InkPhysics

ANSWER BOOK

Telescopes and image formation

Astrophysics · Year 13

AQA 3.9.1.1, 3.9.1.2

20 questions · 60 marks

NAVY EDITION

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SECTION A · Warm-up

A1 The focal planes of the objective and the eye lens coincide (1). The final image is formed at infinity, viewed by a relaxed eye (1). [2]

A2 The angle subtended at the eye by the final image divided by the angle subtended at the unaided eye by the object (1). It is a ratio of angles, not of sizes (1). [2]

A3 A concave parabolic primary mirror and a convex secondary mirror (1). The secondary reflects the converging light back through a central hole in the primary, to a focus just behind it (1). [2]

A4 It is the ratio of two angles: the angle subtended at the eye by the final image divided by the angle subtended by the object at the unaided eye (1). Both angles carry the same unit, which cancels in the ratio (1). [2]

A5 In the objective's focal plane, one focal length behind the lens, because the light arrives as (near-)parallel rays (1). The image is real (and inverted) (1). [2]

A6 $M = f_o/f_e$, so halving f_e doubles the angular magnification (1). [1]

SECTION B · Standard

B1 $M = f_o/f_e = 1.5/0.030$ (1) [3]
$M = 50$ (1)
Length $= f_o + f_e = 1.53$ m (1)

B2 $M = f_o/f_e = 1.0/0.025 = 40$ (1) [3]
Angle through the telescope $= 40 \times 9.0 \times 10^{-3}$ (1)
$= 0.36$ rad (1)

B3 $f_o = 60f_e$ (1) [4]
$f_o + f_e = 1.22$ m (1)
$61f_e = 1.22$ m, so $f_e = 20$ mm (1)
$f_o = 1.20$ m (1)

B4 Glass refracts blue light more than red, so each colour has a different focal length (1) and no single sharp focus exists; images carry coloured fringes (1). Reflection is the same for every wavelength, so mirrors focus all colours together (1). [3]

B5 For a spherical surface, rays striking near the edge focus closer than rays near the axis (1), smearing the focus (1). The primary is ground to a parabola, which brings all rays parallel to the axis to a single focus (1). [3]

B6 $M = 6.0 \times 10^{-3}/(1.5 \times 10^{-4}) = 40$ (1). $f_o = Mf_e$ (1) $= 40 \times 0.020 = 0.80$ m (1). [3]

B7 Diameter of the real image $= f_o\theta$ (1) $= 1.4 \times 1.2 \times 10^{-4} = 1.7 \times 10^{-4}$ m (1). Number of pixels $= 1.7 \times 10^{-4}/(5.0 \times 10^{-6})$ (1) ≈ 34 pixels (accept 33 to 34) (1). [4]

B8 The convex secondary reflects the converging beam back down the tube and through the hole in the primary, folding the light path so the effective focal length is much longer than the tube (1). A short tube is stiffer, cheaper to mount and easier to steer (any one) (1). [2]

B9 $f_e = 1.30 - 1.25 = 0.050$ m (1). $M = f_o/f_e = 1.25/0.050 = 25$ (1). Angle through the telescope $= M\theta$ (1) $= 25 \times 6.0 \times 10^{-5} = 1.5 \times 10^{-3}$ rad (1). [4]

SECTION C · Stretch

C1 $M = f_o/f_e = 3.2/0.0080$ (1) [4]
$M = 400$ (1)
The crater subtends $400 \times 4.0 \times 10^{-5}$ (1)
$= 0.016$ rad (1)

C2 Reflector, any two of the following, one mark each (2): no chromatic aberration; the parabolic primary removes spherical aberration; a mirror can be supported across its back, so large apertures are practical; less light is lost than in thick glass. Refractor: a sealed tube needs little maintenance (1), while mirror coatings need occasional renewal (1). [4]

C3 Magnification only stretches the light already collected; it can be made large with a short-focus eyepiece (1). Image quality depends on the objective's diameter, which sets how much light is gathered and how fine the detail that can be resolved (1). [2]

C4 In normal adjustment f_o = tube length $- f_e = 1.05 - 0.025 = 1.025$ m (1). $M = f_o/f_e = 1.025/0.025 = 41$ (1). A magnification of 60 with this eyepiece would need $f_o = 1.5$ m, so a tube 1.525 m long (OR 41 falls well short of 60) (1). The claim is not consistent with the dimensions (1). [4]

C5 Rays from the distant cluster arrive effectively parallel, and the objective converges them to a real image in its focal plane (1). In normal adjustment this plane is also the focal plane of the eye lens (1), so the light leaves the eye lens as parallel beams and the final image is at infinity, viewed by a relaxed eye (1). An image of height h in the shared focal plane subtends the object's unaided angle $\theta_o \approx h/f_o$ at the objective (1) and the larger angle $\theta_i \approx h/f_e$ at the eye (1). Dividing: $M = \theta_i/\theta_o = f_o/f_e$ (1). [6]