## Q1.

7 (a) electrons fired at <u>metal</u> target ........ B1
electrons decelerated giving off (e.m.) radiation ........ B1
range of decelerations, so continuous spectrum ........ B1
also, electrons in inner orbits are excited ........ B1
de-excitation gives characteristic line spectrum ........ B1 [5]

(b) (i) increase cathode/tube current ........ B1

(ii) increase anode voltage ........ B1

(iii) use aluminium filter (allow metal filter) ........ B1 [3]

(c) $I = I_0 e^{-\mu x}$ ........ C1
$\ln 2 = 0.40\mu$
$\mu = 1.733\ \text{cm}^{-1}$ or $= \ln 2/0.4$ ........ C1
$0.1 = e^{-1.733x}$
$x = 1.33$ cm ........ A1 [3]

## Q2.

8 (a) produces greater intensity (at focus)
limits region of cell damage
allows for accurate guidance ........ B2 [2]

(b) laser beam cauterises tissue
can produce coagulation
vaporisation of water in cells ........ B2 [2]
{in (a) and (b), allow 1 mark each up to max of 3 in either, total not to exceed 4}

## Q3.

9 (a) ability to detect (small) changes in loudness/intensity ........ B1
depends on $I / \Delta I$ ........ B1 [2]

(b) $\Delta I.L. = 10\ \lg(\Delta I / I)$ or $I.L. = 10\lg(I/I_0)$ ........ C1
$3.0 = 10\ \lg\ (I_2 / (4.5 \times 10^{-5}))$ ........ C1
$I_2 = 9.0 \times 10^{-5}\ \text{Wm}^{-2}$, $\Delta I = 4.5 \times 10^{-5}\ \text{W m}^{-2}$ ........ A1 [3]

## Q4.

9 (a) X-ray beam directed through body onto detector (plate) B1
different tissues absorb/attenuate beam by different amounts B1
giving 'shadow' image of structures B1
any other detail e.g. comment re sharpness or contrast B1 [4]

(b) X-ray image is flat OR 2-dimensional (1)
CT scan takes many images of a slice at different angles (1)
these build up an image of a slice through the body (1)
series of images of slices is made (1)
so that 3D image can be built up (1)
image can then be rotated (1)
*1 mark for each point, max 5* B5 [5]

## Q5.

10 large / strong (constant) magnetic field B1
nuclei rotate about direction of field / precess (1)
radio frequency / r.f. pulse B1
causes resonance in nuclei , nuclei absorb energy (1)
(pulse) is at the Larmor frequency (1)
on relaxation / nuclei de-excite emit (pulse of) r.f. B1
detected <u>and</u> processed B1
non-uniform field (superimposed) B1
allows for position of nuclei to be determined B1
and for location of detection to be changed (1)
*(B6 plus any two extra details, 1 each, max 2)* B2 [8]

## Q6.

11 (a) <u>pulse</u> of ultrasound (1)
reflected at boundaries / boundary (1)
received / detected (at surface) by transducer (1)
signal processed and displayed (1)
time between transmission and receipt of pulse gives
(information about) depth of boundary (1)
reflected intensity gives information as to nature of boundary (1)
*(any four points, 1 each, max 4)* B4 [4]

(b) (i) coefficient $= (Z_2 - Z_1)^2 / (Z_2 + Z_1)^2$
$= (6.3 - 1.7)^2 / (6.3 + 1.7)^2$ C1
$= 0.33$ *(unit quoted, then –1)* A1 [2]

(ii) fraction $= \exp(-\mu x)$ C1
$= \exp(-23 \times 4.1 \times 10^{-2})$
$= 0.39$ A1 [2]

(iii) intensity $= 0.33 \times 0.39^2 \times I$ C1
$= 0.050\, I$ A1 [2]
*(do not allow e.c.f. from **(i)** and **(ii)** if these answers are greater than 1)*

## Q7.

| | | | |
|---|---|---|---|
| **10** | **(a)** X-ray taken of slice / plane / section | B1 | |
| | repeated at different angles | B1 | |
| | images / data is processed | B1 | |
| | combined / added to give (2-D) image of slice | B1 | |
| | repeated for successive slices | B1 | |
| | to build up a 3-D image | B1 | |
| | image can be viewed from different angles / rotated | B1 | |
| | | max 6 | [6] |
| | **(b)** **(i)** 16 | A1 | [1] |
| | **(ii)** evidence of deducting 16 then dividing by 3 | C1 | |
| | to give | A1 | [2] |

| | |
|---|---|
| 3 | 2 |
| 6 | 5 |

**Q8.**

| | | | |
|---|---|---|---|
| **11** | *either* quartz *or* piezo-electric crystal | B1 | |
| | opposite faces /two sides coated (with silver) to act as electrodes | B1 | |
| | *either* molecular structure indicated | | |
| | *or* centres of (+) and (–) charge not coincident | B1 | |
| | potential difference across crystal causes crystal to change shape | B1 | |
| | alternating voltage (in US frequency range) applied across crystal | B1 | |
| | causes crystal to oscillate / vibrate | B1 | |
| | (crystal cut) so that it vibrates at resonant frequency | B1 | [6] |
| | (max 6) | | |

**Q9.**

| | | | |
|---|---|---|---|
| **10** | **(a)** product of density (of medium) and speed of sound (in the medium) | B1 | [1] |
| | **(b)** $\alpha$ would be nearly equal to 1 | M1 | |
| | *either* reflected intensity would be nearly equal to incident intensity | | |
| | *or* coefficient for transmitted intensity = $(1 - \alpha)$ | M1 | |
| | transmitted intensity would be small | A1 | [3] |
| | **(c)** **(i)** $\alpha = (1.7 - 1.3)^2 / (1.7 + 1.3)^2$ | C1 | |
| | $= 0.018$ | A1 | [2] |
| | **(ii)** attenuation in fat = $\exp(-48 \times 2x \times 10^{-2})$ | C1 | |
| | $0.012 = 0.018 \exp(-48 \times 2x \times 10^{-2})$ | C1 | |
| | $x = 0.42\,\text{cm}$ | A1 | [3] |

**Q10.**

| | | | |
|---|---|---|---|
| **10** strong / large (uniform) magnetic field | | B1 | |
| nuclei precess / rotate about field direction | (1) | | |
| radio frequency pulse | | B1 | |
| at Larmor frequency | (1) | | |
| causes resonance / nuclei absorb energy | | B1 | |
| on relaxation / de-excitation, nuclei emit r.f. pulse | | B1 | |
| pulse detected and processed | (1) | | |
| non-uniform field superposed on uniform field | | B1 | |
| allows position of resonating nuclei to be determined | | B1 | |
| allows for location of detection to be changed | (1) | | |
| (*six points, 1 each plus any two extra – max 8*) | | | [8] |

## Q11.

| | | |
|---|---|---|
| **11** **(a)** **(i)** e.m. radiation produced whenever charged particle is accelerated | M1 | |
| electrons hitting target have distribution of accelerations | A1 | [2] |
| **(ii)** *either* wavelength shorter/shortest for greater/greatest acceleration | | |
| *or* $\lambda_{min} = hc/E_{max}$ | | |
| *or* minimum wavelength for maximum energy | B1 | |
| all electron energy given up in one collision/converted to single photon | B1 | [2] |
| **(b)** **(i)** hardness measures the penetration of the beam | C1 | |
| greater hardness, greater penetration | A1 | [2] |
| **(ii)** controlled by changing the anode voltage | C1 | |
| higher anode voltage, greater penetration/hardness | A1 | [2] |
| **(c)** **(i)** long-wavelength radiation more likely to be absorbed in the body/less likely to penetrate through body | B1 | [1] |
| **(ii)** (aluminium) filter/metal foil placed in the X-ray beam | B1 | [1] |

## Q12.

| | | |
|---|---|---|
| **12** **(a)** strong uniform (magnetic) field | M1 | |
| *either* aligns nuclei | | |
| *or* gives rise to Larmor/resonant frequency in r.f. region | A1 | |
| non-uniform (magnetic) field | M1 | |
| *either* enables nuclei to be located | | |
| *or* changes the Larmor/resonant frequency | A1 | [4] |
| **(b)** **(i)** difference in flux density = $2.0 \times 10^{-2} \times 3.0 \times 10^{-3} = 6.0 \times 10^{-5}$ T | A1 | [1] |
| **(ii)** $\Delta f = 2 \times c \times \Delta B$ | C1 | |
| $= 2 \times 1.34 \times 10^{8} \times 6.0 \times 10^{-5}$ | | |
| $= 1.6 \times 10^{4}$ Hz | A1 | [2] |

## Q13.

**10** **(a)** e.g. beam is divergent/obeys inverse square law
absorption (in block)
scattering (of beam in block)
reflection (at boundaries)
*(any two sensible suggestions, 1 each)* B2 [2]

**(b)** **(i)** $I = I_0\exp(-\mu x)$ C1
$I_0/I = \exp(0.27 \times 2.4)$
$= 1.9$ A1 [2]

**(ii)** $I_0/I = \exp(0.27 \times 1.3) \times \exp(3.0 \times 1.1)$ C1
$= 1.42 \times 27.1$
$= 38.5$ A1 [2]

**(c)** *either* much greater absorption in bone than in soft tissue
*or* $I_0 / I$ much greater for bone than soft tissue B1 [1]

## Q14.

**10** **(a)** sharpness: how well the edges (of structures) are defined B1
contrast: difference in (degree of) blackening between structures B1 [2]

**(b)** e.g. scattering of photos in tissue/no use of a collimator/no use of lead grid
large penumbra on shadow/large area anode/wide beam
large pixel size
*(any two sensible suggestions, 1 each)* B2 [2]

**(c)** **(i)** $I = I_0 e^{-\mu x}$ C1
ratio $= \exp(-2.85 \times 3.5) / \exp(-0.95 \times 8.0)$ C1
$= (4.65 \times 10^{-5}) / (5.00 \times 10^{-4})$
$= 0.093$ A1 [3]

**(ii)** *either* large difference (in intensities)
*or* ratio much less than 1.0 M1
so good contrast A1 [2]

*(answer given in* **(c)(ii)** *must be consistent with ratio given in* **(c)(i)***)*

## Q15.

**10** **(a)** product of density and speed of sound / wave M1
(density of medium and) speed of sound / wave in medium A1 [2]

**(b)** if $(Z_1 - Z_2)$ is small, mostly transmission M1
if $(Z_1 - Z_2)$ is large, mostly reflection M1
*(if 'mostly' not stated allow 1/2 marks for these first two marks)*
*either* reflection / transmission also depends on $(Z_1 + Z_2)$
*or* intensity reflection coefficient $= (Z_1 - Z_2)^2 / (Z_1 + Z_2)^2$ A1 [3]

**(c)** e.g. smaller structures can be distinguished B1
because better resolution at shorter wavelength / higher frequency B1 [2]

## Q16.

| | | | |
|---|---|---|---|
| **11 (a)** | changing voltage changes energy / speed of <u>electrons</u> | M1 | |
| | changing electron energy changes maximum X-ray photon energy | A1 | [2] |
| **(b) (i) 1.** | loss of power / energy / intensity | B1 | [1] |
| **2.** | intensity changes when beam not parallel | C1 | |
| | decreases when beam is divergent | A1 | [2] |
| **(ii)** | ratio = (exp {–2.9 × 2.5}) / (exp {–0.95 × 6.0}) | C1 | |
| | = 0.21 *(min. 2 sig. fig.)* | A1 | [2] |
| | *(values of both lengths incorrect by factor of $10^{-2}$ to give ratio of 0.985 scores 1 mark)* | | |

## Q17.

| | | | |
|---|---|---|---|
| **9 (a)** | product of density (of medium) and speed of <u>sound</u> (in medium) | B1 | [1] |
| **(b)** | difference in acoustic impedance | M1 | |
| | determines fraction of incident intensity that is reflected/amount of reflection | A1 | [2] |
| **(c)** | <u>pulse</u> of ultrasound (directed into body) | B1 | |
| | reflected at boundary (between tissues) | B1 | |
| | (reflected pulse is) detected and processed | B1 | |
| | time for return of echo gives (information on) depth | B1 | |
| | amount of reflection gives information on tissue structures | B1 | [5] |

## Q18.

| | | | | |
|---|---|---|---|---|
| **11 (a)** | CT image: (thin) slice (through structure) | | B1 | |
| | any further detail e.g. built up from many 'slices' / 3-D image | | B1 | |
| | X-ray image: 'shadow' image (of whole structure) / 2-D image | | B1 | [3] |
| **(b)** | X-ray image <u>of slice</u> taken from many different angles | (1) | | |
| | these images are combined (and processed) | (1) | | |
| | repeated for many different slices | (1) | | |
| | to build up a 3-D image | (1) | | |
| | 3-D image can be rotated | (1) | | |
| | computer required to store and process huge quantity of data | (1) | | |
| | (*any five, 1 each to max 5*) | | B5 | [5] |

## Q19.

**11** large / 1 T magnetic field applied along body (*allow 'across'*) (1)
r.f. pulse applied .......... (1)
causes hydrogen nuclei / protons .......... (1)
to resonate .......... (1)
(nuclei) return to equilibrium state / after relaxation time .......... (1)
r.f. (pulse) emitted .......... (1)
pulses detected, processed and displayed .......... (1)
resonant frequency depends on magnetic field strength .......... (1)
calibrated non-uniform field enables nuclei to be located .......... (1)

any six points, one mark each .......... B6 [6]

**[Total: 6]**

## Q20.

**10 (a) (i)** e.m. radiation / photons is produced whenever a charged particle
is accelerated .......... M1
wavelength depens on magnitude of acceleration .......... A1
electrons have a distribution of accelerations .......... A1
so continuous spectrum .......... A0 [3]

**(ii)** *either* when electron loses all its energy in one collision
*or* when energy of electron produces a single photon .......... B1 [1]

**(b) (i)** parallel beam (in matter) .......... B1
$I = I_0 \exp(-\mu x)$ .......... M1
$I$, $I_0$, ($\mu$) and $x$ explained .......... A1 [3]

**(ii)** *either* low-energy photons absorbed (much) more readily
*or* low-energy photons (far) less penetrating .......... B1
low-energy photons do not contribute to X-ray image .......... B1
low energy photons could cause tissue damage .......... B1 [3]

**[Total: 10]**

## Q21.

10 (a) (i) density × <u>speed of wave</u> (in the medium) B1 [1]

(ii) $\rho$ = $(7.0 \times 10^6) / 4100$
= 1700 kg $m^{-3}$ A1 [1]

(b) (i) $I = I_T + I_R$ B1 [1]

(ii) 1. $\alpha$ = $(0.1 \times 10^6)^2 / (3.1 \times 10^6)^2$ C1
= 0.001 A1 [2]

2. $\alpha \approx 1$ A1 [1]

| | | | |
|---|---|---|---|
| (c) *either* | very little transmission at an air-skin boundary | M1 | |
| | (almost) complete transmission at a gel-skin boundary | M1 | |
| | when wave travels in or out of the body | A1 | [3] |
| *or* | no gel, majority reflection | (M1) | |
| | with gel, little reflection | (M1) | |
| | when wave travels in or out of the body | (A1) | |

## Q22.

9 (a) (i) edges can be (clearly) distinguished B1 [1]

(ii) e.g. size of X-ray source / anode / target / aperture
scattering of X-ray beam
pixel size
(*any two, 1 each*) B2
further detail e.g. use of lead grid B1 [3]

| | | |
|---|---|---|
| (b) X-ray image involves a <u>single</u> exposure | B1 | |
| CT scan: exposure of a <u>slice</u> from many different angles | M1 | |
| repeated for different slices | A1 | |
| CT scan involves a (much) <u>greater exposure</u> | B1 | [4] |

## Q23.

11 (a) (i) $I / I_0$ = exp(–1.5 × 2.9) C1
= 0.013 A1 [2]

(ii) $I / I_0$ = exp(–4.6 × 0.95)
= 0.013 A1 [1]

| | | |
|---|---|---|
| (b) attenuation (coefficients) in muscle and in fat are similar | B1 | |
| attenuation (coefficients) in bone and muscle / fat are different | B1 | |
| contrast depends on difference in attenuation | B1 | [3] |

## Q24.

| | | |
|---|---|---|
| **10** quartz/piezo-electric crystal | B1 | |
| p.d. across crystal causes *either* centres of (+) and (–) charge to move | | |
| *or* crystal to change shape | B1 | |
| alternating p.d. (in ultrasound frequency range) causes crystal to vibrate | B1 | |
| crystal cut to produce resonance | B1 | |
| when crystal made to vibrate by ultrasound wave | M1 | |
| alternating p.d. produced across the crystal | A1 | [6] |

## Q25.

| | | |
|---|---|---|
| **11** **(a)** sharpness: ease with which edges of structures can be seen | B1 | |
| contrast: <u>difference</u> in degree of blackening between structures | B1 | [2] |
| **(b)** **(i)** $I = I_0 e^{-\mu x}$ | C1 | |
| $I/I_0 = \exp(-0.20 \times 8)$ | | |
| $= 0.20$ | A1 | [2] |
| **(ii)** $I/I_0 = \exp(-\mu_1 \times x_1) \times \exp(-\mu_2 \times x_2)$ *(could be three terms)* | C1 | |
| $I/I_0 = \exp(-0.20 \times 4) \times \exp(-12 \times 4)$ | C1 | |
| $I/I_0 = 6.4 \times 10^{-22}$ or $I/I_0 \approx 0$ | A1 | [3] |
| **(c)** **(i)** sharpness unknown/no | B1 | [1] |
| **(ii)** contrast good/yes *(ecf from **(b)**)* | B1 | [1] |

## Q26.

| | | | |
|---|---|---|---|
| **10** X-ray images taken from different angles / X-rays directed from different angles | | B1 | |
| of one section / slice | (1) | | |
| all images in the same plane | (1) | | |
| images combined to give image of section / slice | | B1 | |
| images of successive sections / slices combined | | B1 | |
| image formed using a computer | | B1 | |
| image formed is 3D image | (1) | | |
| that can be rotated / viewed from different angles | (1) | | |
| (*four B-marks plus any two additional marks*) | | B2 | [6] |

## Q27.

| | | | | |
|---|---|---|---|---|
| 10 | (a) | background reading = 19 | B1 | [1] |
| | (b) | A = 2 | A1 | |
| | | B = 5 | A1 | |
| | | C = 9 | A1 | |
| | | D = 3 | A1 | [4] |
| | | (*Allow 1 mark if only subtracts background reading*) | | |
| | (c) | (i) *either* 5, 14 *or* 14, 5 (A+D, B+C or *v.v.*) | B1 | [1] |
| | | (ii) Three numbers and 'inside' number is 8 (B+D) | B1 | |
| | | Three numbers and 'outside' numbers are *either* 2,9 *or* 9,2 (A,C or *v.v.*) | B1 | [2] |

## Q28.

| | | | | | |
|---|---|---|---|---|---|
| 10 | (a) | pulse (of ultrasound) | | B1 | |
| | | produced by quartz / piezo-electric crystal | (1) | | |
| | | reflected from boundaries (between media) | | B1 | |
| | | reflected pulse detected | | B1 | |
| | | by the ultrasound transmitter | (1) | | |
| | | signal processed and displayed | | B1 | |
| | | intensity of reflected pulse gives information about the boundary | (1) | | |
| | | time delay gives information about depth | (1) | | |
| | | (*four B marks plus any two from the four, max. 6*) | | B2 | [6] |
| | (b) | shorter wavelength | | B1 | |
| | | smaller structures resolved / detected (*not more sharpness)* | | B1 | [2] |
| | (c) | (i) $I = I_0 e^{-\mu x}$ | | C1 | |
| | | ratio = $\exp(-23 \times 6.4 \times 10^{-2})$ | | C1 | |
| | | = 0.23 | | A1 | [3] |
| | | (ii) later signal has passed through greater thickness of medium | | M1 | |
| | | so has greater attenuation / greater absorption / smaller intensity | | A1 | [2] |

## Q29.

| | | | | |
|---|---|---|---|---|
| 10 | (a) | nuclei spin/precess | B1 | |
| | | spin/precess about direction of magnetic field | B1 | |
| | | *either* frequency of precession depends on magnetic field strength | | |
| | | *or* large field means frequency in radio frequency range | B1 | [3] |
| | (b) | non-uniform field means frequency of precession different in different regions of subject | B1 | |
| | | enables location of precessing nuclei to be determined | B1 | |
| | | enables thickness of slice to be varied/location of slice to be changed | B1 | [3] |

## Q30.

| | | | | |
|---|---|---|---|---|
| 12 | (a) | series of X-ray images (for one section/slice) | M1 | |
| | | taken from different angles | M1 | |
| | | to give image of the section/slice | A1 | |
| | | repeated for many slices | M1 | |
| | | to build up three-dimensional image (of whole object) | A1 | [5] |
| | (b) | deduction of background from readings | C1 | |
| | | division by three | C1 | |
| | | $P = 5$ $Q = 9$ $R = 7$ $S = 13$ | | |
| | | (four correct 2/2, three correct 1/2) | A2 | [4] |

**Q31.**

| | | | | |
|---|---|---|---|---|
| 11 | (a) | X-ray: flat / shadow / 2D image | B1 | |
| | | regardless of depth of object / depth not indicated | B1 | |
| | | CT scan: built up from (many) images at different angles | B1 | |
| | | image is three-dimensional | B1 | |
| | | image can be rotated / viewed at different angles | B1 | [5] |
| | (b) (i) | $I = I_0 e^{-\mu x}$ | C1 | |
| | | $0.25 = e^{-0.69x}$ | | |
| | | $x = 2.0$ mm (*allow 1 s.f.*) | A1 | [2] |
| | (ii) | for aluminium, $I / I_0 = e^{-0.46 \times 2.4}$ | | |
| | | $= 0.33$ | C1 | |
| | | fraction $= 0.33 \times 0.25$ | | |
| | | $= 0.083$ | A1 | [2] |
| | (iii) | gain / dB $= 10 \lg(I / I_0)$ | C1 | |
| | | $= 10 \lg(0.083)$ | | |
| | | $= (–)$ 10.8 dB (*allow 2 s.f.*) | A1 | |
| | | with negative sign | B1 | [3] |

**Q32.**

| | | | | |
|---|---|---|---|---|
| 11 | (a) | X-ray beam contains many wavelengths | B1 | |
| | | aluminium filter absorbs long wavelength X-ray radiation | M1 | |
| | | that would be absorbed by the body (and not contribute to the image) | A1 | [3] |
| | (b) | CT scan consists of (many) X-ray images of a slice | M1 | |
| | | and there are many slices | A1 | |
| | | X-ray image is a single exposure | B1 | |
| | | (so much) greater exposure with CT scan | B1 | [4] |

**Q33.**

| | | | | |
|---|---|---|---|---|
| **11** | **(a)** | product of density and speed | M1 | |
| | | density of medium, speed of wave in medium | A1 | [2] |
| | | (*not "speed of light", 0/2*) | | |
| | **(b) (i)** | $\alpha = (6.4 - 1.7)^2 / (6.4 + 1.7)^2$ | C1 | |
| | | $= 0.34$ | A1 | [2] |
| | **(ii)** | $I / I_0 = e^{-\mu x}$ | C1 | |
| | | $= \exp(-23 \times 3.4 \times 10^{-2})$ | C1 | |
| | | $= 0.46$ | A1 | [3] |
| | **(iii)** | $I_R / I = (0.46)^2 \times 0.34$ | C1 | |
| | | $= 0.072$ | A1 | [2] |