A-Level Physics

Non-Ionising Imaging

Mark Scheme

Time available: 59 minutes
Marks available: 43 marks

1. **The mark scheme gives some guidance as to what statements are expected to be seen in a 1 or 2 mark (L1), 3 or 4 mark (L2) and 5 or 6 mark (L3) answer.**
Guidance provided in section 3.10 of the 'Mark Scheme Instructions' document should be used to assist in marking this question.

Mark	Criteria
6	Ultrasound identified and justified, quality comments on all 3, at least 2 other factors.
5	Ultrasound identified and justified, quality comments on all 3, at least 1 other factor.
4	Ultrasound or CT scanner identified. Quality comments on all 3 or 2 quality comments and 1 other factor.
3	Ultrasound or CT scanner identified. Quality comments on 2 and at least 1 other factor Or MR scanner identified and stated as highest resolution, with 2 quality comments and 2 others factors.
2	Any choice, with a relevant supporting argument (allow MR scanner as highest resolution provided one other relevant factor is provided).
1	Any valid comments (ignore MR scanner as highest resolution).
0	No relevant comments.

Points to consider:

Relevant quality
- MR scanner – low quality image of calcium / kidney stones (allow cannot see)
- CT scanner – high resolution image
- Ultrasound – low resolution image

Other factors
- CT scanner is more expensive than ultrasound
- Ultrasound causes no harm
- CT scanner emits ionising radiation
- Ionising radiation damages cells

Justified choice
- Ultrasound
- Quality is good enough, cheaper and safe

[6]

2. (a) Align spins of protons ✓

Allow precession for spin

Allow to increase the energy difference between the two spin modes.

1

(b) RF photons excite protons ✓

Flip the spin of protons ✓

(When pulse stopped) protons emit RF signals when they relax ✓

MAX 2

2

[3]

3. (a) The mark scheme gives some guidance as to what statements are expected to be seen in a 1 or 2 mark (L1), 3 or 4 mark (L2) and 5 or 6 mark (L3) answer.
Guidance provided in section 3.10 of the 'Mark Scheme Instructions' document should be used to assist in marking this question.

Mark	Criteria
6	All 3 areas covered in some detail. 6 marks can be awarded even if there is an error and/or parts of one aspect missing.
5	All 3 areas covered at least 2 in detail. Whilst there will be gaps, there should only be an occasional error.
4	Two areas successfully discussed, or one discussed and two others covered partially. Whilst there will be several gaps, there should only be an occasional error.
3	One area discussed and one discussed partially, or all three covered partially. There are likely to be several errors and omissions in the discussion.
2	Only one area discussed, or makes a partial attempt at two areas.
1	None of the three areas covered without significant error.
0	No relevant analysis.

Points to consider

How an ultrasound pulse is produced:
- alternating potential difference applied across the crystal
- causes crystal to expand and contract
- creating pressure waves in the crystal / plastic membrane
- frequency of alternating pd equal to that of crystal / resonant frequency of crystal
- which is above 20 kHz.

How the ultrasound reflection is detected:
- pressure wave in the crystal
- causes crystal to expand and contract
- which produces a potential difference across the crystal.

The same transducer acts as receiver as well as transmitter:

- short application of ac to produce short pulse
- use of backing material to damp and stop vibration of crystal
- crystal must stop vibrating before reflection reaches it.

6

(b) $\lambda = \frac{c}{f} = \frac{1600}{1.0 \times 10^6} = 0.0016$

Resolution = 1.6 mm ✓

Allow 1 sf answer of 2 mm

1

(c) $Z_1 = \rho c$ = 1.3 × 330 (= 429) or

$Z_2 = \rho c$ = 1075 × 1580 (= 1.70×10^6) ✓

$\left(\frac{Z_2 - Z_1}{Z_2 + Z_1}\right)^2 = \left(\frac{1.70 \times 10^6 - 4.29 \times 10^2}{1.70 \times 10^6 + 4.29 \times 10^2}\right)^2$ ✓ = 0.999 ✓

100 – 99.9 = 0.1% ✓

Allow ecf

Allow 1 sf

4

(d) Not suitable as all/most/99.9% of the ultrasound would be reflected ✓

Allow correct argument based around transmission

when going from the air inside the lungs to the lung tissue ✓

MP2 is for the direction where most is reflected.

2

[13]

4. (a) Coherent bundle – fixed arrangement of fibres at each end ✓

Used to transmit image (from inside the body to the viewer) ✓

Non-coherent bundle – random arrangement of fibres ✓

Used to transmit light into the body / to illuminate (area under investigation) ✓

Name of bundle plus either point for first mark.

If no marks awarded, give 1 mark if both bundles have been named.

4

(b) Core at 1.6; cladding 1.55 ie half way between their core and 1.5 ✓

Series of clear horizontal steps with air at 1.0 ✓

Although they are told to do a calculation, give the mark on the diagram for 1.55 even if no calc shown.

If no marks awarded for drawing, then give 1 mark for correct calculation.

2

[6]

5. (a) (i) Coherent − used to transfer / transmit image (out of body)

1

Coherent − same fibre arrangements **at both ends of bundle**

Allow same relative position

Do not allow symmetrical

1

(ii) Non-coherent − used to transfer light into body (to illuminate)

1

Non-coherent − random fibre arrangement along bundle

Do not allow not symmetrical

1

(b) $\sin \theta_c = 1.49 / 1.52$
$\theta_c = 79$ (degree)

1

[5]

6. (a) Idea that fibres in a coherent bundle maintain the same relative position to each other

B1

In incoherent bundles the fibres may be in different / random positions (at each end)

B1

Coherent bundle needs to be used for the observation image.
Incoherent bundle may be used for the light transmission

B1

3

(b) Mentions charge coupled device / CCD

B1

Capacitor / photosite / photodiode charges / stores charge as light falls on it

B1

(Photons arriving cause) electrons to be excited / emitted

B1

Charge depends on light intensity

B1

Lots of photosites / concept of pixels

B1

ANY 3

Max 3

(c) (i) Core

M0

So that total internal reflection can occur

A1

1

(ii) 79(.4)(°)

B1

1

(iii) Ray leaving one fibre and entering adjacent fibre

B1

Reduces resolution / image will be blurred / less clear / limits angle through which fibre may be bent

B1

2

[10]