \text{ K})^4 = 3.32 \times 10^{26} \text{ W}$$

Luminosity and unit. Spread that power over a sphere at observer distance.

$$I = \frac{L}{4\pi d^2} = \frac{3.324 \times 10^{26} \text{ W}}{4\pi (2.0 \times 10^{11} \text{ m})^2} = 661 \text{ W m}^{-2}$$

Intensity. R is stellar radius; d is star-to-planet distance, describing different physical spheres.

Exercise 3.2

3.2 On an HR diagram, temperature decreases to the right. Describe where to place the Sun, a red giant and a white dwarf. Explain how a red giant can be cooler but brighter than the Sun. Distinguish an evolutionary track from spatial motion. [5]

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red giant

white dwarf

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3.2 Sun near 5800K, one solar luminosity, on main sequence. Red giant upper right, cool but luminous; white dwarf lower left, hot but faint. Large giant radius/surface area can more than offset lower T^4 in $L = 4\pi R^2 \sigma T^4$. A track records changing temperature and luminosity, not physical travel across space.

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3.3 Explain a Sun-like star's development from a gas cloud through main sequence and red giant to its remnant. Contrast a very massive star's late outcome and explain why more initial fuel need not mean a longer main-sequence lifetime. [8]



star



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3.3 Gravity contracts a gas/dust cloud and heats its core. Hydrogen fusion sustains main sequence, with pressure balancing gravity. Depletion of core hydrogen causes core contraction and heating. Shell hydrogen burning and later helium fusion accompany red-giant expansion. Outer layers are lost, leaving a white dwarf without sustained fusion, which cools. A very massive star can fuse heavier nuclei before core collapse/supernova, leaving a neutron star or black hole rather than the Sun's white-dwarf outcome. Its hotter core consumes fuel much faster, so greater fuel supply need not outweigh its much greater fusion rate.