inkPhysics

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

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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) [3]
$= -1.5 - 5\log(0.264)$ (1)
$M = +1.4$ (1)

B3 $m = M + 5\log(d/10)$ (1) [3]
$= 0.6 + 5\log(2.5)$ (1)
$m = +2.6$ (1)

B4 $m - M = 7.5 = 5\log(d/10)$ (1) [4]
$\log(d/10) = 1.5$ (1)
$d = 10 \times 10^{1.5}$ (1)
$d = 316$ pc, about 3.2×10^2 pc (1)

B5 m differs by $5\log(50/5.0)$ (1) [3]
$= 5.0$ magnitudes (1)
The nearer star appears $2.51^5 = 100$ times brighter (1)

B6 $F = L/4\pi d^2$ (1) $= 3.2 \times 10^{28}/(4\pi \times (4.1 \times 10^{17})^2)$ (1) $= 1.5 \times 10^{-8}$ 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) $= 3.2 \times 10^{20}$ m (1) $= 3.2 \times 10^{20}/(3.08 \times 10^{16}) \approx 1.0 \times 10^4$ 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]
$d = 12.9$ 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 arcsecond $= (1/3600) \times (\pi/180) = 4.85 \times 10^{-6}$ 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) $= 3.09 \times 10^{16}$ m $\approx 3.1 \times 10^{16}$ m (1). [3]