

Question 1: Detectors

- (a) The index of refraction for X-rays, n , is given by

$$n = 1 - \frac{N_A r_e}{2} \rho \lambda^2 = 1 - \delta \quad (1.1)$$

where N_A is Avogadro's number, $r_e = 2.8 \times 10^{-15}$ m, ρ the density and λ the wavelength.

- (i) Using Snell's law, show that the critical angle for reflection of X-rays is given approximately by

$$\theta_c = \sqrt{2\delta} \quad (1.2)$$

where θ_c is measured with respect to the surface tangent.

- (ii) Determine the critical angle for reflection of X-rays with an energy of $E = 5$ keV off gold ($\rho = 19.3$ g cm⁻³).
- (iii) Sketch the major components of a Wolter telescope.

- (b) The major detectors used in X-ray astronomy are proportional counters and Silicon based Charge Coupled Devices. Describe how these detectors work and compare their general properties such as the energy resolution, imaging capabilities and useful energy range.
- (c) In order to understand the physics of Active Galactic Nuclei, why is it important to perform space measurements?

The following constants might be useful for solving this question.

$$\begin{aligned} h &= 6.63 \times 10^{-34} \text{ J s} \\ c &= 3 \times 10^8 \text{ m s}^{-1} \\ 1 \text{ eV} &= 1.6 \times 10^{-19} \text{ J} \\ N_A &= 6 \times 10^{23} \end{aligned}$$