A-LEVEL
PHYSICS

7408/3BB – Medical Physics
Report on the Examination

7408
June 2022

Version: 1.0

Question 1

1.1 Most students were able to identify that the eye defect was hypermetropia. Myopia was the most commonly chosen distractor, with only a very few choosing astigmatism.

1.2 Many students could successfully complete this calculation, with the majority scoring at least one mark. However, a common mistake was mixing up u and v in the lens equation and therefore getting a magnification of 2.0 instead of 0.50. A majority of students gave the answer to one significant figure (sf) which was condoned on this occasion but the answer should have been given to two sf. A small number of students lost a mark by giving the answer as a fraction $\frac{1}{2}$. The other common mistakes were for students to confuse the focal length with the power of the lens and to use $\frac{1}{v}$ in the magnification equation instead of v.

1.3 Many students could name all three components of the eyes or state the function of at least one of the components. However, there were also many who mixed up one or more of the components. The most common mistakes were mistaking the iris for the ciliary muscles, the cornea for the sclera, and the lens for the pupil.

Many students knew that the iris controls the amount of light entering the eye, although a few students confused intensity with the amount of the light and did not get a mark when they indicated that the *intensity* of light entering the eye was controlled by the iris.

Students generally knew that refraction occurred at the cornea. Examiners did not insist that students stated that most of the refraction occurred there, but the mark was denied when students indicated that there was only a little refraction occurring there or otherwise indicated that the lens refracted the light more. The mark was not given to students who incorrectly stated that the cornea focussed the light on the lens or those that stated that the cornea could diverge the light.

Students struggled to recognise or express the idea that the primary optical function of the lens is to change shape to allow accommodation: to focus light from objects at different distances.

A small minority of students confused refraction with reflection or diffraction.

Question 2

2.1 This question was not answered well; while many students were familiar with the three techniques, they struggled to link their knowledge to the context given, or to determine what was relevant in this context. Descriptions of how the detectors worked were not relevant and gained no credit. There were also a number of misconceptions about the techniques, including which technique minimises the radiation dose.

The key to the question was to pick the technique that minimised the dose to the patient. However, this could only get a mark when it was linked to a technique where this was actually true. Some students knew that the intensifying screen was more sensitive, although many struggled to express this idea clearly. However, they failed to realise that, as the intensifying screen showed a live moving image, it exposed the patients to X-rays for the entire duration of the viewing and therefore resulted in the highest dose. Marks for selecting ‘film’ could be given for saying it reduced the dose of radiation but not when it compared film explicitly to the flat panel detector. A significant number of students thought the flat panel detector exposed the patient to large doses of radiation, when in reality it exposes the patient to the lowest dose of the three options.

There was also confusion about timing, with all options being quoted as the quickest. Often students did not understand the relevance of time, the most important reason being the time exposed to X-rays rather than the time to develop the film. Most did not realise that while a fluoroscopic image intensifying screen did produce a real-time image, the patient would be exposed to X-rays while the image was being viewed, not simply for the short time it takes to form the image.

When referring to the detectors a significant number of students confused the contrast produced or the sensitivity of the detector with the resolution.

A small number of students did not understand that it was the X-rays which were ionising not the detection methods; in particular there was a lack of understanding of where the intensification was done in the fluoroscopic technique, with some thinking that this was occurring inside the body.

While the best solution was a FTP detector, marks could be gained for correct physics when other options were chosen.

2.2 Most students were able to make an attempt at this question and score some marks. The most common mark was 3 marks, with students correctly using $I = I_0 e^{-\mu x}$ to calculate the transmitted intensity, then multiplying by an area to calculate a power which they converted to an energy by multiplying by time. Only a few students realised they needed the absorbed intensity which could be gained by subtracting the transmitted intensity from the original intensity. Only a very few were able to calculate the cross-sectional area perpendicular to the incident X-rays, instead calculating the circular cross-section of the bone. Another common error when calculating the area was to use the area of the film instead of the cross-sectional area of the bone.

A very small minority of students used the threshold of hearing 1.0×10^{-12} for I_0 instead of the incident intensity of X-rays. A very small number of students confused I and I_0.

Each correct step gained a mark with error carried forward available for all steps.

2.3 This question proved difficult for most students with only a very small number of students scoring 2 marks. A large number of students were not able to score on this question.

Some students were able to identify that X-rays absorbed by tissues before the bone reduce I_0 and therefore reduce the intensity of X-rays absorbed. Credit was given for suggesting that not all of the reduction in intensity was caused by absorbed X-rays but some were also scattered. A lot of students incorrectly stated that X-rays were reflected, which was treated as neutral (i.e. ignored).

Only a very few students could clearly state that the amount absorbed assumed that the X-rays all travelled through 0.04 m of bone which was not true due to the bone being a cylinder. Only the X-rays in the centre travelled through 0.04 m of bone, the rest travelled through less bone. Students had to make clear it was the x in $I = I_0 e^{-\mu x}$ that was too large and not the diameter used to calculate the cross sectional area. Most students referred instead to the area calculation, which already took the variation in diameter into account by quoting a mean value. Some students also referred to a change in x but along the length of the bone; this did not get the mark because this variation in x is included in the mean value.

It was also possible to gain this mark by using a mean value for x in Question 02.2 or by suggesting that the cross sectional area of the bone was less than the area of the film, if the area of the film was used in 02.2, although very few students answered with either of these options.

Question 3

3.1 Some students were clearly not familiar with this graph.

The most common mark was awarded for knowing the general shape of the graph. A simple U shape was sufficient for this mark, although a small number of students knew the shape with more detail. The most common mistake was made by students who drew the graph upside-down.

A significant number of students knew that something happened at 3 kHz, with most of these knowing that it was the minimum. However, some of these students were not precise enough with their sketches and the identified frequency of 3 kHz was not at the location of the minimum. The most common incorrect minima were 4 kHz (where most damage occurs in hearing loss due to exposure to loud noises) and 1 kHz (the reference frequency for the dB scale).

The log scale proved to be the most challenging aspect of the question, with the majority of students being unfamiliar with how a log scale worked. This could be seen in mislabelling or not labelling the origin, mislabelling 3 kHz and treating the scale as linear. All of these lost the first mark, although a clear indication of where the student thought 3 kHz was allowed them to pick up the second mark when it was at the minimum of the graph. In a number of cases where 3 kHz was not labelled, the scale was marked incorrectly enough that no judgement could be reached about the frequency of the minimum and therefore the second marking point could not be awarded.

3.2 A large number of students were not familiar with this procedure, with over half not scoring.

Some students were familiar with this procedure and were able to describe it well. A majority of these students knew that the reference frequency was 1 kHz. To gain the first mark it had to be clear that the reference frequency of 1 kHz is compared to sounds at other frequencies. A mention of 1 kHz was not enough by itself.

Some methods suggested lacked rigour because they involved either just stating the frequency should be altered or failing to explain that the intensity or volume must be changed until the two signals sound with the same loudness. For two marks it had to be clear that a second signal must be kept at constant frequency while the volume was changed until two signals were heard to be equally loud.

A minority described the procedure for determining the threshold of hearing rather than equal loudness curves; this did not score any marks.

3.3 A large number of students were able to perform this calculation. However, the majority of answers quoted their final answer to 1 sf and so lost a mark.

A small number of students did not use the threshold of hearing from the Data and Formulae sheet. The most common error was to mix up the intensity level and the intensity. A small number used logarithms with base e instead of base 10. A very small number were unable to perform the algebra correctly.

Question 4

The levels-of-response question was more accessible than in previous years, with very few students scoring 0 or 1 mark. A mark of 4 was the most common score.

Most students were familiar with the three types of scans and were able to list information about them, with only a minority mixing up the features of the three scans. However, this question required students to evaluate the scans' suitability in a particular context, rather than list everything they knew about the scan. While MR scans do produce high-resolution images of soft tissue, the question asked about kidney stones, which were described in the question as looking like bone in the three scans. Students should have recognised that MR scans perform poorly when viewing bone and were therefore not suitable in this case, particularly when viewed against their high cost. The question then became a comparison between the higher quality image with a large exposure to radiation with the CT scanner weighed against the lower quality image but with a lack of ionising radiation of the ultrasound scan. Both scans are used in the NHS for identifying kidney stones and selecting either enabled the answer to access top marks.

Some students did provide a very detailed description of how one or more of the scans worked. However, this did not address the question that was asked and therefore gained no marks, unless it touched on any of the relevant factors. While metal in the body is something which doctors have to consider when performing MR scans, this does not prevent MR scans taking place in a lot of cases and therefore any comments about metal in the body with reference to MR scans was treated as neutral. A significant number of students tried to focus on the 2-D or 3-D nature of MR scans and CT scans, with students stating either of the two scans being 2-D compared to the other which was 3-D. Both scans take multiple 2-D cross-sections which can be combined into a 3-D image by a computer. However, this is not usually necessary and is rarely done. Therefore this was also treated as neutral, as in previous questions on the topic.

Some students incorrectly stated that a barium meal should be used or tried to suggest X-ray techniques that are not applicable to CT scans to minimise the dosage of radiation. A significant number of students stressed the real-time nature of an MR scan. While real-time MR scans have been developed in recent years, they are rarer and more expensive than a standard MR scan and are used for tracking moving objects in the body and would therefore not be relevant to a discussion about kidney stones; this was therefore treated as a neutral comment.

For a higher band answer worth 5-6 marks, students were expected to recognise the trade-off between quality and safety. For 6 marks the quality comparison needed to use the appropriate terminology such as resolution or detail visible, while a 5-mark answer typically just referred to better quality images. At this level of comparison very few answers lacked the details required for the top band.

For a middle band answer, typical answers would not compare the quality of ultrasound with the CT scan – just referring to both being able to image bone. There was also less detail about the scans, with most 4-mark answers typically only making one relevant comment about each scan. Often these answers did not address the quality issue at all beyond commenting that the MR scan did not produce a good image of bone or focussing entirely on the quality of the image without recognising any of the other relevant issues, such as safety. Alternatively, some answers did not adequately express the idea that an ultrasound is capable of imaging bone but it does so at low resolution. A typical 3-mark answer often only made a correct comment about two of the scans or had significant errors. In this band some errors were introduced, for example students thought that because ultrasound could not see through bone, it could not then image the bone itself. While the term non-invasive could be applied to all 3 scans, it was clear that a number of students were mixing up the term non-invasive with non-ionising when they used the term to contrast MR scans and ultrasounds with CT scans.

For a lower band answer, students typically selected the MR scan focussing on its high quality images of soft tissue but not recognising that this was not relevant for imaging kidney stones. An MR scan focussed answer could gain 3 marks when it was sufficiently detailed and listed relevant factors in the other scans, but this was rare. Most answers in this band were able to list some relevant factors about the scans and therefore only a very few answers scored 1 mark. A very small number of students did not state a preference for the type of scan and therefore also scored in this band. These students however, did not usually provide a level of detail that would have moved them much higher even if they had stated a preference.

Question 5

5.1 Some students had a clear understanding of how the spins of the protons in hydrogen aligned or precessed around the magnetic field. However, many students struggled to express this clearly, with over half not providing sufficient clarity to score a mark. Many students did not differentiate between the quantum property of spin and classical angular momentum and described rotating protons. This was not penalised in this paper, but students should know the difference. Elsewhere, this question insisted on a correct use of language and a reference to aligning the spins or the precession of the protons, not merely '*aligning the protons*'. Although it had to be clear that the magnetic field aligned the spin of the protons or caused them to precess, it does not cause them to spin. Answers had to refer to protons or hydrogen nuclei; references to hydrogen atoms were not accepted. A small but significant group of students were confused about the precession frequency and referred to protons vibrating or all spinning with the same frequency; these answers did not gain credit. A very small minority incorrectly stated that the spins of electrons or photons were aligned.

5.2 This question was more tolerant of imprecise language than 5.1 so that students were not penalised twice for the same mistake. Consequently this was more accessible than 5.1. Most students had some idea of how this worked and were able to gain marks on this question. When describing the emission of radio-frequency photons, it had to be clear that the photons released were radio frequency or the same frequency as the incident pulses. It also had to be clear that it was de-excitation rather than excitation which released the photons. A distinction was drawn between the pulses *causing* the protons to excite and flip their spin and the pulses *allowing* the protons to excite or flip their spin; the latter did not gain credit.

Mark Ranges and Award of Grades

Grade boundaries and cumulative percentage grades are available on the [Results Statistics] page of the AQA Website.