

Q1.

- 7 (a) electrons fired at metal 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
 $0.1 = e^{-1.733x}$
 $x = 1.33 \text{ cm}$ 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 $\Delta I / I$ B1 [2]
- (b) $\Delta I / I = 10 \lg(\Delta I / I)$ or $I / I_0 = 10 \lg(I / I_0)$ C1
 $3.6 = 10 \lg(I_2 / (4.5 \times 10^{-5}))$ C1
 $I_2 = 9.0 \times 10^{-5} \text{ W m}^{-2}$, $\Delta I = 4.5 \times 10^{-5} \text{ W m}^{-2}$ A1 [3]

Q4.

MEGA LECTURE

- 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 and 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) pulse 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 = $(Z_2 - Z_1)^2 / (Z_2 + Z_1)^2$ C1
= $(6.3 - 1.7)^2 / (6.3 + 1.7)^2$ A1 [2]
= 0.33 (unit quoted, then -1)
- (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
 repeated at different angles
 images / data is processed
 combined / added to give (2-D) image of slice
 repeated for successive slices
 to build up a 3-D image
 image can be viewed from different angles / rotated
- B1
 B1
 B1
 B1
 B1
 B1
 B1
 max 6 [6]

(b) (i) 16

A1 [1]

(ii) evidence of deducting 16 then dividing by 3
 to give

C1
 A1 [2]

3	2
6	5

Q8.

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

 B1
 B1
 B1
 B1
 B1 [6]

Q9.

- 10 (a) product of density (of medium) and speed of sound (in the medium)
- B1 [1]
- (b) α would be nearly equal to 1
either reflected intensity would be nearly equal to incident intensity
or coefficient for transmitted intensity = $(1 - \alpha)$
 transmitted intensity would be small
- M1
 M1
 A1 [3]
- (c) (i) $\alpha = (1.7 - 1.3)^2 / (1.7 + 1.3)^2$
 = 0.018
- C1
 A1 [2]
- (ii) attenuation in fat = $\exp(-48 \times 2x \times 10^{-2})$
 0.012 = $0.018 \exp(-48 \times 2x \times 10^{-2})$
 $x = 0.42 \text{ cm}$
- C1
 C1
 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 = $2.0 \times 10^{-2} \times 3.0 \times 10^{-3} = 6.0 \times 10^{-5} \text{ T}$ A1 [1]
- (ii) $\Delta f = 2 \times c \times \Delta B$ C1
 $= 2 \times 1.34 \times 10^8 \times 6.0 \times 10^{-5}$
 $= 1.6 \times 10^4 \text{ Hz}$ 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
 $I_0/I = \exp(0.27 \times 2.4)$ A1 [2]
 $= 1.9$
- (ii) $I_0/I = \exp(0.27 \times 1.3) \times \exp(3.0 \times 1.1)$ C1
 $= 1.42 \times 27.1$ A1 [2]
 $= 38.5$
- (c) either much greater absorption in bone than in soft tissue B1 [1]
or I_0/I much greater for bone than soft tissue

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 $= \exp(-2.85 \times 3.5) / \exp(-3.95 \times 8.0)$ C1
 $= (4.65 \times 10^{-5}) / (5.00 \times 10^{-7})$ A1 [3]
 $= 0.093$
- (ii) either large difference in intensities M1
or ratio much less than 1.0 A1 [2]
so good contrast
- (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 electronsM1
 changing electron energy changes maximum X-ray photon energyA1 [2]
- (b) (i) 1. loss of power / energy / intensityB1 [1]
 2. intensity changes when beam not parallelC1
 decreases when beam is divergentA1 [2]
- (ii) ratio = $(\exp \{-2.9 \times 2.5\}) / (\exp \{-0.95 \times 6.0\})$ 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 sound (in medium)B1 [1]
- (b) difference in acoustic impedanceM1
 determines fraction of incident intensityA1 [2]
 that is reflected/amount of reflection
- (c) pulse of ultrasound (directed into body)B1
 reflected at boundary (between tissues)B1
 (reflected pulse is) detected and processedB1
 time for return of echo gives (information on) depthB1
 amount of reflection gives information on tissue structuresB1 [5]

Q18.

- 11 (a) CT image: (thin) slice (through structure)B1
 any further detail e.g. built up from many 'slices' / 3-D imageB1
 X-ray image: 'shadow' image (of whole structure) / 2-D imageB1 [3]
- (b) X-ray image of slice 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 depends 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 B1 [1]
- or* when energy of electron produces a single photon
- (b) (i) parallel beam (in matter) B1
- | | |
|---|--------|
| $I = I_0 \exp(-\mu x)$ | M1 |
| I , I_0 , (μ) and x explained | A1 [3] |
- (ii) *either* low-energy photons absorbed (much) more readily B1
- or* low-energy photons (far) less penetrating B1
- | | |
|--|--------|
| low-energy photons do not contribute to X-ray <u>image</u> | B1 |
| low energy photons could cause tissue damage | B1 [3] |
- [Total: 10]

Q21.

- 10 (a) (i) density \times speed of wave (in the medium) B1 [1]
- (ii) $\rho = (7.0 \times 10^6) / 4100$
 $= 1700 \text{ kg m}^{-3}$ A1 [1]
- (b) (i) $I = I_T + I_R$ B1 [1]
- (ii) 1. $\alpha = (0.1 \times 10^6)^2 / (3.1 \times 10^6)^2$
 $= 0.001$ C1
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 single exposure B1
CT scan: exposure of a slice from many different angles M1
repeated for different slices A1
CT scan involves a (much) greater exposure B1 [4]

Q23.

- 11 (a) (i) $I / I_0 = \exp(-1.5 \times 2.9)$
 $= 0.013$ C1
A1 [2]
- (ii) $I / I_0 = \exp(-4.6 \times 0.95)$
 $= 0.013$ 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 B1
 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: difference 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
- $P = 5 \quad Q = 9 \quad R = 7 \quad S = 13$
- (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
 $0.25 = e^{-0.69x}$
 $x = 2.0 \text{ mm}$ (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
 $= 10 \lg(0.083)$
 $= (-) 10.8 \text{ dB}$ (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
density of medium, speed of wave in medium
(not "speed of light", 0/2)

M1
A1 [2]

(b) (i) $\alpha = (6.4 - 1.7)^2 / (6.4 + 1.7)^2$
 $= 0.34$

C1
A1 [2]

(ii) $I/I_0 = e^{-\mu x}$
 $= \exp(-23 \times 3.4 \times 10^{-2})$
 $= 0.46$

C1
C1
A1 [3]

(iii) $I_R/I = (0.46)^2 \times 0.34$
 $= 0.072$

C1
A1 [2]



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