



ANSWER BOOK

# Star brightness and magnitude

Astrophysics · Year 13

AQA 3.9.2.1, 3.9.2.2 · CIE 25.1.1, 25.1.2, 25.1.3, 25.1.4 · OCR A 5.5.3(a), 5.5.3(b), 5.5.3(c)

20 questions · 56 marks

NAVY EDITION

**SECTION A** · Warm-up

- A1** Brighter objects have smaller, and then negative, magnitudes; the scale runs backwards (1). The dimmest naked-eye stars are about magnitude +6 (1). [2]
- A2** One parsec is the distance at which one astronomical unit, the mean Earth-Sun distance, subtends an angle of one arcsecond (1). 1 pc = 3.26 light years (1). [2]
- A3** One magnitude step is a received-intensity ratio of 2.51 (1); five steps are exactly 100 (1). The eye judges brightness roughly logarithmically, so the equal-feeling steps of the ancient scale correspond to equal ratios of intensity (1). [3]
- A4** The astronomical unit is the mean distance from the Earth to the Sun (1). The light year is the distance light travels through a vacuum in one year (1). [2]
- A5** They are equal: at  $d = 10$  pc,  $m - M = 5 \log(10/10) = 0$  (1). [1]
- A6** The difference  $m - M$  between the apparent and absolute magnitudes (1). Since  $m - M = 5 \log(d/10)$ , it gives the star's distance in parsecs (1). [2]

**SECTION B** · Standard

- B1** P is the brighter, having the smaller number, by  $2.51^{(7.0 - 2.0)} = 2.51^5$  (1) = 100 times (1) [2]
- B2**  $M = m - 5 \log(d/10)$  (1)  
 $= -1.5 - 5 \log(0.264)$  (1)  
 $M = +1.4$  (1) [3]
- B3**  $m = M + 5 \log(d/10)$  (1)  
 $= 0.6 + 5 \log(2.5)$  (1)  
 $m = +2.6$  (1) [3]
- B4**  $m - M = 7.5 = 5 \log(d/10)$  (1)  
 $\log(d/10) = 1.5$  (1)  
 $d = 10 \times 10^{1.5}$  (1)  
 $d = 316$  pc, about  $3.2 \times 10^2$  pc (1) [4]
- B5**  $m$  differs by  $5 \log(50/5.0)$  (1)  
 $= 5.0$  magnitudes (1)  
The nearer star appears  $2.51^5 = 100$  times brighter (1) [3]

- B6**  $F = L/4\pi d^2$  (1)  $= 3.2 \times 10^{28} / (4\pi \times (4.1 \times 10^{17})^2)$  (1)  $= 1.5 \times 10^{-8} \text{ W m}^{-2}$  (1). [3]
- B7**  $F = L/4\pi d^2$ , so  $d = \sqrt{(L/4\pi F)}$  (1)  $= \sqrt{(7.8 \times 10^{29} / (4\pi \times 6.2 \times 10^{-13}))}$  (1)  $= 3.2 \times 10^{20} \text{ m}$  (1)  $= 3.2 \times 10^{20} / (3.08 \times 10^{16}) \approx 1.0 \times 10^4 \text{ pc}$  (1). [4]
- B8**  $2.51^{\Delta m} = 16$ , so  $\Delta m = \log 16 / \log 2.51$  (1)  $= 3.0$  magnitudes, V carrying the smaller number (1). [2]

## SECTION C · Stretch

- C1**  $d = 42/3.26$  (1) [4]  
 $d = 12.9 \text{ pc}$  (1)  
 $M = m - 5 \log(d/10) = 5.0 - 5 \log(12.9/10)$  (1)  
 $M = +4.4$  (1)
- C2** The magnitude difference is 25.2 (1) [3]  
 Ratio  $= 2.51^{25.2}$  (1)  
 $\approx 1.2 \times 10^{10}$  (1)
- C3** Apparent magnitude mixes the star's true output with its distance: a feeble nearby star can look brighter than a distant giant (1). Absolute magnitude removes the distance by quoting the apparent magnitude every star would have at the same standard 10 pc (1). [2]
- C4**  $m = M + 5 \log(d/10)$  (1)  $= 7.5 + 5 \log(0.35) = 7.5 - 2.3$  (1)  $= +5.2$  (1). This is a smaller (brighter) magnitude than the +6 limit, so the star is just visible to the naked eye (1). [4]
- C5** T:  $m = -2.0 + 5 \log(25) = +5.0$  (1). U:  $m = +1.0 + 5 \log(1.5) = +1.9$  (1). U has the smaller apparent magnitude (1), so U appears the brighter, even though T is by far the more luminous star (1). [4]
- C6**  $1 \text{ arcsecond} = (1/3600) \times (\pi/180) = 4.85 \times 10^{-6} \text{ rad}$  (1). One parsec is the distance at which 1 AU subtends this angle, so  $d = 1.50 \times 10^{11} / (4.85 \times 10^{-6})$  (1)  $= 3.09 \times 10^{16} \text{ m} \approx 3.1 \times 10^{16} \text{ m}$  (1). [3]