M1.(a) (i) Provide aperture through which X-rays may pass, stopping others ✓

Alternatives: provides collimation; produces narrow beam of X-rays; protects areas of the body not being scanned

1

(ii) Filters out (most) low energy photons (but allows high energy photons to pass through) ✓

Allow 'soft' or underpower' for low energy
Allow only high energy photons pass through

1

(b) $I / I_0 = 0.917$ ✓
$\ln (0.917) = -\mu \times 2.7 \times 10^{-3}$ ✓
$\mu = 32.1$ ✓
$\mu_m = \mu / 2700 = 0.012$ ✓
$m^2 kg^{-1}$ ✓

If 0.083 or 91.7 used, final 3 calc marks can be given
If 0.83 or 8.3 or 9.17 used, final 2 calc marks can be given
Unit mark is independent mark

5

[7]

M2. (i) thickness needed to reduce intensity by half **(1)**
for X-rays of specific energy **(1)**

(ii) $\mu = \frac{\ln 2}{x}$ **(1)**

$= 58\ m^{-1}$ (1) ($57.8\ m^{-1}$)

(iii) (use of $I = I_0 e^{-\mu x}$ gives) $0.05 = e^{-57.8x}$ **(1)**
$x = 0.052$ m (or 52 mm) **(1)** (51.8 mm)
(allow C.E. for value of μ from (ii))

[6]

M3. (a) for clear image need large difference in densities between part being investigated and parts around it **(1)**
when this is not natural, add material to part under investigation **(1)**
which has high density to provide good attenuation of X-rays **(1)**
barium meal use barium sulphate **(1)**

max 3

(b) μ (= $\rho\mu$m) = 2700 – 0.012 = 32.4 **(1)**

(use of $I = I_0 e^{-\mu x}$ gives) $1.2 \times 10^{-2} = 3.2 \times 10^{-2} \times e^{-32.4x}$ **(1)**

(allow C.E. for value of μ)

x = 0.03(0) m **(1)**

3

[6]

M4.(a) 1: vacuum / evacuated (tube) **(1)**
2: lead (lined shield) **(1)**
3: electrons (beam) **(1)**

3

(b) (i) heat is spread over a greater volume / area / section **(1)**
thus allows more energetic X-rays to be produced
[or allows X-rays to be generated for longer] **(1)**

(ii) (bevelled edge) gives larger target area **(1)**
but small source area (to produce sharp image) **(1)**

max 3

(c) (i) the fraction of X-rays removed per unit thickness of the material **(1)**

(ii) the thickness of the material which will reduce the intensity to half its original level **(1)**
for a specified energy of the X-rays (in either (i) or (ii)) **(1)**

2

(d) (use of $\mu = \frac{\ln 2}{t_{1/2}}$ gives) $\mu = \frac{\ln 2}{3.2}$ = 0.22mm^{-1} **(1)**(0.217 mm^{-1})

(use of $I = I_o e^{\mu x}$ gives) I = 6.0 × e$^{-0.217 \times 2}$ **(1)**
(allow C.E. for value of μ)
= 3.9 W m^{-2} **(1)**

3

[11]