InkPhysics

ANSWER BOOK

Telescopes across the spectrum

Astrophysics · Year 13

AQA 3.9.1.3, 3.9.1.4

10 questions · 31 marks

NAVY EDITION

inkphysics.co.uk

SECTION A · Warm-up

A1 The atmosphere absorbs ultraviolet and X-rays high above the ground, so they never reach a ground-based instrument. It is transparent to radio wavelengths, so a dish at sea level receives them day and night, even through cloud. [2]

A2 The sources are just resolved when the central maximum of one diffraction pattern falls on the first minimum of the other: their angular separation is then $\theta \approx \lambda/D$, with θ in radians. [1]

A3 Quantum efficiency is the fraction (or percentage) of the photons arriving at the detector that are actually registered. A CCD achieves about 80%; the eye manages about 1%. [2]

SECTION B · Standard

B1 $\theta \approx \lambda/D = 5.5 \times 10^{-7}/5.0 = 1.1 \times 10^{-7}$ rad. [3]

B2 Eye: $\theta \approx 5.0 \times 10^{-7}/5.0 \times 10^{-3} = 1.0 \times 10^{-4}$ rad. Dish: $\theta \approx 0.21/64 = 3.3 \times 10^{-3}$ rad. The eye's angle is the smaller, so the eye resolves finer detail: the dish's wavelength is nearly a million times longer. [4]

B3 Collecting power $\propto D^2$, so the ratio $= (10/2.0)^2 = 25$: the larger mirror gathers 25 times the light. [3]

B4 $\theta \approx \lambda/D = 5.5 \times 10^{-7}/2.4 = 2.3 \times 10^{-7}$ rad. Smallest feature $\approx \theta d = 2.3 \times 10^{-7} \times 3.8 \times 10^{8} \approx 87$ m: nothing left on the Moon by astronauts is visible to any telescope of this size. [2]

SECTION C · Stretch

C1 Optical: $\theta \approx 5.0 \times 10^{-7}/0.15 = 3.3 \times 10^{-6}$ rad. Radio: $D = \lambda/\theta = 0.21/3.3 \times 10^{-6} = 63$ km. A single dish 63 km across cannot be built, which is why radio astronomers link widely separated dishes to act as one large aperture. [4]

C2 Its quantum efficiency is far higher (about 80% against about 1%); it can accumulate light over an exposure of minutes or hours while the eye refreshes many times a second; it produces a permanent, shareable record whose brightness can be measured; and it responds beyond the visible, into the infrared and ultraviolet. [4]

C3 Infrared: sited on high, dry mountains or in space because water vapour absorbs infrared, and the detectors are cooled so the instrument's own warmth does not swamp the signal. X-ray: placed in orbit, and focused by grazing-incidence nested mirrors, because X-rays penetrate an ordinary mirror surface instead of reflecting. [3]