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A LEVEL

Examiners' report

PHYSICS A

H556

For first teaching in 2015

H556/02 Summer 2023 series

Version 1

Contents

Introduction

Our examiners' reports are produced to offer constructive feedback on candidates' performance in the examinations. They provide useful guidance for future candidates.

The reports will include a general commentary on candidates' performance, identify technical aspects examined in the questions and highlight good performance and where performance could be improved. A selection of candidate answers is also provided. The reports will also explain aspects which caused difficulty and why the difficulties arose, whether through a lack of knowledge, poor examination technique, or any other identifiable and explainable reason.

Where overall performance on a question/question part was considered good, with no particular areas to highlight, these questions have not been included in the report.

A full copy of the question paper and the mark scheme can be downloaded from OCR.

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Paper 2 series overview

H556/02 is one of the three assessed components of the A Level Physics Specification A and assesses modules 1, 2, 4 and 6 from the specification. The component is worth 100 marks and is split into two sections; Section A contains 15 multiple choice questions (MCQs) and allows the breadth coverage of the specification and Section B includes short answer style questions, two level of response (LoR) questions, problem solving, calculations and practical. The assessment of practical skills, as outlined in module 1 (development of practical skills in physics) and module 2 (foundations of physics), forms an integral part of the assessment. The data, formulae and relationships booklet is a valuable resource in examinations and allows candidates to demonstrate their knowledge and application of physics without the need to rote learn physical data, equations, and mathematical relationships. The weighting of this component is 37% and duration of the examination paper is 2 hours 15 minutes. H556/01 Component has weighting 37%. It assesses material from modules 1, 2, 3 and 5. H556/03 Component has weighting 26% and is synoptic. It assesses material from all modules (1 to 6).

Candidates who did well on this paper generally:	Candidates who did less well on this paper generally:
• wrote scientifically using appropriate technical language • made good use of working in calculations showing intermediate steps where necessary • gave thought to significant figures and rounding • drew diagrams with care, using pencils when appropriate to allow for corrections • gave answers to numerical questions in standard form therefore avoiding 'decimal point counting' errors • drew a line of best fit on the graph carefully, aiming to have an equal distribution of points either side of the line where possible • showed a clear appreciation of command words • gave detail and structure in the LoR questions, paying particular attention to the detailed requirements of the question.	• did not complete all of the multiple choice questions, although time did not appear to be an issue • showed limited (or little) working in extended calculations, thereby not allowing access to C marks (compensatory method marks) where appropriate • did not have a good knowledge of unit prefixes and so produced power of ten (PoT) errors • were limited mathematically especially in the questions involving logarithms • gave limited detail in explanations, in particular not completing a logical structure when developing an argument • were careless in graph point plotting and line drawing • took points from the table when calculating a gradient, despite the points not being on the line • answered only one section of the two required in one or more of the LoR questions.

Section A overview

Section A has 15 multiple choice questions (MCQs) from modules 1, 2, 4 and 6. Each of the MCQs has four possible alternatives, of which only one is correct. The MCQs are worth 1 mark each, giving a maximum possible mark of 15 for Section A.

Candidates are requested to insert their response into the square box provided and it is important for this to be done carefully to avoid any ambiguity. Space is provided on the question paper for candidates' working and they may annotate text or diagrams if it is found to be helpful. Candidates may make use of any shortcuts or ingenuity to reach their answer.

Questions 2, 4, 7, 14 and 15 proved to be accessible to most candidates, while questions 8, 11, 12 and 13 were more challenging and only accessible to the higher end candidates.

Question 1

1 Which of these units is a base unit?

A A

B J

C m^2

D N

Your answer ☐ **[1]**

The majority of candidates were able to correctly recall the ampere as the correct base unit. **C** was a common distractor, most likely as it contains the obvious metre.

Question 2

2 The accepted value of g is $9.81\,ms^{-2}$. In an experiment to verify the value of g, students obtained a value of $10.20\,ms^{-2}$.

What is the percentage difference between the students' value and the accepted value of g?

A 1%

B 2%

C 4%

D 8%

Your answer [ ] **[1]**

This question was answered correctly by the vast majority of candidates and it was encouraging to see detailed working at the side of the question.

Question 3

3 Which of these statements is/are true?

1 Antiprotons are hadrons so are subject to the strong nuclear and weak nuclear forces.
2 Neutrons are subject to the weak nuclear force only.
3 The weak nuclear force is the only force that causes a change of quark type.

A 1, 2 and 3

B Only 1 and 2

C Only 1 and 3

D Only 3

Your answer [ ] **[1]**

A good proportion of candidates were able to answer this correctly. Good practice in this style of questions is to tick the statements that the candidates are sure is correct and try a 'best fit'. Most candidates knew statement 3 was correct and so response **B** was fairly uncommon as an incorrect response.

Question 4

4 A 200 W heater is used for 90 minutes. The cost per kWh is 13 pence.

How much did it cost to use the heater?

A 3.9p

B 39p

C £2.34

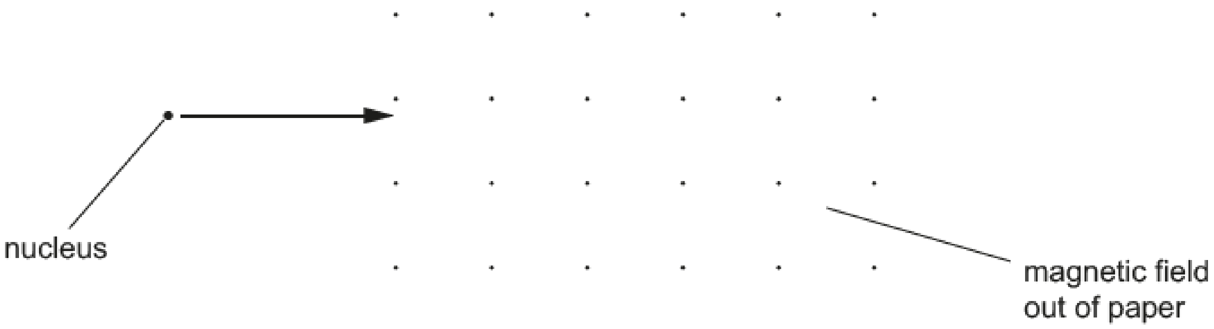
D £23.40

Your answer [1]

This relatively simple calculation was done correctly by a large majority of the candidates. It is good to see candidate's workings on the question, as there are potential pitfalls in this. A number of candidates answered with response **D,** which showed a lack of appreciation of their calculation with actual costings.

Question 5

5 The diagram shows the path of a nucleus entering a magnetic field.



In which direction does the force on the nucleus act as it enters the magnetic field?

A down the page

B into the page

C out of the page

D up the page

Your answer **[1]**

Just over half of the candidates correctly applied Fleming's Left Hand Rule to obtain the correct response. Candidates should be familiar with the terms 'into, down, out of, up' in relation to directions in this style of question.

Question 6

6 Technetium-99m (Tc-99m) is a metastable isotope used in medical diagnosis.

Which ionising radiation does Tc-99m emit?

A alpha

B beta-minus

C beta-plus

D gamma

Your answer **[1]**

The majority of candidates were able to recall the correct emission, with the remaining responses being fairly well split across the other options, suggesting some guess work was involved.

Question 7

7 The power dissipated across a 1 kΩ resistor is 20 W.

What is the potential difference across the resistor?

A 0.02 V

B 50 V

C 140 V

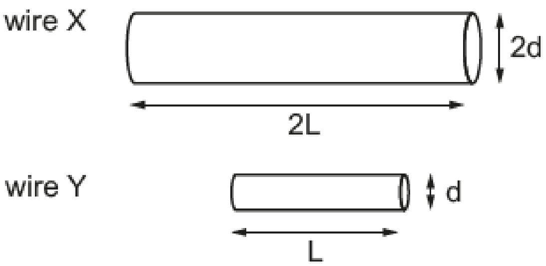
D 20 000 V

Your answer ☐ **[1]**

This is a relatively simple calculation and was answered correctly by the vast majority of candidates. Although it is quite possible to do this in one calculation on a calculator, it is always good practice to show working as it is less likely to result in a ‘power of ten’ or ‘transcription‘ error.

Question 8

8 The diagram shows the relative lengths and diameters of two copper wires, labelled wire X and wire Y.



What is the ratio of the resistivity of wire Y to wire X?

A 1 : 1

B 1 : 2

C 1 : 4

D 1 : 8

Your answer [1]

This question will have looked familiar to many candidates, as it involves changing dimensions of wire to calculate a value. Here, however, the question is asking about the resistivity of the wire which (given that they are both copper) remains the same. Only a little over one quarter of the candidates appreciated this; by far the majority calculated the ratio of resistances and gave the response **B**. This highlights the importance of reading the question carefully and not assuming that it is the same as one they have previously seen.

Question 9

9 The centres of a positron and a helium nucleus are separated by 2 mm.

What is the electrostatic force between them?

A 1.15×10^{-28} N

B 2.30×10^{-25} N

C 5.75×10^{-23} N

D 1.15×10^{-22} N

Your answer ☐ **[1]**

Around two thirds of candidates were able to correctly apply Coulomb's law and obtain the correct response. Response **C** was a common distractor and this was evident for working as the charge on the helium nucleus was given as a single multiple of the fundamental charge.

Question 10

10 A column of air in a tube of length *L*, closed at one end, is forced to vibrate at its fundamental frequency. A standing wave is set up inside the tube.

Which row in the table is correct for this standing wave?

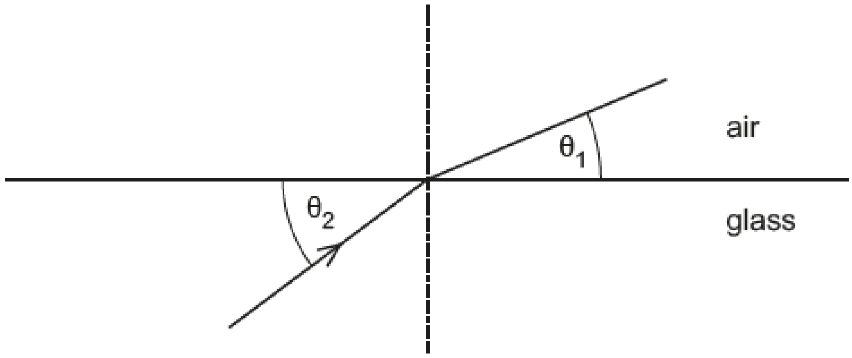
	Number of nodes inside the tube	**Wavelength / m**
A	1	L
B	1	2L
C	1	4L
D	2	2L

Your answer ☐ **[1]**

A large number of candidates were able to correctly identify the correct response and many drew a diagram to support their answer.

Question 11

11 A ray of light is travelling through glass with refractive index n = 1.51. The diagram (not to scale) shows light incident on a glass / air interface.



Which of these statements is/are true?

1 wavelength of light in glass < wavelength of light in air

2 $n_{glass} = 2n_{air}$

3 $\theta_2 > 48°$

A 1 only

B 1 and 2

C 3 only

D 1 and 3

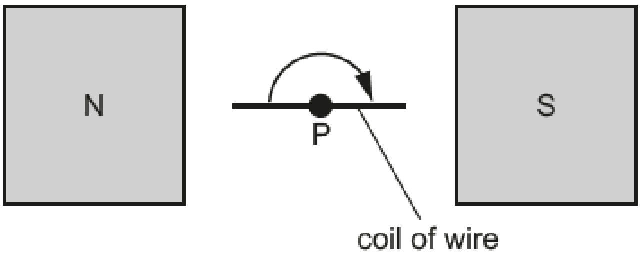
Your answer **[1]**

Around one third of candidates were able to identify the correct response; the main difficulty appeared to be that the given angle in the glass was not given relative to the normal (as is usual) and this meant that a common distractor was **A**.

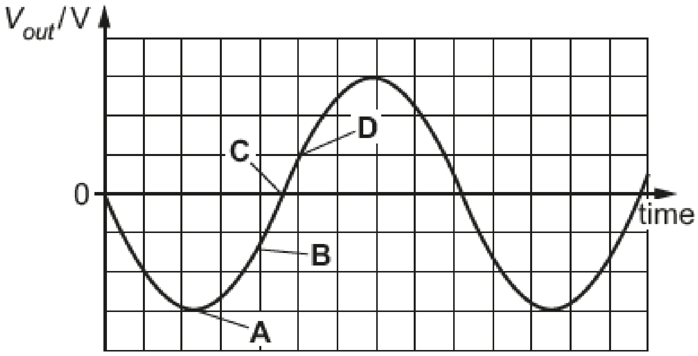
Question 12

12 The diagram shows a coil of wire rotating between two permanent magnets in a model generator.

The coil is rotating clockwise about point P at constant angular velocity.



Which letter represents the output of the generator at the instant in the diagram?



Your answer

[1]

A majority of candidates were able to identify the correct response. The vast majority of incorrect responses were **C**, probably from the flux linkage at that point, rather than the rate of change of flux linkage.

Question 13

13 In the Rutherford scattering experiment alpha particles are directed at a gold foil.

Gold nuclei have 79 protons. The distance of closest approach is 47.0 fm.

Which is the best estimate of the work done on an alpha particle as it moves from 53.0 fm to the point of closest approach?

A 10^{-18} J

B 10^{-16} J

C 10^{-15} J

D 10^{-13} J

Your answer ☐ **[1]**

A little under half of the candidates were able to calculate and select the correct response. The most common incorrect response was **B**, although it was not entirely clear why this was the case from candidates working. A very small minority of candidates did not answer this question.

Question 14

14 A step-down transformer has an input potential difference of 200 V. There are 250 turns on the primary coil and 50 turns on the secondary coil. The secondary coil is connected to a 1.0 kΩ resistor.

What is the current through the resistor?

A 2×10^{-4} A

B 0.04 A

C 1 A

D 40 A

Your answer ☐ **[1]**

This question was correctly answered by a good proportion of the candidates, as it was a relatively simple two step calculation. The vast majority of incorrect responses showed little useful working, showing a lack of knowledge of transformers.

Question 15

15 Which statement is Faraday's law?

A The direction of electric current induced by a changing magnetic field is such that the magnetic field created by the induced current opposes changes in the initial magnetic field.

B The magnitude of the electrostatic force between two point charges is directly proportional to the product of the magnitudes of charges and inversely proportional to the square of the separation.

C The magnitude of induced EMF is proportional to the rate of change of the magnetic flux linkage.

D The total energy of an isolated system remains constant.

Your answer [ ] **[1]**

The majority of candidates were correctly able to identify Faraday's law from a list of physical laws. Many candidates knew that it was related to electromagnetism and so the majority of incorrect responses were **A**.

Section B overview

Section B consists of eight short answer style questions containing problem solving, calculations and practical style questions; it also includes two level of response (LoR) questions each of which have a maximum of 6 marks. This section is worth a total of 85 marks and candidates are expected to spend about 1 hour 45 minutes on this.

There was no real evidence of candidates having time issues on this paper; although there were several questions not answered by some candidates. As is often the case, these tended to be on the more challenging questions and generally spread throughout the paper.

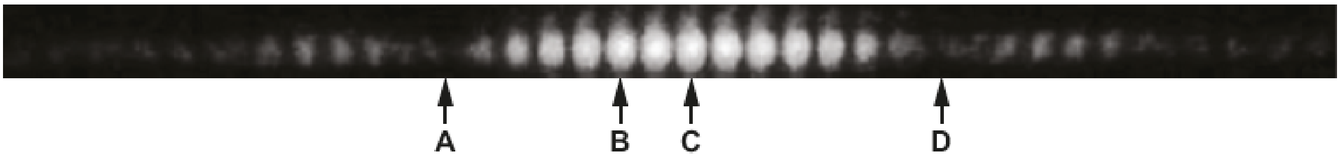
OCR support

If centres are not already aware, they may find the following document – *exam hints for students* – helpful in guiding their candidates in answering questions.

Question 16 (a)

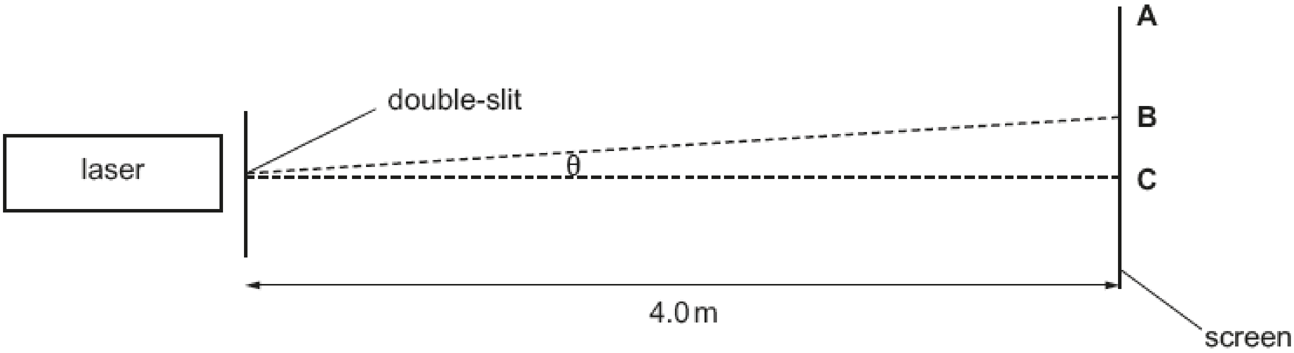
16 **Fig. 16.1** shows the pattern obtained in a Young double-slit experiment. The pattern is **not** to scale. Three regions of the pattern are labelled **A**, **B** and **D**. The central maximum is labelled **C**.

Fig. 16.1



Red light of wavelength 640 nm was used in the experiment. The distance between the centres of the two slits was 1.00×10^{-5} m. The distance from the double-slit to the screen was 4.0 m.

Fig. 16.2



(a) Name the physical processes that cause the features labelled **A**, **D** and **B**, **C** in **Fig. 16.1**.

A and **D** ....

B and **C** ....

[2]

Most candidates were able to appreciate that the pattern in **Fig. 16.1** was an interference pattern and that the 'dark and light' were the result of interference. The first mark could also be credited for the use of the term 'diffraction' as at that point the single slit diffraction pattern is dominant.

Question 16 (b)

(b) The Young double-slit experiment uses **coherent** waves. State what **coherent** means.

....

.... **[1]**

Coherence is a term that candidates will likely have come across many times in their study of waves. While many candidates had an appreciation that it was related to phase, there were many responses that it was when two waves were in phase. Around half of candidates were able to correctly explain coherence.

Question 16 (c)

(c) Explain how the part of the pattern labelled **B** is formed.

....

....

.... **[2]**

Around half of the candidates were able to achieve at least 1 mark and had a good idea that the waves must arrive in phase. Some candidates confused path difference and phase, giving statements such as 'the phase difference is one wavelength'. Only a small number of candidates appreciated that this was a maximum two away from the central maximum and so had a path difference of 2 × wavelengths (or equivalent in phase).

Many candidates who did not score gave responses in terms of superposition but gave little detail beyond the use of the terms.

Question 16 (d)

(d) Calculate the angle θ from the central maximum **C** to the maximum labelled **B** as shown in **Fig. 16.2**.

θ = ... ° **[3]**

There was a roughly equal spread between 0, 1, 2 and 3 marks on this question and it illustrated the variety of ways in which the candidates attempted it. This calculation could be attempted in a number of ways; each of which would produce the correct final value. Most candidates who made an attempt were able to determine the fringe separation distance on the screen, generally by using the double slit formula. Only around a quarter of candidates appreciated that maximum **B** was the two away from the central maximum which was needed for the correct answer. Use of the diffraction grating formula gave a similar mark distribution.

It is to be noted that, **in general¸** incorrect answers with no working will gain no marks and it is very important that candidates who show no working run the risk of not gaining marks. In this case, an incorrect response of 3.7° could gain 2 marks as it was very evident where it came from.

Question 17 (a)

17 Ultrasound B-scans can be used to image unborn babies.

(a) Explain what is meant by ultrasound.

....

....

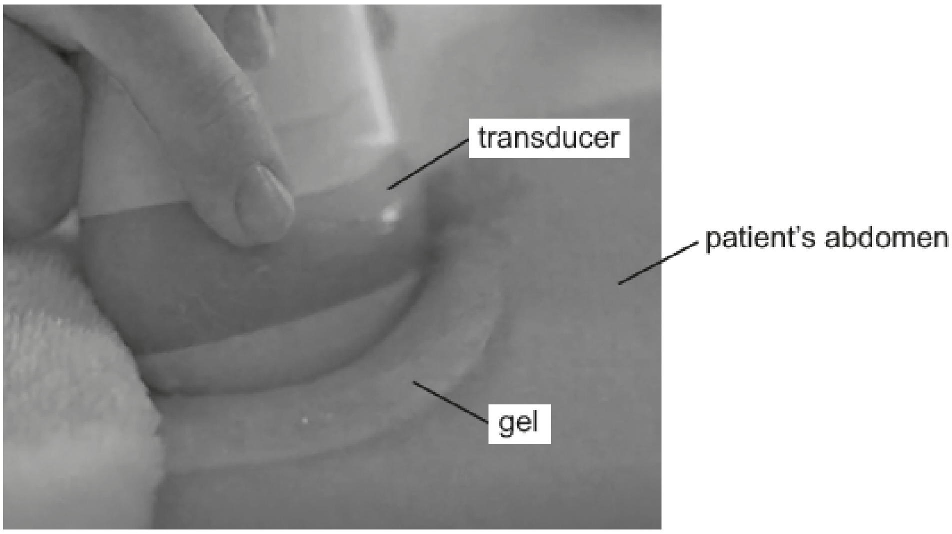
.... **[2]**

Many candidates attempted to answer this question in terms of the use of ultrasound, presumably prompted by the first line of the question. While many good responses were given along these lines, it was not the purpose of the question. Many candidates gave vague answers such as 'outside of the human hearing range' but a little under a half of candidates knew (and wrote) the value of 20 kHz. Only around one fifth were able to state it was a longitudinal wave.

Question 17 (b)*

(b)* **Fig. 17.1** is a labelled photograph of an ultrasound examination of a patient.

Fig. 17.1



Explain how the transducer both produces and receives ultrasound waves.

Explain the purpose of the gel. **[6]**

This level of response (LoR) question was designed to assess Section 6.5.3 (b), (e) and (f) of the specification.

A holistic approach to marking is used, with marks given according to answers matching the descriptors for the various levels. No one answer is perfect for this question and examiners will expect a varied approach. The indicative scientific points are used as a basis; however other correct, relevant physics may also be taken into account. The nature of this question is such that it can be conveniently separated into two sections; a description of producing and receiving ultrasound by the transducer, and the purpose of the gel in this case.

The key points in the production and receiving of ultrasound that examiners were looking for were:

- an explanation of the piezoelectric effect
- what causes it, and the effect on the crystal
- how this produces the ultrasound waves
- how a reverse of this will lead to its detection.

The key points in the purpose of the gel were:- an explanation of acoustic impedance and an idea of what would happen if no gel were to be used – some idea of the term impedance matching and how this occurs with the gel.

It was clear that many candidates had a good knowledge and understanding the use of ultrasound in this context and were able to describe this well, leading to a good number of candidates being given Level 3. The very best answers were detailed and well-structured and made every attempt to fully answer each section of the question using correct scientific terms. Many candidates wasted time and space describing how the ultrasound was reflected in the body, which is not required, or other irrelevant detail. Some drew diagrams, which can be helpful, but in this case did not really add to the text.

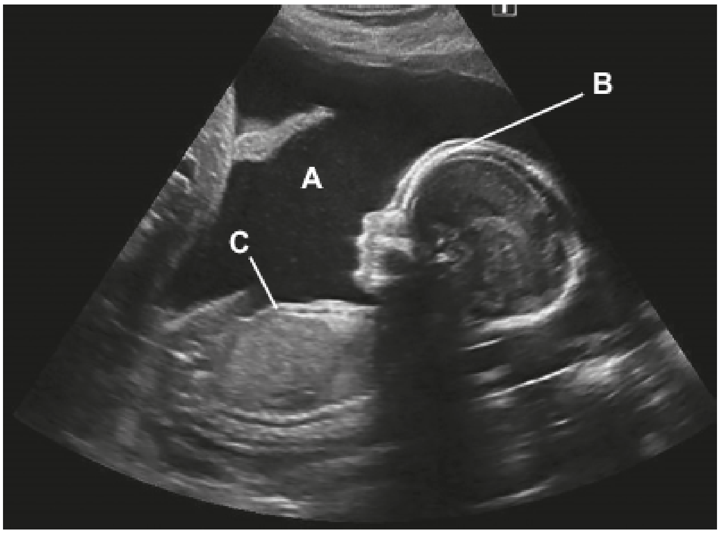
For the most part, the description of the gel was done better than the description of production, most likely because the piezoelectric effect can be difficult to explain clearly. Candidates were not penalised for the use of incorrect values in the frequency of ultrasound here, or in any values of size (or voltage applied to) the transducer. The equation for reflection of ultrasound was given by several candidates but was not always explained to support the answer.

Many strong candidates only answered one part of the question; this highlights the need to read it carefully – there will nearly always be two parts – and make sure that, as far as possible, equal weighting is given to both.

Question 17 (c) (i)

(c) **Fig. 17.2** shows a B-scan of an unborn baby.

Fig. 17.2



(i) Explain why no signal is received back from **A**.

....

.... **[1]**

Many candidates gave vague answers such as 'it's all the same' or 'it is all air'. This response did require the idea that a boundary or some change must be present for the reflection to occur. Several candidates thought that it was absorbed at A. Around half of the candidates were able to score a mark on this question.

Question 17 (c) (ii)

(ii) Explain why a greater signal is received back from **B** than **C**.

....

....

.... **[2]**

This question required the use of the term 'acoustic impedance' for any marks as this would lead to crediting quality responses. The term 'attenuation coefficient' was used by a large number of candidates in place of the acoustic impedance. Only around 40% used the term correctly and only half of this appreciated that this was the difference between B and C and their surrounding mediums rather than simply the difference between B and C. This question highlights the need for correct terminology and not vague statements.

Question 17 (d)

(d) Doppler ultrasound can be used to measure the speed of blood flow through blood vessels.

The speed of ultrasound in blood is $1600\,\text{ms}^{-1}$.

A transducer emitting ultrasound of frequency 10.0000 MHz is placed at 50° to the blood vessel.

The reflected ultrasound has a frequency of 9.9987 MHz.

Calculate the speed *v* of the blood flow.

v = ... ms^{-1} **[2]**

This question was correctly done by around two thirds of candidates. Although not a particularly complex calculation, there are some challenges in it. Common mistakes were using the speed of light for *c*, using the reflected frequency for the change of frequency, power of ten errors and using the reflected frequency in the denominator. Many candidates wrote out the formula and rearranged it for *v* before substituting the numbers which help with the calculation. Those who avoided this occasionally made substitution/transcription errors.

Question 18 (a)

18 **Fig. 18** represents a tube open at both ends.

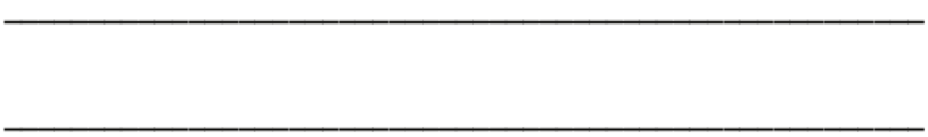
Air inside the tube is forced to oscillate by a speaker and produces a standing wave.

The length of the tube is 30.0 cm.

The wave speed inside the tube is $340\,\text{m s}^{-1}$.

(a) On **Fig. 18** sketch the standing wave for the fundamental mode of vibration.

Fig. 18



[1]

The majority of candidates were able to correctly identify and draw the fundamental mode in between the two given lines. Examiners were fairly generous on this; however the following would be penalised: not drawing the node in the centre, having the wrong curvature, and drawing straight lines. This is a relatively simple sketch, but candidates must take care. Some candidates attempted a longitudinal wave sketch and several others just drew a large number of waves, indicating they had not really appreciated the question. As always, it is recommended that candidates use pencil; those who made mistakes often drew another set of a parallel lines and then put in their answer. Examiners will always consider this; however it is better to use the original question image.

Question 18 (b)

(b) Calculate the frequency f_0 of the speaker that is producing the standing wave inside the tube.

f_0 = ... Hz **[1]**

Around two thirds of candidates were able to calculate this correctly. The majority of incorrect responses were naturally when using 0.30 m as the wavelength. Relatively few candidates did not change their wavelength into metres, but a significant number were unable to rearrange the formula correctly.

Question 18 (c)

(c) The frequency of the speaker is increased.

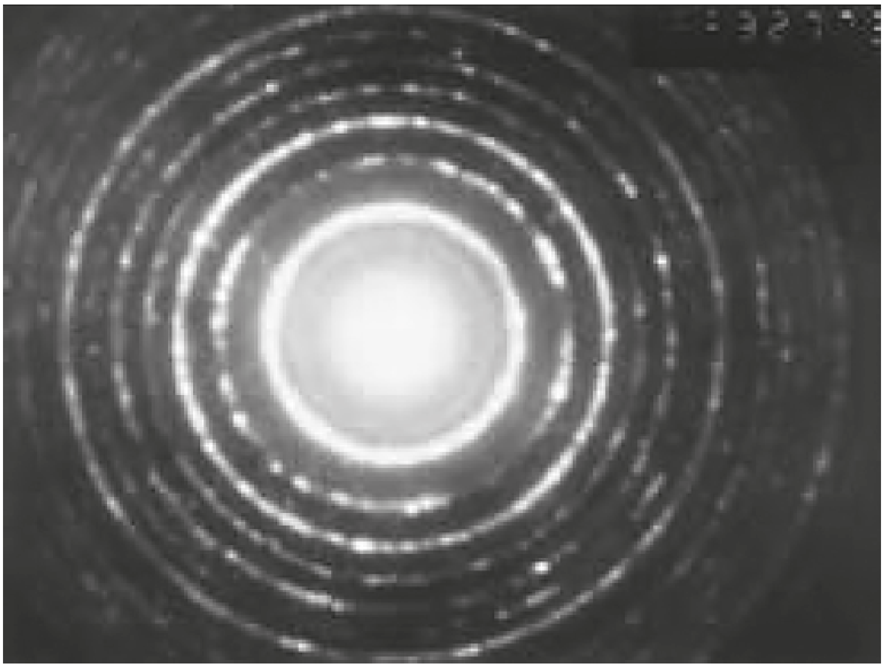
Calculate the next frequency f_1 that will produce a standing wave in this tube.

f_1 = ... Hz **[2]**

Most candidates appreciated that the wavelength would be smaller (and many drew a sketch) to produce the next frequency. However, it was difficult to score marks on this if the previous answers were incorrect. Error carried forward is often applied, but in this case major errors will compound and it is not possible to work through the candidates thinking.

Question 19 (a)

19 The picture shows an electron diffraction pattern produced by graphite in a cathode-ray tube.



(a) Describe the experiment that produces this pattern. Draw a labelled diagram of the apparatus to help you.

....

....

....

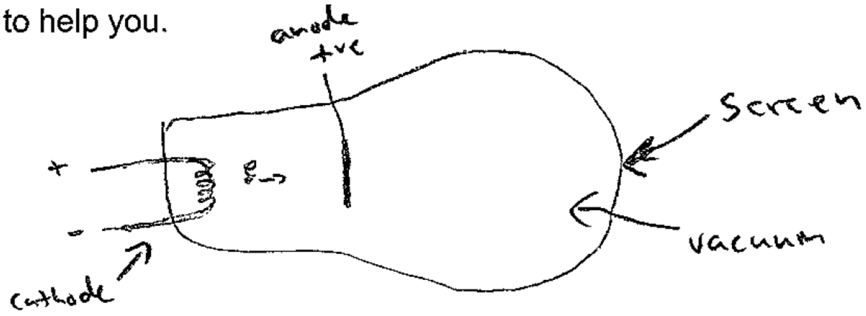
....

.... **[4]**

A diagram is always helpful if suggested and candidates who drew a labelled diagram were often able to score marks that they would not have gained in the text. Candidates who had seen this experimental set-up were at an advantage and often gave good descriptions, although relatively few gained full marks. Several candidates confused anode and cathode and others assumed that the graphite was in some way responsible for the production of the electrons. Nearly one third of candidates scored no marks on this question; those who did often had little knowledge of the experiment although it is specifically mentioned in the specification. Incorrect responses included considering it as a ripple tank.

Exemplar 1

apparatus to help you.



the cathode heats up and emits electrons through thermionic emission. The electrons are accelerated to an anode which has holes between atoms close to the size of the debroglie wavelength of the electron, which causes the electrons to diffract. The electrons hit a screen which shows the pattern **[4]**

This response shows a candidate using a diagram to gain marks that would not otherwise be covered in the text. The word 'vacuum' will score the first mark for the evacuated tube.

Question 19 (b)

(b) Explain why light and dark circles as shown in the picture are produced, stating what this evidence provides about electron behaviour.

....

....

....

....

.... **[3]**

Most candidates appreciated that this was evidence of the wave nature of electrons, although a simple statement of 'wave-particle duality' does not really explain what the evidence provides. Although the circles could be described in terms of probability of electrons arriving, in the context of the question the concept of interference of the electron-waves was sufficient and was clearly the explanation that many candidates had been given and close to one half of candidates were able to achieve full marks.

Question 19 (c) (i)

(c) A potential difference (p.d.) 5 kV is used to accelerate the electrons.

(i) Calculate the work done *W* on the electrons.

W = ... J **[1]**

The vast majority of candidates were able to carry out this simple calculation; most errors came from an incorrect conversion of kV rather than lack of knowledge of the calculation.

Question 19 (c) (ii)

(ii) Calculate the de Broglie wavelength λ of the accelerated electrons.

λ = ... m **[2]**

Around one half of candidates were able to correctly calculate the de Broglie wavelength. This is potentially difficult for the average candidate to carry out in a single calculation, so it is very helpful to show the working in a slightly extended calculation. Most candidates calculated the electron speed first from the kinetic energy equation and then correctly substituted it. Several candidates used the proton rest mass in place of the electron rest mass, but the majority of incorrect responses came from using the speed of light for the speed. This is a physics error which can score no marks.

Question 19 (c) (iii)

(iii) Suggest a value for the spacing between the graphite atoms.
Justify your answer.

....

....

.... **[1]**

The justification for the spacing is in the context of the question and so must relate to their previously calculated value. Around half of the candidates correctly gave a value and supporting reason, which needed to relate their wavelength to the process of diffraction. Common incorrect answers included values of around 1fm (irrespective of their calculation) presumably from their knowledge of the nuclear radius.

Question 20 (a)

20 In an experiment a circuit is set up so that a capacitor with a resistor in series can be charged and at some later time discharged through the same resistor without changing the positions of the components. This process can be repeated.

The supply has a potential difference (p.d.) 6.0 V d.c.

The capacitor has capacitance 1.0 μF.

The resistor has resistance 10 kΩ.

A voltmeter is used to measure the p.d. across the capacitor.

(a) Draw a circuit diagram for this experiment.

[2]

Many candidates were able to correctly draw the supply, capacitor, and resistor in series with a voltmeter in parallel for a single mark. The position of a switch/switches to allow a discharge was less simple and many candidates had a single switch in series with their components. There are several ways to correctly draw this, and examiners allowed the use of double throw type switches as long as the idea was clear. Placing the capacitor and resistor in parallel with the supply may have allowed access to the second marking point as it would allow the discharge but not the charging. As always, clarity of the diagram makes it easier for examiners to understand. Several candidates appeared not to know the symbol for the capacitor and used a capital C in a circle. Less than one fifth of candidates were able to correctly draw the required diagram.

Question 20 (b)

(b) Calculate the charge *Q* stored on the capacitor when it is fully charged.

Q = ... C **[1]**

The vast majority of candidates were able to calculate this correctly and the main reason for not awarding the mark tended to be from a power of ten error.

Question 20 (c)

(c) Use a calculation to explain why it will not be possible to measure the variation of p.d. across the capacitor with time, using a stop watch.

....

.... **[4]**

Candidates were credited with calculations that produced a time or voltage that showed the time for decay was rapid. There were many possible routes to an answer and candidates were credited with any method that would produce a correct solution. As the question also included an explanation, it was often necessary to justify candidates' values for further credit rather than simply determine a numerical answer. The calculations were, in general, completed well and a good number of candidates were able to score 2 or more marks. Explanations in terms of reaction time were quite rare and often a vague answer such as 'the time is short' or 'human error' was given. Many candidates also related it to the precision of the stopwatch rather than the limitations of their use due to human reaction time.

Exemplar 2

the capacitor with time, using a stop watch.

$1 = 6e^{-t/(10\times10^{3}\times1\times10^{-6})}$

$\ln\left(\frac{1}{6}\right) = -\frac{t}{10\times10^{3}\times1\times10^{-6}}$ $t = 0.01792$

For the capacitor to discharge to 1V it takes ~~around a milliseconds~~ less than a second which is less then human reaction time. **[4]**
hence a large uncertainty due to random error

In this response the candidate has chosen to determine the time taken to fall to 1 V. The calculation has been done correctly for the first 2 marks (although there is no unit, it is clear what *t* is). The third marking point has not been satisfied – a comment would be needed (however brief) on why 1 V was chosen. The final marking point is given for the idea that this is time is less than human reaction time.

Question 20 (d)

(d) State how this experiment can be modified to measure the variation of p.d. across the capacitor with time as the capacitor charges.

....

.... **[1]**

While changing the value of the resistor or capacitor would increase the charging time, that would alter 'this experiment' and as such was not credited. In the context of this question, it is how the variation can be determined using the given values. Few candidates appreciated this, however there were significant numbers who knew that an oscilloscope could be used in place of the voltmeter.

Question 20 (e) (i)

(e) The capacitor was completely charged and then discharged to 4.12 V.

(i) Calculate the time *t* required for the p.d. across the capacitor to reach 4.12 V when discharging.

t = ...s **[2]**

Most candidates were able to calculate the correct time for the discharge, by taking substituting values into the logarithmic equation. Common errors included incorrect taking of logs by division rather than subtraction (depending on their original set-up) and power of ten errors or transcription errors in the values of *C* or *R*. As with many calculations, those who spent a little time setting out the working carefully were more likely to get the correct answer.

Question 20 (e) (ii)

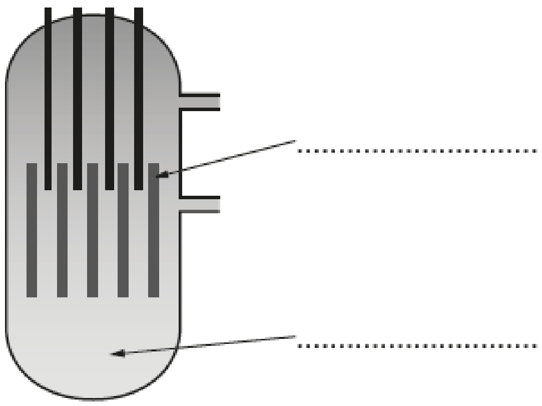
(ii) Calculate the average rate at which energy is lost by the capacitor as it discharges from 6.0 V to 4.12 V.

average rate at which energy is lost = ... $J s^{-1}$ **[3]**

Only around one third of candidates were able to correctly calculate this answer. By far the most common error was to calculate the change in energy using the difference in voltages (using 1.88 V) rather than calculating the separate energies and then subtracting. Several candidates left their answer at this point, rather than going on to divide by their value for the time.

Question 21 (a)

21 The diagram shows a simplified layout of a nuclear fission reactor used in a nuclear power station.



(a) Complete the labels on the diagram **[2]**

Many candidates were able to demonstrate their knowledge of the internal structure of a fission reactor and correctly label the components or the material they are made from. Simple answers such as 'reactor core' or 'fluid' are not sufficient at this level.

Question 21 (b)*

(b)* Describe how fission of nuclei is induced and controlled in the nuclear reactor.

Show how fission leads to the release of large amounts of energy.

The following masses may be useful.

Particle	Mass / u
U-235 nucleus	235.04395
Ba-141 nucleus	140.91440
Kr-92 nucleus	91.92617
${}^{1}_{0}n$ neutron	1.00867

[6]

This is the second level of response (LoR) question in this paper, and was designed to assess nuclear physics, specifically Sections 6.4.4 (a), (b), (g) and (h). In particular, there are two parts (description and calculation) both of which need to be answered to obtain a Level 3. As previous, there are no specific marking points and examiners use a 'best fit' approach to the marking. Indicative scientific points are given in the mark scheme as a guidance to what to expect, but not all need to be satisfied for full credit, however for full credit for the calculation, the energy released per fission is the minimum end point. Incorrect physics can be expected to be penalised, however. Candidates should always be encouraged to structure their answers carefully and in calculations aim to give explanation of each stage rather than just produce a number. The two separate sections can be separated into a description of the induction and control, and calculation of the energy released.

The key points in the description that examiners were looking for were: - idea of induced fission by a thermal neutron– the chain reaction leading to more neutrons released - a description of the role of the moderator – a description of the role of the control rods.

The key points in the calculation that examiners were looking for were: - calculation of the mass before fission – calculation of the mass after the fission – difference between these two masses – calculation of the energy equivalent (hence released) from this mass difference.

The descriptions of the induction and control varied hugely both in quality and quantity. Many candidates did not start from U-235 but went straight into the fission. Most candidates were aware that extra neutrons were released in fission and had a good idea of the absorption of the extra neutrons by the control rods, but there was often confusion about the role of the moderator (by explaining that it simply 'controlled the reaction') and a significant number did not appreciate why a slower neutron was needed. However, there were many excellent explanations covering all of the indicative points and going beyond.

The calculations were attempted well by many candidates and obtaining the energy equivalence of one fission was a suitable point to stop the calculation. A comment supporting the size of the energy compared to this number of fissions per second helped to confirm the large release of energy. Several candidates took this further and calculated the energy per kg, showing how large this was. The main source of error was in not accounting for the mass of the initial neutron in the reaction and so the energy calculated was one 'neutron mass equivalence' too high. Several candidates ended their calculation with a mass difference, or even attempted to calculate the mass defect in the formation of U-235, but this led nowhere.

There was a fair number of candidates who made no attempt on the calculation despite having given a good description and it can be assumed that they hadn't fully read what they were asked to do. Similarly there were some excellent calculations but no with no description. Candidates are always encouraged to consider both parts of any LoR question.

Exemplar 3

- U-235 + $^{1}_{0}n$ → BA-141 + KR-92 + 3 $^{1}_{0}n$

(235.04395)   (140.91440 + 91.92617 + (3 × 1.00867))

= 235.86658

M_D = 235.86658 − 235.04395 = 0.82263

0.82263 × 1.661 × 10^{-27} = 1.367 × 10^{-27}

$\Delta E = mc^2$

E = 1.366 × 10^{-27} × $(3 \times 10^8)^2$ = 1.23 × 10^{-10} J per reaction

- ~~The moderator~~ A fission reaction is induced by a neutron being absorbed by a radioactive nucleus, which is split into two lighter nuclei ~~and~~ and more neutrons.
- Energy is released. Neutrons are then absorbed by other radioactive nuclei causing a chain reaction.
- The moderator slows down the fast moving neutrons released in the reactions into thermal neutrons, as they are more likely to ~~be~~ continue the reaction.
- Control rods absorb some of the thermal neutrons leaving on average one left from each reaction so the reaction is controlled.

This is an example of a Level 2 response to a LoR question. The candidate has given a clear calculation with a good structure but has forgotten to add the neutron mass to the uranium mass to give the initial mass. The remainder of the calculation is correct, giving a final value for the energy per fission which is incorrect by a value of the neutron mass-energy. The explanation of the induction and control is good, if a little brief and lacking in real detail. On the holistic approach taken to the LoR questions, this is a clear Level 2. The communication is good and the setting out of the response is clear.

Question 21 (c)

(c) The energy released from the fusion of 1 kg of hydrogen is more than seven times the energy released by the fission of 1 kg of uranium.

Compare the practicalities of using nuclear fusion of hydrogen with using nuclear fission of uranium to meet our energy needs.

....

....

....

....

....

.... **[4]**

This question needed candidates to use appropriate scientific knowledge and understanding to discuss the differences between fission and fusion in terms of the practicalities. Many candidates were able to give good responses to several of the main points with careful comparisons. One of the key features of this question is to avoid social and economic arguments and base the points on ideas from the course. It is not a 'compare and contrast' question, but many of the marking points can be gained that way. A relatively small number of candidates gained full marks on this, as may be expected, however a good fraction gained 2 or more marks. Responses which could not be credited were simple statements like 'safer', 'easier to use', 'no toxic waste' and 'renewable'. Examiners will have worked strictly to the mark scheme, and so given marks consistently.

Question 22 (a)

22 Radiographers commonly use molecules containing fluorine F-18 as tracers in positron emission tomography (PET) scanning.

Fluorine has a proton number of 9.

F-18 decays to oxygen (O) by β^+ decay.

(a) Write the equation for the decay of a nucleus of F-18 using nuclear notation.

[2]

Most candidates will have gained the first mark for the correct isotope of fluorine. Those who didn't likely reversed the positions of the nucleon and proton number. It was noticeable that a large number of candidates were unable to balance the equation and while they had the correct values for the positron, the oxygen isotope was incorrect.

Question 22 (b)

(b) The β^+ particle (positron) produced travels only a short distance in the patient before it meets an electron and is annihilated.

Calculate the wavelength λ of gamma photons produced.

λ = ... m **[3]**

Well over half of the candidates were able to score 2 or more marks on this question. A great deal scored 2 marks due to the inclusion of a factor of two, which was then not removed (or vice versa). Some candidates used the formula for kinetic energy – which by coincidence may give the correct answer – however this was not credited, nor was the more common use of the de Broglie formula. Examiners sometimes had a difficult decision on this question, whether the response was a physics error or not, and if in doubt a candidate would be awarded the marks.

Question 22 (c)

(c) X-rays and gamma-rays are produced by different physical processes.

Briefly describe both processes.

....

....

.... **[2]**

The main principle behind this question was to distinguish between the X-ray production by electrons and gamma ray production by nuclei. Fairly specific details were required for each, although a wide range of answers were accepted. This question discriminated well among the candidates with roughly equal fractions getting 0, 1 and 2 marks.

Question 22 (d)

(d) F-18 has a half-life of 109.7 minutes.

Explain the advantage that this has for the patient but the disadvantage that this has for the radiographers.

....

....

....

....

.... **[3]**

Although apparently a simple set of ideas, the detail required for this question meant that only a small fraction of candidates were able to gain full marks. It was necessary to state that the half-life was (relatively) short, which many of the stronger candidates did not do. The advantage to the patient requires the use of the term 'ionising' as this is the fundamental issue with the radiation. Similarly, candidates had to make it clear that the disadvantage was due to the short time to carry out the scan rather than just a statement of needing to work quickly.

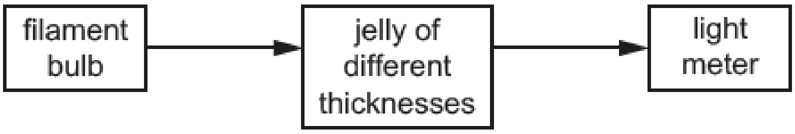
Question 23 (a) (i)

23 As light passes through a substance its intensity decreases exponentially with distance.

$I_x = I_0 e^{-\mu x}$

I_x is the intensity of light at a given thickness of jelly
I_0 is the intensity of light immediately before it enters the jelly
μ is the constant of proportionality
x is the thickness of the jelly that the light has passed through.

Some students are studying the absorption of visible light by red jelly. They set up the experiment below.



- The power to the bulb is kept constant.
- The distance between the bulb and the light meter is kept constant.
- Blocks of jelly of different thickness are used.
- They measure the intensity of light using a light meter.

(a) The table below shows their results and the natural log of the light intensity.

Thickness of jelly/mm	Light intensity/Wm^{-2}	ln (light intensity/Wm^{-2})
1	122	
2	46.5	
3	17.8	2.88
4	6.82	1.92
5	2.62	0.960

(i) Complete the last column of the results table for the 1 mm and 2 mm thicknesses of jelly. **[1]**

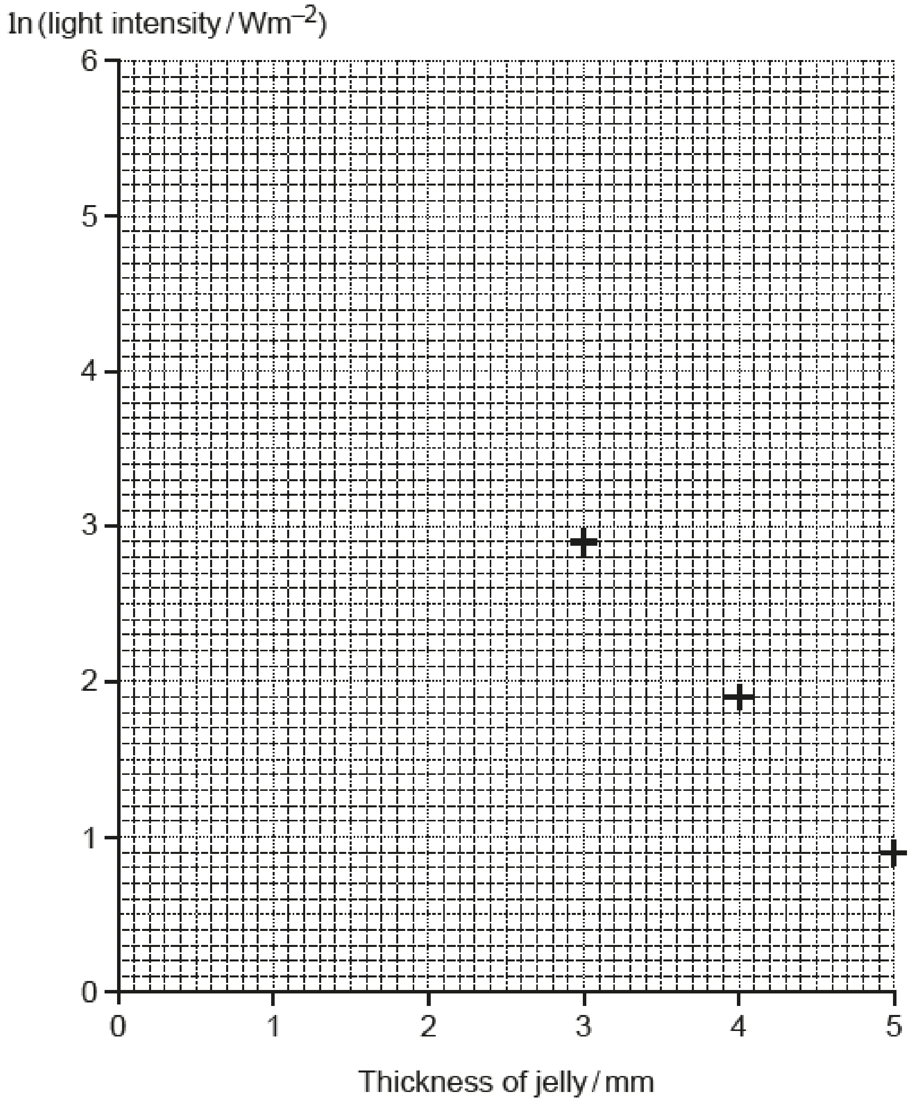
Very few candidates made calculation errors here; the main reason for not gaining marks was usually due to the number of significant figures used. As a general rule, 3sf is usually the number for a logarithmic calculation however it would also be appropriate to match the number to any data already given.

Question 23 (a) (ii)

(ii) Plot the results from the table on the graph. Three points have already been plotted. **[1]**

The relatively simple scales meant that practically all of the candidates gained this mark. The most common fault was in the placing of the x-value.

Question 23 (a) (iii)



(iii) Draw a best-fit straight line through your data points. **[1]**

A best-fit line should, as far as possible with a fair distribution and no anomalies, have equal numbers of points on either side of the line. Candidates should be wary of simply joining up the first and last points – in this case, it is likely to not have scored the mark as the points at 2 and 3 mm would be above the line. This resulted in only around two thirds of the candidates being given this mark.

Question 23 (b) (i)

(b) (i) Show how the equation for exponential absorption of light can give a straight line graph with a negative gradient.

[2]

Most candidates were able to take logs correctly and produce a linear formula. This style of question generally needs the formula to be written in the form of $y = mx + c$, and then related to the equation of the straight line. Many candidates drew arrows between the two formulae to show how they are related which is good.

Question 23 (b) (ii)

(ii) Use your graph to determine the intensity of the light I_0 before it enters the jelly.

I_0 = ... Wm^{-2} **[2]**

The majority of candidates were able to appreciate that the initial intensity came from the intercept and were able to read and calculate it correctly. A small number simply wrote their value of the intercept as their final answer.

Question 23 (b) (iii)

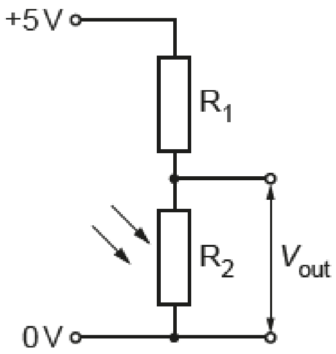
(iii) Use your graph to determine the constant of proportionality μ in units of mm^{-1}.

μ = ... mm^{-1} **[2]**

Gradient calculations should always be done from the line, rather than points in the table, and covering more than half of the axes. Most candidates used the change in *x* as the full range of 5 (mm) and used their intercept from the previous question and the *y*-value from the line. The easy scale meant that this was a relatively simple task although those using the tabulated values would not gain this mark. The constant was the positive value of the gradient and a fair number gave it as negative.

Question 23 (c) (i)

(c) The students decide to make their own light meter using this circuit.



The value of R_1 is 5 kΩ. The value of R_2 was 100 Ω when 1 mm jelly was used and 8 kΩ when 5 mm jelly was used.

(i) Calculate the output voltage range obtained in this experiment.

range = ... V **[2]**

This was correctly done by around three quarters of the candidates. Most used a version of the potential divider formula twice and then either gave these two values as the extremities or the difference between them. There were some clear calculational errors despite the equation being used correctly. Some candidates had a value of the maximum voltage above the supply voltage which should have alerted them to a problem.

Question 23 (c) (ii)

(ii) Describe **two** ways the output voltage range could be increased.

1 ....

....

2 ....

.... **[2]**

Candidates should make sure that they only give the required number of responses when prompted, as any incorrect responses may invalidate correct ones. It is important to make sure that the sense of change of any quantity is given, rather than simply a change. Over three quarters of candidates were able to achieve at least 1 mark on this question.

Question 23 (c) (iii)

(iii) Explain how the circuit responds to a change in light intensity.

....

....

.... **[1]**

Although many candidates had a good understanding of this response, only around a third were able to give a complete and structured response. Three points needed to be made: how the light intensity varies, its effect on the resistance of the LDR and the effect on the output p.d.. Many candidates mentioned just changes rather than the sense of change, and also missed out some detail making the explanation incomplete.

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