X-rays Answers – Medical Physics Option

1. (a) A glass tube **(1)**
(sealed), evacuated, allows electrons to travel unimpeded **(1)**

B rotating anode [or target] **(1)**
rotation of anode [or target] to spread heated area **(1)**
target which emits X-rays when hit by (energetic) electrons **(1)**

C filament [or cathode] **(1)**
heat source to release electrons from surface of cathode by thermionic emission **(1)**

D lead housing **(1)**
prevent X-rays from escaping in unwanted directions **(1)** max 8

(b) path of electrons shown from filament (C) to anode (B) **(1)**
path of X-rays shown starting at anode (B)
and emerging through window in lead housing (D) **(1)** 2

[10]

2. (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) $\mu = \frac{\ln 2}{3.2} = 0.22\ \text{mm}^{-1}$ **(1)** ($0.217\ \text{mm}^{-1}$)

(use of $I = I_0\, e^{-\mu x}$ gives) $I = 6.0 \times e^{-0.217 \times 2}$ **(1)**
(allow C.E. for value of μ)
$= 3.9\ \text{W m}^{-2}$ **(1)** 3

[11]

3. (a) (i) converts X rays to visible photons **(1)**

(ii) converts photons to emission of electrons **(1)**

(iii) increases kinetic energy of electrons travelling from cathode to anode **(1)**
focuses rays of electrons to produce faithful image **(1)**

(iv) converts (increased) electron <u>energy</u> into light photons max 4

(b) dynamic process such as fluid flow **(1)**
cuts radiation dose whilst still providing good image
[or allows multiple or continuous use of X ray] **(1)** 2

[6]

4. (a) (i) method 1: increasing pd across the tube **(1)**
method 2: increasing tube current or increasing filament temperature **(1)**

(ii) method 1: will increase the maximum photon energy **(1)**
method 2: will not change the maximum photon energy **(1)** max 3

(b) reduces intensity of low energy photons **(1)**
hardly changes intensity of high energy photons **(1)**
need high energy for picture
[or low energy no good for picture] **(1)**
reducing low energy reduces dose received by patient **(1)** max 3

[6]

5. (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]

6. technique: broken arm – X-ray, foetus – ultrasound **(1)**

reasons: (X-ray) good contrast
sharp image
good resolution any two **(1)** **(1)**

(ultrasound) non-ionising (safe)
detects change in tissue type
allows real-time image any two **(1)** **(1)** max 4

[4]

7. (a) specific to anode element/target atoms/material **(1)**
energy level transition **(1)** 2

(b) new curve to show:
entire curve has more intensity **(1)**
stops at 90 kV **(1)**
spikes in same position **(1)** 3

(c) % into heat = (100 – 0.70) = 99.3 **(1)**

rate of heat produced = $\frac{99.3}{100} \times 80 \times 10^3 \times 120 \times 10^{-3}$ **(1)**

= 9.5 kW **(1)** (9.53 kW) 3

[8]

8. A scintillator crystal(s)/fluorescent screen **(1)**
convert X-ray photons into light **(1)**

B photocathode **(1)**
light energy releases electrons **(1)**
number of electrons released proportional to X-ray intensity **(1)**

C anodes **(1)** max 8
increase energy of the electrons **(1)**
focus the electrons to form an image **(1)**

D fluorescent screen **(1)**
converts electron energy into light photons **(1)**

[8]