Qualification Accredited

OCR
Oxford Cambridge and RSA

A LEVEL

Examiners' report

PHYSICS A

H556

For first teaching in 2015

H556/02 Summer 2024 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.

Paper 2 series overview

H556/02 is one of the three assessed components of the GCE Physics Specification A, A Level, and assesses modules 1, 2, 4 and 6 from this 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 examination 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 the 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. Component H556/03 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:
• showed working in MCQs which, although not necessary, supports the response • made clear corrections to MCQs where the candidate changed their mind • used calculators carefully and rounded to appropriate numbers of significant figures • carefully applied unit conversions when necessary • put in an appropriate amount of detail in the Level of Response questions and in particular paying careful attention to the requirements of the question • demonstrated a good use of logarithms and logarithmic graphs • paid careful attention to command words • showed working in lengthier calculations which helps awarding of method marks and error carried forward marks.	• did not complete all the MCQs • did not show sufficient working in a lengthier calculation which means that method marks cannot be given if the final answer is incorrect • did not give sufficient detail in the LoR questions. For example, poor use of the diagram in Question 18 (a) or not naming any safety precautions in Question 21 (d) • had a limited ability to write in length, in particular in Question 16 (d) • cut off their final answer to a single significant figure, common in Questions 18 (b) (iii) and 22 (b) (ii) • lacked appropriate use of scientific terminology especially in Questions 17 (a) and 20 (c) (i) • were not able to use logarithms appropriately in Questions 21 (b) (ii) and 21 (d).

Section A overview

Section A has 15 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 exam paper for candidates' working and they may annotate text or diagrams if it is found to be helpful. Only the response in the box is marked and so candidates may make use of any shortcuts or ingenuity to reach their answer.

Questions 3, 4, 11 and 13 proved to be accessible to most candidates. Questions 7, 9 and 14 were more challenging and only accessible to the higher end candidates.

Question 1

1 What are the base units of a kilowatt-hour?

A J

B $kg\,m^2\,s^{-1}$

C $kg\,m^2\,s^{-2}$

D W s

Your answer ☐ **[1]**

A little over half of candidates were able to identify the correct response. Many candidates showed working to obtain their answer. **D** was a common incorrect response.

Question 2

2 A neutrino is a fundamental particle.

Which row of the table correctly describes a neutrino?

	Classification	Force felt
A	hadron	strong nuclear
B	hadron	weak nuclear
C	lepton	strong nuclear
D	lepton	weak nuclear

Your answer ☐ **[1]**

Most candidates were able to correctly identify the classification and force. To reduce their options, many candidates circled the correct force.

Question 3

3 Which one of these non-invasive medical scans does **not** expose the patient to ionising radiation?

A CAT

B PET

C Ultrasound

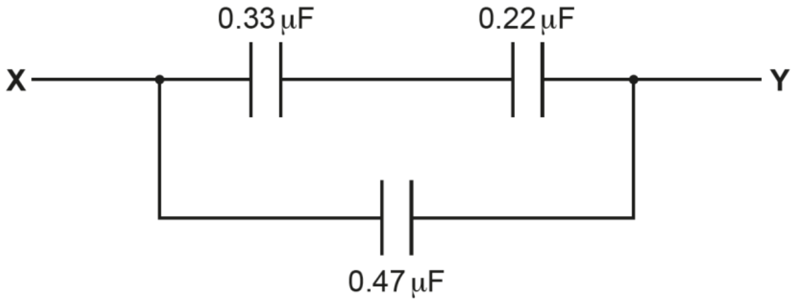
D X-ray

Your answer ☐ **[1]**

This question was correctly answered by most of the candidates and demonstrated a good knowledge of ionising radiations in medical applications.

Question 4

4 Three capacitors are arranged in a circuit.



The capacitance of each capacitor is shown.

What is the total capacitance between **X** and **Y**?

A 0.25 μF

B 0.60 μF

C 1.02 μF

D 8.0 μF

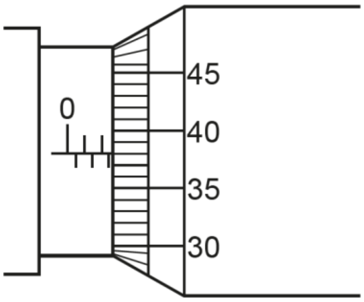
Your answer **[1]**

Most candidates were able to correctly calculate the total capacitance, and many showed working to support a correct method. **A** was the most common distractor, being calculated as if the capacitors were resistors.

Question 5

5 The image shows a micrometer that is being used to measure the diameter of a wire.

The micrometer has a zero error of +0.07 mm. The measured value of the diameter from the micrometer scale is 2.88 mm.



What is the correct area of cross-section of the wire?

A $2.21 \times 10^{-6}\,m^2$

B $6.20 \times 10^{-6}\,m^2$

C $6.51 \times 10^{-6}\,m^2$

D $6.84 \times 10^{-6}\,m^2$

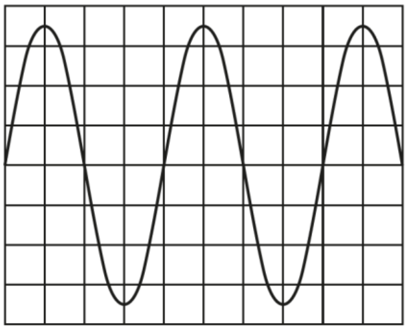
Your answer [ ] **[1]**

Around two thirds of candidates were able to correctly apply the zero error in their calculation. **D** was a common distractor where the zero error was added onto the micrometre reading.

Question 6

6 The image shows a display of an oscilloscope which is measuring an alternating voltage. The time base is set at 0.1 s / division. The voltage scale (y-sensitivity) is set at 0.5 V / division.

Which row of the table shows the correct amplitude and correct frequency?



	amplitude / V	**frequency / Hz**
A	1.75	0.4
B	1.75	2.5
C	3.50	0.4
D	3.50	2.5

Your answer [ ] **[1]**

Most candidates were able to correctly calculate the amplitude and frequency. **A** was the most common distractor where candidates simply identified the time period rather than then calculate the frequency.

Question 7

7 This question is about the rate of decay of a radioactive source.

Which of the following statements is/are true?

The rate of decay is

1 dependent on the decay constant.
2 independent of the mass of the source.
3 dependent on time.

A 1 only

B 1 and 3

C 2 only

D 2 and 3

Your answer ☐ **[1]**

A little under half of the candidates were able to correctly identify the correct statements. A helpful approach to this type of question is to 'tick' the statements which the candidate is certain of, which then reduces the options available.

Question 8

8 A student is using a spreadsheet to model the decay of charge on a capacitor.

They are using the equation $\frac{\Delta Q}{\Delta t} = -\frac{Q}{2.5}$.

The student chooses a time interval of 0.5 s. At time t = 0.0 s the charge on the capacitor is 600 μC.

Part of the modelling spreadsheet is shown below.

***t* / s**	**Charge *Q* left on capacitor after time *t* / μC**	**Charge Δ*Q* decaying in the next 0.5 s / μC**
0.0	600	120
0.5	480	
1.0		
1.5		
2.0		

What is the charge on the capacitor at t = 1.5 s?

A 130 μC

B 240 μC

C 246 μC

D 307 μC

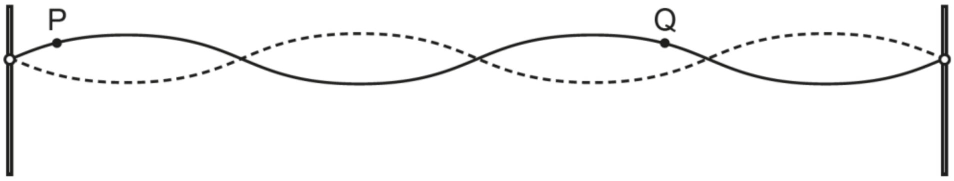
Your answer [ ] **[1]**

Most candidates were able to correctly calculate the charge. Although not a difficult calculation, there are plenty of stages and potential for error at each. Most of the candidates filled in the table at each point which would be a helpful way of keeping on track of the charge.

Question 9

9 The diagram shows a string stretched between two posts.

The string is plucked and a stationary wave is set up.



What is the phase difference between P and Q?

A 0 rad

B $\frac{\pi}{4}$ rad

C $\frac{\pi}{2}$ rad

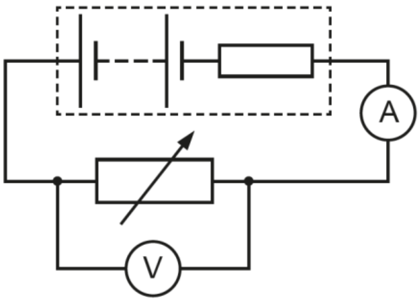
D π rad

Your answer [1]

Relatively few candidates got this phase difference correct; it was clear from many that they thought that it was a progressive wave as they attempted to add on fractions of cycles. It may also be the case that candidates are unfamiliar with phase differences in stationary waves.

Question 10

10 A student uses the circuit below to determine the electromotive force (e.m.f.) and internal resistance of a battery.



They measure the current and potential difference (p.d.) across the variable resistor for different resistor values.

A graph is drawn with p.d. on the *y*-axis and current on the *x*-axis.

Which row is correct for calculating the e.m.f. and the internal resistance of the battery?

	e.m.f	**internal resistance**
A	magnitude of gradient	intercept on *y*-axis
B	magnitude of $\frac{1}{\text{gradient}}$	intercept on *y*-axis
C	intercept *y*-axis	magnitude of $\frac{1}{\text{gradient}}$
D	intercept *y*-axis	magnitude of gradient

Your answer [ ] **[1]**

This was correctly answered by most candidates. They were able to identify how to obtain the emf correctly but less certain on the internal resistance, which led to **C** being my far the most common incorrect response.

Question 11

11 At the Earth's equator the magnetic flux density *B* is approximately 25 μT.

What is the magnitude of the force on an electron with velocity $v = 100\,\text{km}\,\text{s}^{-1}$ as it is moving perpendicular to the Earth's magnetic field at the equator?

A 4.0×10^{-25} N

B 4.0×10^{-22} N

C 4.0×10^{-19} N

D 4.0×10^{-16} N

Your answer ☐ **[1]**

Most candidates were able to calculate the force, using F = BQv. The powers of ten in the various quantites appeared to have caused few problems. SThis was the multiple choice question that had the most 'no responses'.

Question 12

12 What is the radius of a carbon nucleus that has 6 protons and 7 neutrons?

Assume that the average radius of a nucleon r_0 is 1.2 fm.

A 2.2 fm

B 2.3 fm

C 2.8 fm

D 1.6 fm

Your answer ☐ **[1]**

Most candidates were able to correctly calculate the radius and it was clear that most knew how to correctly apply the formula.

Question 13

13 A sub-atomic particle has a positive charge.

Which type of particle is it?

A anti-proton

B down quark

C neutrino

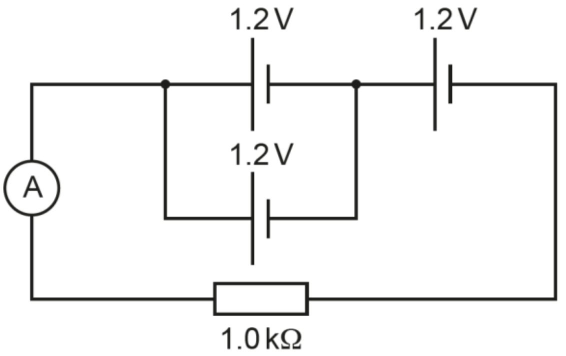
D positron

Your answer [ ] **[1]**

This relatively simple question was correctly answered by of the vast majority of candidates. The most common distractor was **B** which was presumably due to a lack of certainty of quark charges.

Question 14

14 A 1.0 kΩ resistor is connected in series to a battery made of three 1.2 V cells connected as shown. The cells have negligible internal resistance.



What is the reading on the ammeter?

A 1.2 mA

B 1.8 mA

C 2.4 mA

D 3.6 mA

Your answer [ ] **[1]**

This question was relatively poorly answered with fewer than half of the candidates getting the correct response. **B** and **D** were the two common distractors with **B** treating the cells as if they were resistors, and **D** simply adding up the three voltages.

Question 15

15 Which sequence shows the energies below in **increasing** order of magnitude?

1 The change in kinetic energy of an electron accelerated through a potential difference of 1 V.
2 The kinetic energy of a proton with a velocity of $1000\,\text{m}\,\text{s}^{-1}$.
3 The energy of an X-ray photon with a frequency of 3×10^{17} Hz.

A 1 2 3

B 3 1 2

C 2 1 3

D 1 3 2

Your answer [ ] **[1]**

Approximately half of the candidates were able to correctly identify the order. Many set out the calculations to the side before putting them in rank order and this generally proved successful. Most of the incorrect responses showed little or no working, leading to the assumption that there may have been some guesswork involved.

Section B overview

Section B consists of 7 short answer style questions containing problem-solving, calculations and practical style questions; it also includes two Level of Response (LoR) questions each of has 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 and the LoR questions were often answered in considerable detail. Some candidates omitted the more challenging questions early and whether they ran out of time to complete them or simply couldn't answer them is not known.

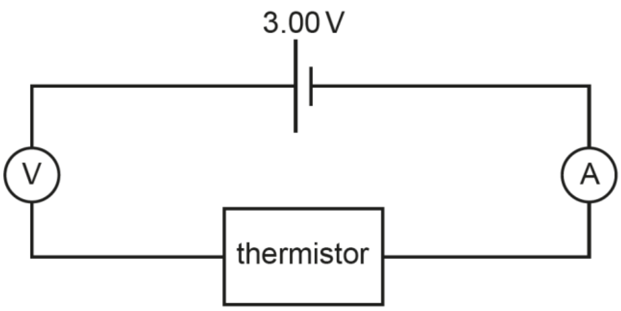
Question 16 (a)

16 Thermistors are circuit components whose resistance varies with temperature.

There are two major types; negative temperature coefficient (NTC) thermistors, whose resistance decreases with increasing temperature and positive temperature coefficient (PTC) thermistors, whose resistance increases with increasing temperature.

A student is investigating how the resistance of a thermistor varies with temperature by measuring current and voltage. The thermistor is placed in a water bath and the temperature of the water measured using a thermometer.

The diagram below shows how the student set up the experiment (water bath not shown). The circuit has been set up **incorrectly**.



(a) Describe how the student should change the circuit.

....

.... **[1]**

This relatively simple first question was correctly answered by the significant majority of candidates. In general, it was lack of detail, such as 'place it in parallel' which meant that the mark would not be scored. A small number of candidates mentioned placing the ammeter in parallel.

Question 16 (b) (i)

(b) The circuit was corrected and then used to collect data.

The table shows data collected from the investigation.

Temperature / °C	Current / mA	Voltage / V
30	0.75	3.00
40	1.10	3.00
50	1.51	3.00
60	2.10	3.00
70	2.80	3.00
80	3.66	3.00
90	4.76	3.00

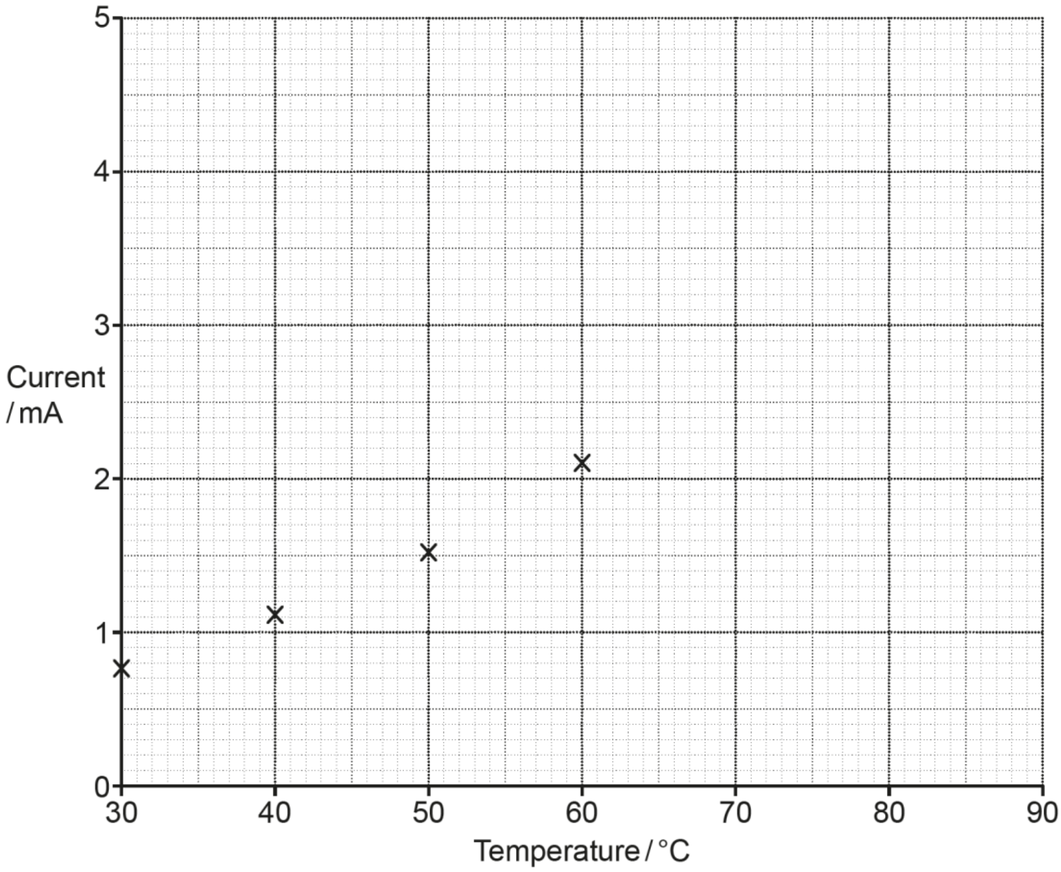
(i) The axes below show a plot of current against temperature. The first four points from the table have been plotted. Plot the remaining points.

[1]

Point plotting is always likely to form part of a question in this paper. The general rule is that each point should be plotted within ½ a small square of the correct position. Candidates are encouraged to plot points as 'crosses' and use a sharp pencil. The vast majority of candidates plotted these three points correctly with the second point most commonly being plotted incorrectly.

Question 16 (b) (ii)

(ii) Draw a suitable line of best fit through the data points. **[1]**



The suitable line is a curve of increasing gradient and well over half of the candidates were able to draw this carefully. There were very few lines which simply joined the points as 'dot-to-dot' straight lines although a considerable number drew a single straight line often through the (false) origin which should have looked clearly unsuitable. When drawing the curve it needs to pass within a single small square of each data point; several candidates drew careless lines missing data points by some distance. Candidates are also encouraged to use a sharp pencil for this line. There were a reasonable number who attempted to correct a line drawn in pencil, often making it difficult to award a mark.

OCR support

The Practical skills handbook: Physics has support for drawing tables and graphs in Appendix 5, including examples of acceptable and unacceptable graph drawing.

Question 16 (c)

(c) Describe, using the graph and calculations using data from the table, how the resistance of the thermistor varies for increasing temperature.
Hence determine whether the thermistor the student used was an NTC or a PTC thermistor.

....

....

....

....

....

....

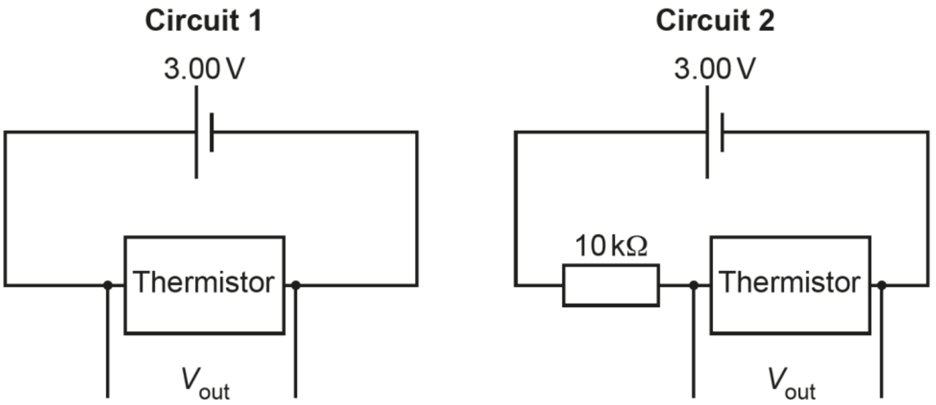
.... **[3]**

Candidates were asked to use both the graph and table to draw their conclusion and for full credit both of these needed to be done. A simple description of the variance of current with temperature was all that was needed for the graph mark but calculations of resistance needed to be carried out from the table. Most candidates were able to score at least 1 mark on this question although some incorrectly identified the type of thermistor (as PTC) despite having the rest of the response correct.

Question 16 (d)

(d) The thermistor is used in a temperature-sensing circuit for a heating system to warm milk for a baby.

The student considers two possible designs for the circuit which are shown below.



In each circuit, the voltage V_{out} across the thermistor is connected to the heating system for warming the milk.

Discuss which circuit may be suitable for the heating system by considering the response of the circuit to changes in temperature.

....

....

....

....

....

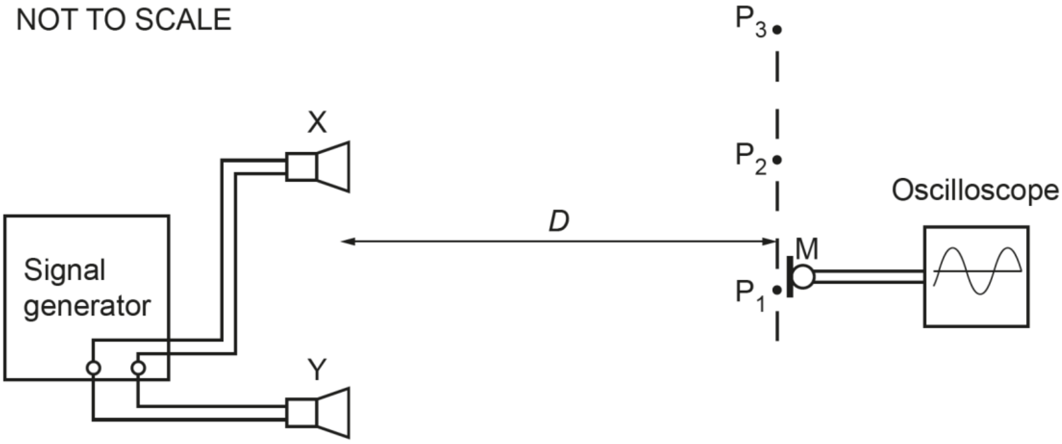
.... **[4]**

A significant number of candidates did not score on this question despite giving a response, indicating a lack of understanding of voltage in circuits. In particular, those who did not appreciate that the full voltage was across the thermistor in circuit 1 generally struggled to obtain any marks. However, there were many good descriptions of a potential divider in circuit 2 and these often went into detail about the operation of the circuit and its suitability.

Question 17 (a)

17 The diagram shows two identical loudspeakers X and Y connected to a signal generator.
The loudspeakers emit sound waves of the same amplitude and frequency which are in phase.

A microphone M is moved along a line from P_1 to P_3 and the signal recorded on an oscilloscope.



As the microphone is moved along the line P_1 to P_3 the oscilloscope shows maximum signal at P_1, zero signal at P_2 and the next maximum signal at P_3.

(a) Explain these observations.

....

....

....

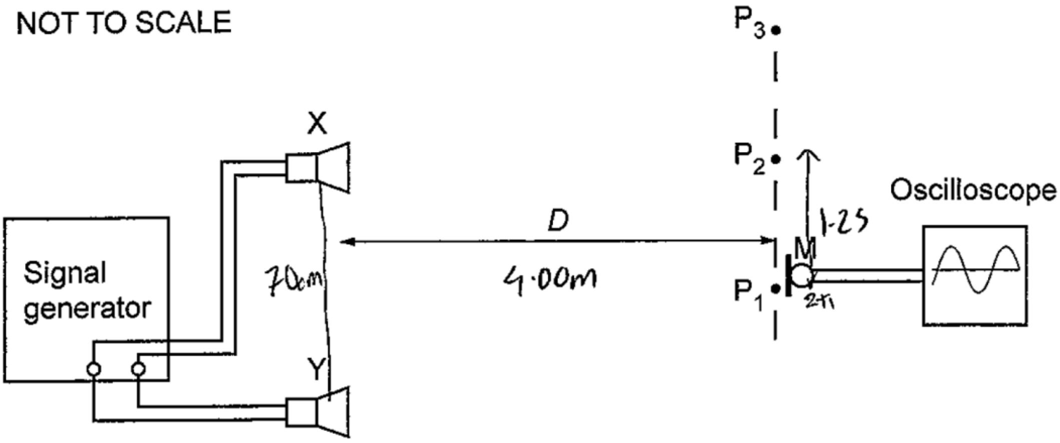
.... **[2]**

Candidates needed to appreciate that the maximum and minimum were due to interference and then give an explanation of constructive and destructive interference in terms of phase or path differences. It was a common misunderstanding that a stationary wave was formed, and a significant number of candidates described the observations in terms of nodes and antinodes. It was also common to see confusion between path and phase difference, with candidates giving phase differences in terms of wavelengths.

Exemplar 1

17 The diagram shows two identical loudspeakers X and Y connected to a signal generator.
The loudspeakers emit sound waves of the same amplitude and frequency which are in phase.

A microphone M is moved along a line from P_1 to P_3 and the signal recorded on an oscilloscope.



As the microphone is moved along the line P_1 to P_3 the oscilloscope shows maximum signal at P_1, zero signal at P_2 and the next maximum signal at P_3.

(a) Explain these observations.

At P_1 and P_3, there is constructive interference as waves arrive in phase, have path difference of nλ so there is a maxima. At P_2 the waves are destructively interfering showing a minima. **[2]**

In Exemplar 1, the candidate has given an excellent response to the maximum – stating constructive interference and then giving two reasons why this occurs (assuming n is an integer). However, the minima stops and isn't developed, even though there is still some space, and the additional space at the back can also be used. It is likely that the candidate knew the reason for the destructive interference, and this demonstrates how important it is to complete descriptions and explanations.

Question 17 (b)

(b) The distance between the centres of X and Y is 70.0 cm, the distance *D* (as shown in the diagram) is 4.00 m and the distance from P_1 to P_2 is 1.25 m.

Use the two source interference formula to calculate the frequency of the sound waves. (Speed of sound = 340 m s^{-1})

frequency = ... Hz **[3]**

The majority of candidates were able to use the two source formula, however used 1.25m for their value of *x*, rather than double this. A small number of candidates attempted a geometrical solution, attempting to calculate angles, but this was unlikely on its own to score any marks.

Question 17 (c)

(c) Loudspeaker Y is now replaced with a loudspeaker that produces sound waves of twice the original amplitude.

Describe how the signal observed on the oscilloscope varies as the microphone is moved along the line P_1 to P_3.

....

....

....

.... **[2]**

This question specifically asked about the observed signal and so responses based on loudness or sound volume are not appropriate. Candidates needed to be very clear that they were describing particular positions and how the signal varied from the previous situation. There was no penalty for an incorrect value of the increase in signal, although many candidates were able to state this correctly.

Question 17 (d) (i)

(d)
(i) Explain what is meant by the term *intensity*.

....

.... **[1]**

Candidates need to give a clear and specific answer to this question, which is best expressed in words. The Data and Formulae booklet contains the equation for intensity in symbols, however it is important to state the 'per unit area' in the explanation rather than a vaguer statement such as 'power over area'. Many candidates gave very simplistic responses such as 'the amount of energy a wave has' indicating a lack of appreciation for the detail required.

Question 17 (d) (ii)

(ii) Calculate the factor by which the intensity of the sound waves at P_1 in **(c)** is larger than the intensity of the original sound waves at P_1.

factor = ... **[3]**

Some candidates were able to correctly calculate the factor, which could be expressed in a number of ways. Many candidates were able to correctly state the relationship between intensity and amplitude but not able to identify how the amplitudes were different and so could not carry on with the calculation, so only scoring a single mark.

Question 18* (a)

18*

(a) Describe how an experiment can be conducted to determine how the output current of a step-up transformer depends on the number of turns on the secondary coil.

Explain how the data collected can be analysed to establish the relationship between the output current and the number of turns on the secondary coil.

You are provided with wire and a suitable core on which to wind the wire, as well as any other normal laboratory equipment.

Use the space below to draw a labelled circuit diagram. **[6]**

This Level of Response (LoR) question was designed to assess practical skills of planning, implementation, analysis and evaluation from Module 6 of the specification, specifically 6.3.3(f), along with HSW3 and HSW4. 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 were expecting a varied approach, with common themes, which would lead to a correct conclusion. The nature of the question is such that it can be conveniently separated into a description of the experiment and an analysis of it.

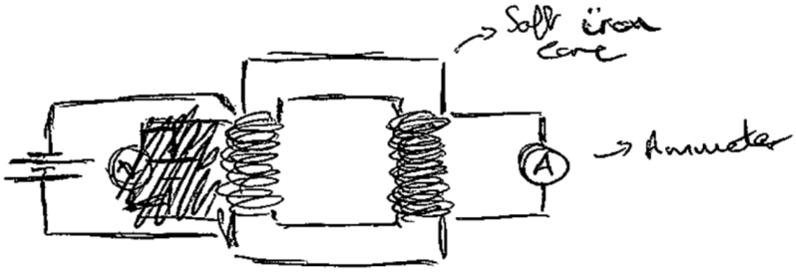
The key points in the description that examiners were looking for were: - a suitable circuit diagram with a transformer and coils along with a supply and metres – use of an ac supply - a description of the method used, specifically controlling variables, and measuring an output – a statement or description of how the output current is to be determined – a statement of how the secondary turns is to be varied.

The key points in the analysis that examiners were looking for were: - a statement of the transformer equation in terms of current and turns – a suitable arrangement of this formula to give either the dependent or independent variable as the subject – a suitable graph which would give a linear relation – an explanation of how this graph would appear.

It was clear that many candidates had carried out this experiment by investigating voltage however the use of current here caused some difficulties to less successful candidates.

The very best responses were detailed, with a clear diagram and well-structured making every attempt to fully answer each section. In many cases the diagram did little to add to the description, however the very best were suitable on their own. Many candidates had a single supply for both the primary and secondary turns and a significant number used a dc supply. Good responses often included the additional detail that the transformer was a step up so that there would be a larger number of turns on the secondary, often giving suitable numbers. Many candidates stated that they would plot secondary current against secondary turns and then stated that it would show inverse proportionality. It is to be explained that any relation should be shown through a straight line graph wherever possible.

Exemplar 2



$$\frac{n_s}{n_p} = \frac{I_p}{I_s}$$

$$I_s = \frac{I_p n_p}{n_s}$$

Set up experiment as shown in diagram. Place a AC power supply on primary coil at constant voltage and an ammeter on other end. Wind the wire on each side keeping primary coil the same and noting down how many turns are on both coils. Switch on the power and take readings of the current from ammeter. After doing so increase the number of turns on secondary coil and repeat experiment. Repeat this at least 7 times, changing the number of turns by a constant interval each time.

Once you have obtained all the data Plot a graph of 1/number of turns against the current in secondary coil. This should show a straight line through origin as

~~$y = mx + c$~~ $y = mx\ c$ gradient

$I_S = \frac{I_p n_p}{n_S} = (I_p n_p) \times \frac{1}{n_S}$ should be constant and

when there are no turns there is no induced ε and ∴ no current. Relationship is $I_S \propto \frac{1}{n_S}$.

Exemplar 2 shows a response which does not necessarily have all the indicative points contained but would be given Level 3 and 6 marks. Firstly, the diagram doesn't have any method for measuring input current or have a load resistor, but it is clear what it represents and it also looks like it is a step-up transformer. The diagram has a dc cell symbol, but this is overridden by a statement that it is an ac supply in the text. This does not have to be treated as a contradiction, as the symbol for ac is not likely to be known. The method explains how this is to be carried out quite well and is structured in an ordered way.

The analysis is brief but complete. It shows the equation that has been used, arranged in the form of y = mx + c and then stating what should be plotted and what it will show.

This is an example of a perfectly good response that will achieve maximum marks without having to get every indicative point.

Question 18 (b) (i)

(b) A simple laminated iron-core transformer takes mains voltage 230 V, 50 Hz into the primary coil. The output voltage from the secondary coil is 5.0 V. The primary coil has 920 turns.

(i) State *Faraday's law*.

....

.... **[1]**

It was encouraging to see that over half of the candidates were able to correctly recall Faraday's law, which is specifically stated in the specification. The vast majority of incorrect responses were a statement, generally in words, of the transformer equation presumably as it was used in the following question.

Question 18 (b) (ii)

(ii) Show that the number of turns on the secondary coil is 20.

[2]

The vast majority of candidates were able to correctly show the number of turns on the secondary coil was 20. As always with a 'show that' question it is important that each step is clearly shown and that there is no doubt that the candidate has evaluated the answer. Candidates who did not score on this generally were not explicit enough in their working.

Question 18 (b) (iii)

(iii) At one particular instant, the output voltage from the transformer is 3.4 V.

Calculate the change in magnetic flux experienced by the secondary coil in a short time interval of 1.2 ms and state its unit.

Assume that the output voltage from the transformer remains constant at 3.4 V over this time interval.

$\Delta\Phi$ = ... unit .... **[4]**

This question was generally well answered with over a third gaining all 4 marks. Most candidates chose the correct equation, although its rearrangement caused some problems, along with the number of turns to use. The correct numerical answer was 2.0 x 10^{-4} which several candidates incorrectly (in terms of significant figures) gave as 2 x 10^{-4} thus losing a mark. Candidates should be reminded that, in general, answers should be given to the lowest number of significant figures in the question, in this case 2sf. Many candidates who struggled with the calculation were able to get the standalone mark for the unit although there was a reasonable number of W rather than Wb.

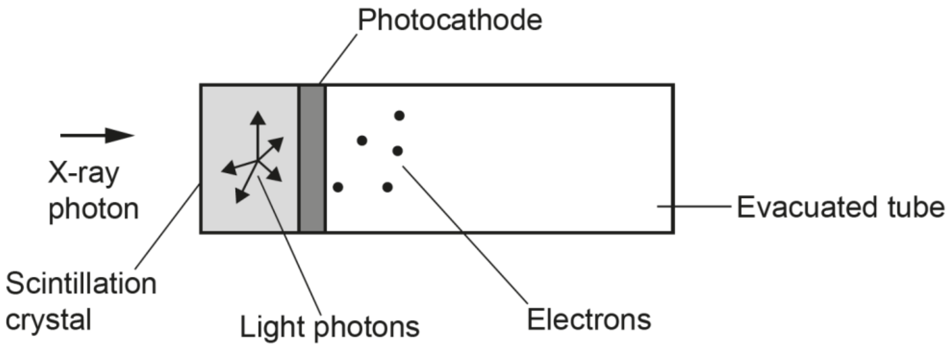
Misconception

? The formula stating $\Delta(N\Phi)$ seemed to cause some misunderstanding and a fair number of candidates seemed to calculate the difference in the number of turns (920 – 20) therefore using 900 as the number of turns.

Question 19 (a)

19 The diagram shows part of an X-ray telescope which uses a crystal scintillation device to detect low energy X-rays from the stars.

X-rays hit the crystal and cause it to emit visible light photons. These travel to the photocathode in an evacuated tube. The photocathode uses the light photons to produce electrons.



Each X-ray photon detected by the telescope has an energy of 32 keV.

The light photons have a wavelength of 510 nm.

The efficiency of the crystal is 15%.

(a) Show that each X-ray photon produces about 2000 light photons.

[3]

Most candidates were able to correctly show that the number of light photons was close to 1970. There were a number of methods and units that could be used and the inclusion of the 15% factor could be done at several points. Examiners were aware of these various routes and gave credit to working at each point where appropriate. The conversion of the keV to joules and the conversion of nm seemed to cause no difficulties.

Question 19 (b) (i)

(b) The photocathode has a work function of 2.3 eV.

(i) Explain what is meant by the *work function*.

....

.... **[1]**

This explanation requires some specific detail; that it is a *minimum* energy and that it is not being applied to an atom. Nearly two thirds of candidates gave an explanation clear enough for credit and most of those who missed out on the mark simply weren't detailed enough rather than being wholly wrong. Responses such as 'the minimum energy for the photoelectric effect to occur' are not quite detailed enough.

Question 19 (b) (ii)

(ii) Calculate the maximum kinetic energy of the electrons leaving the photocathode.

maximum kinetic energy = ...J **[2]**

Most candidates were able to obtain at least 1 mark by correctly converting the work function into joules. As always, correct working is very helpful in obtaining the intermediate marks. Several arranged the equation incorrectly, by adding on the work function, but well over half of the candidates correctly evaluated the maximum kinetic energy.

Question 19 (b) (iii)

(iii) 12 X-ray photons are detected every minute.

Use your answer to **(a)** to calculate the current I leaving the photocathode. Assume that all the photons of light produce photoelectrons.

I = ... A **[2]**

A little under half of the candidates were able to correctly calculate the current. Incorrect methods included missing out the factor of 12, or by dividing by 3600 instead of 60.

Question 19 (b) (iv)

(iv) State one other assumption you have made to enable you to calculate the current I in **(b)(iii)**.

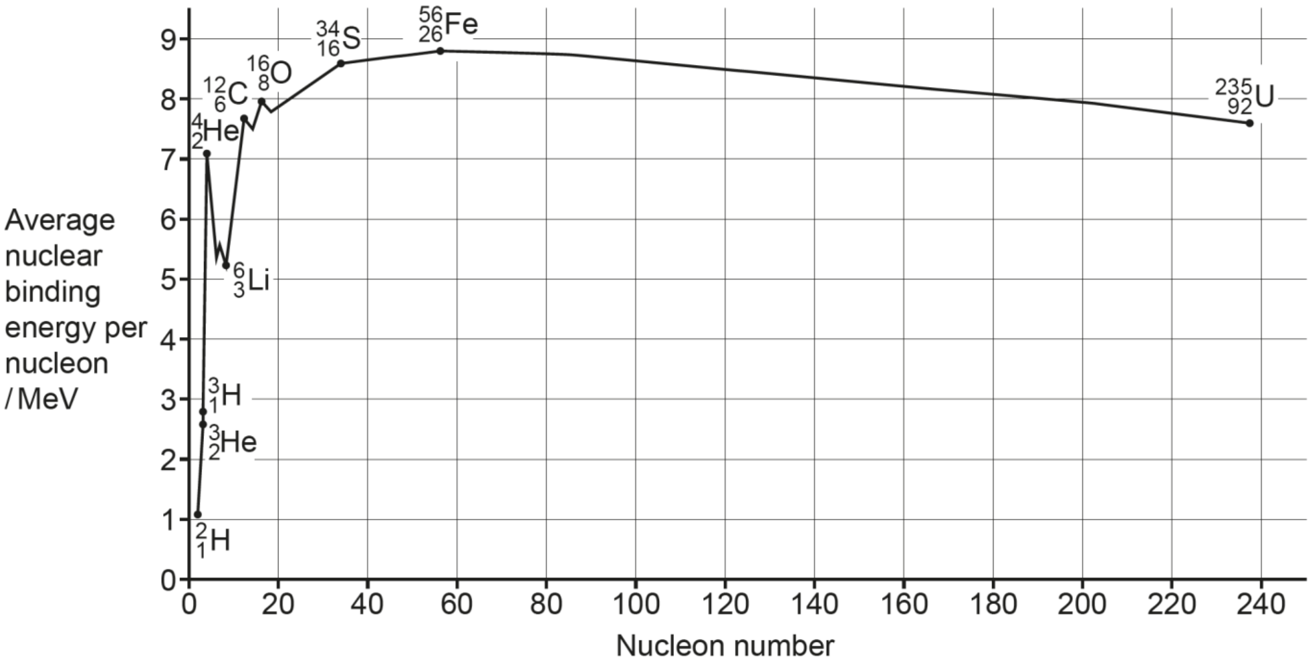
....

.... **[1]**

The main expectation for this question was to appreciate the one-to-one relation between the photon and the electron, although other valid answers were given. Ideas about efficiency are a little too limited for credit, along with statements like 'there are exactly 2000 photons'. Information in the question has to be treated as correct in any case, so is not an assumption.

Question 20 (a)

20 The diagram below shows the average nuclear binding energy per nucleon for a number of different isotopes.



(a) Explain what is meant by *nuclear binding energy* of a nucleus.

....

.... **[1]**

A little less than half gave a suitable explanation for the binding energy; many incorrect responses were based on the idea that it was the energy holding the nucleus together. Several responses correctly stated the relationship between binding energy and mass defect although this did not answer the question.

Question 20 (b)

(b) Suggest why the $^{1}_{1}$H isotope of hydrogen has **not** been included on the above diagram.

....

.... **[1]**

Around half of candidates gave a clear suggestion why hydrogen was not included. Many appreciated that the single nucleon had no binding energy although not all made a link. Several candidates described a hydrogen atom instead of the nucleus causing confusion over electron binding energy.

Question 20 (c) (i)

(c) The main nuclear fusion reaction in the Sun is between nuclei of deuterium (^2_1H) and tritium (^3_1H). This reaction can be written as shown below.

$$^2_1H + ^3_1H \rightarrow ^4_2He + ^1_0n$$

(i) Explain why isotopes with low mass numbers, such as hydrogen, are those which undergo nuclear fusion.

....

....

.... **[1]**

This question was quite poorly answered with few candidates appreciating the idea that an increase in binding energy per nucleon would result in energy given out. Many candidates simply restated the question, by saying low mass would join to give higher mass or stated that iron was the most stable isotope.

Question 20 (c) (ii)

(ii) Use the diagram given at the start of this question to show that, for the reaction of deuterium and tritium, the energy released in each fusion event is approximately 3×10^{-12} J.

[3]

As always with a 'show that' question, it is vital to include as many steps as possible, the key to this question involved reading from the graph and then including the number of nucleons in the calculation. A fair number of candidates correctly read the point but did not multiply this with the nucleon number. There were relatively few misreads from the graph and the tolerance allowed some variation. Many simple (and incorrect) methods would give a value fairly close to 3 x 10^{-12} and so candidates would feel that they had correctly answered the question. Very few candidates struggled with the conversion from MeV to joules, although this may have been supported by having the power of ten given to them. It is also important to make sure that any value is given to a greater number of significant figures than that asked for, if appropriate. Around a third of candidates were able to obtain all 3 marks on what a potentially challenging calculation is.

Question 20 (c) (iii)

(iii) The Sun's mass deceases by 4.3×10^9 kg every second. Assume that the mass loss is only due to this reaction.

Calculate the number of fusion events per second occurring in the Sun.

number of fusion events per second = ... s^{-1} **[2]**

There are several routes to obtain the correct answer and credit is always given to any correct method. Neatly two thirds of candidates scored both marks on this question, even if they had not completed the previous part by using the 'show that' value. Candidates should always be aware that a 'show that' value is likely to be used in subsequent calculations.

Question 20 (d) (i)

(d) In the Sun, deuterium (^2_1H) is produced from fusion of two hydrogen (^1_1H) nuclei, as shown below. There is a particle missing.

$$^1_1H + ^1_1H \rightarrow ^2_1H + ^0_1\beta^+ + \text{......................}$$

(i) Determine the charge of the missing particle.

.... **[1]**

Most candidates were able to identify the charge. Most who gave incorrect responses answered a charge of -1, presumably due to the β^+.

Question 20 (d) (ii)

(ii) The missing particle is a lepton. Name this lepton.

.... **[1]**

Most candidates appreciated that this was a neutrino, with some giving the symbol in the equation too. There were relatively few antineutrino responses with electron being the most common incorrect answer. There seemed to be little connection between this and the previous question for several candidates who correctly gave the charge in (d)(i) but then named a charged particle here, or vice versa.

Question 20 (d) (iii)

(iii) In the fusion reaction above, determine the total number of up quarks at the **start** of the reaction.

.... **[1]**

Most candidates were able to determine the correct number of quarks; the most common incorrect response was six, being the total number of quarks.

Question 20 (e)

(e) Tritium (^3_1H) is another isotope of hydrogen which is formed in stars. On the Earth, tritium is a radioactive element which decays by β^- emission.

Write down the equation for β^- decay in terms of quarks.

[2]

Candidates needed to show the quark change for a single mark, being a down quark to an up quark. This could be done in a number of ways, as long as there was one fewer d and one more u on the right hand side of the equation. This was done fairly well but the other particles were less clear. A neutrino was often given instead of an antineutrino and even though a beta-minus was given in the question, this was often written as a beta plus. A significant number of candidates gave no response to this question. This did not seem to be an issue of time.

Question 21 (a) (i)

21 Technetium-99m ($^{99}_{43}Tc^{m}$) is a metastable radioisotope which can be used as a tracer in medical diagnosis. It is injected into the body and decays by gamma emission into technetium-99 according to the following chemical equation.

$$^{99}_{43}Tc^{m} \rightarrow {}^{99}_{43}Tc + {}^{0}_{0}\gamma$$

(a)
(i) Explain what is meant by a *tracer*.

....

.... **[1]**

There are many possible answers to this question, but it was felt that the key point being looked for was the idea that a location in the body could be identified. General uses of tracers was not specific enough and several candidates simply stated that the tracer could be traced. Only around a quarter of candidates gave a suitable response to this question.

Question 21 (a) (ii)

(ii) $^{99}_{43}Tc^{m}$ only emits gamma radiation.

Give **two** advantages of using a tracer which only emits gamma radiation.

1 ....

....

2 ....

....

[2]

This relatively simple question was correctly answered by the majority of candidates. There was no additional detail required apart from the two simple facts although it was good to see many candidates putting these into context. Candidates should be reminded that in a question like this, only two responses should be given. Including a third runs the risk of a contradiction. Common misconceptions included the idea that the half-life of a source of gamma radiation was shorter (or longer) than alpha and beta, and that gamma radiation was 'safer'.

Question 21 (b) (i)

(b)
(i) A technetium-99m tracer with an activity of 900 MBq is injected into a body. The half-life of technetium-99m is 6.01 hours.

Calculate the number of technetium-99m nuclei initially present in the tracer.

number = ... **[3]**

It was very encouraging to see that nearly two thirds of candidates were able to score all 3 marks on this question. Logarithms can challenge candidates but it was clear that many understood how to carry this out and were able to effectively. There were relatively few who were confused by the time units, but credit could be given even when the unit was used incorrectly.

Question 21 (b) (ii)

(ii) Calculate the time in hours taken for the activity of the tracer to have fallen to 3.0% of its initial activity.

time = ... hours **[3]**

This calculation was also carried out very well, with many gaining full marks. There are several different ways to obtain the correct answer and part credit can be given for any method which will use the decay equation correctly. Most candidates calculated what 35 of the initial activity would be, putting both A and A_0 into the calculation, rather than just using 0.03 as the ratio.

Question 21 (c)

(c) The daughter nucleus ($^{99}_{43}Tc$) decays by beta emission with a half-life of a little over 200 000 years. Approximately 50% of it is stored in the bones, and 50% is passed out of the body.

Suggest why the presence of this remaining $^{99}_{43}Tc$ in the body causes little additional risk to the patient.

....

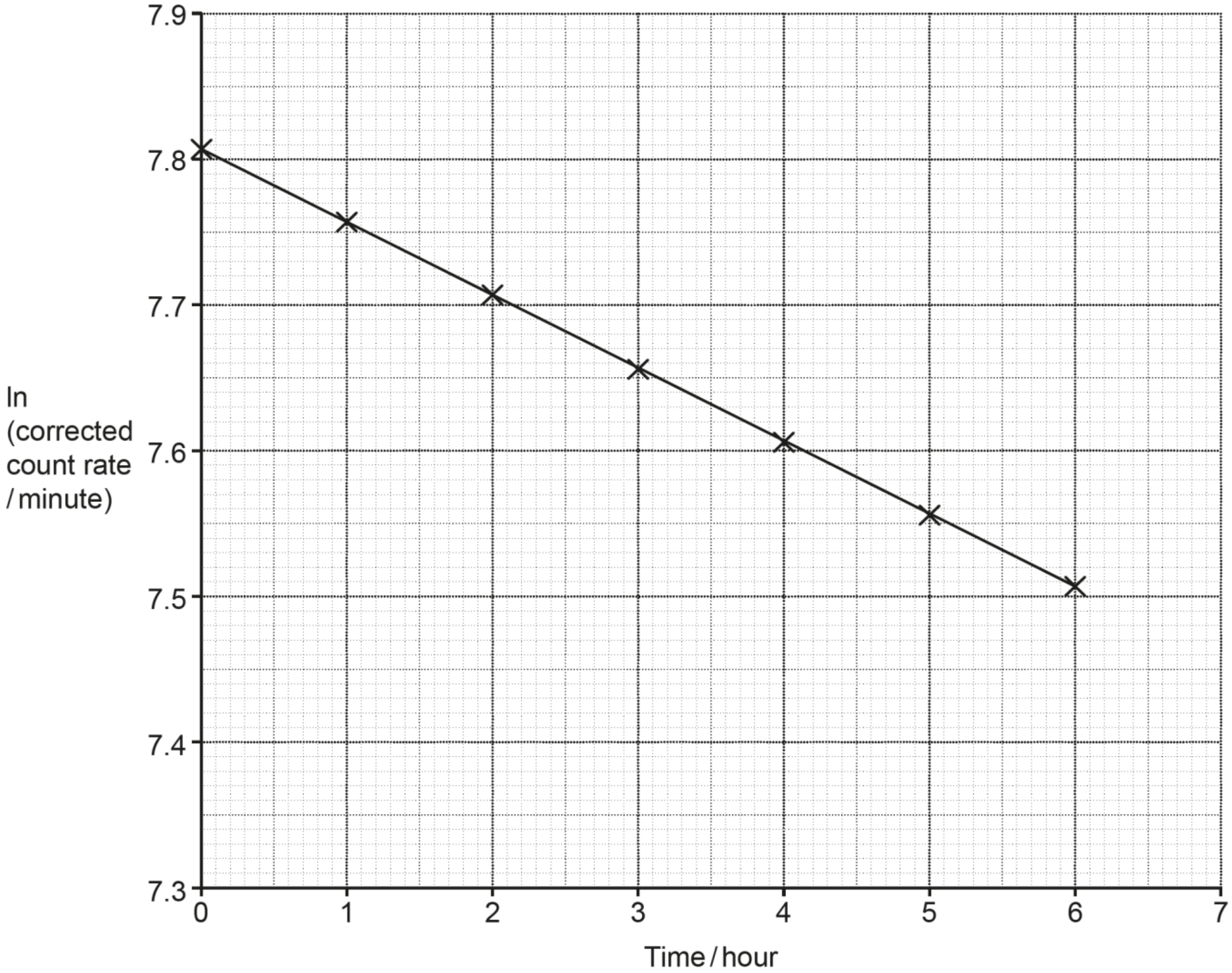
....

.... **[1]**

The required response here was to do with the activity of the remaining Tc. It needed to be clear that the activity was very low, or that it was low compared to any background count. Using the half-life alone as the response would not be worth any credit. A noticeable number of candidates misinterpreted the question and answered why the presence of the Tc does continue to cause a risk. Many also gave responses relating to the beta emission, stating that it was safe or wouldn't affect bones.

Question 21 (d)*

(d)* The half-life of a different radioisotope is to be determined using suitable apparatus. Each count represents one decay. The number of counts is measured for one minute every hour over a period of 6 hours. When the data has been collected, a graph of ln(corrected count rate / minute) against time is plotted and shown below.



- Describe an appropriate method that could be used to obtain this data, naming any apparatus and safety precautions taken.
- Use the graph given above to determine the half-life of this radioisotope showing clear working. **[6]**

This is the second Level of Response (LoR) question in this paper, and was designed to assess nuclear and particle physics, specifically sections 6.4.3e of the specification. In particular, there are two parts (description and calculation) relating to a method and graphical data.

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 what to expect, but not all need to be satisfied to be given full marks. 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 producing a number. The two separate sections can be separated into a description of the method for obtaining the data, and a calculation using the graph to determine the half-life.

The key points in the description that examiners were looking for were: - named apparatus - measurement of background radiation – calculation of corrected count rate – safety requirements.

The key points in the calculation that examiners were looking for were: - arrangement of decay equation having taken logs – demonstration that the gradient is the decay constant - calculation of the gradient – use of the gradient to determine the half-life.

The descriptions of the method varied significantly. Some were extensive and detailed and others a very limited response despite being a procedure that candidates are likely to have come across. Most candidates gave a simple safety precaution, such as holding at arm's length, but there were plenty of vague responses such as wearing coats. Not all candidates could explain how, or why, the background was taken and a fair number missed this out completely. Quite a few candidates gave extensive detail about storing the source, which although is relevant, is not the key point to the question.

The analysis was done better and in general well-structured and clear. The working was set out well for the most part and it was simple to follow the candidates working. Not all gave a clear reason for how they were obtaining the half-life, but this was not fully necessary as long as the answer was correct. One common error was to take logs of the data on the y-axis rather than appreciating that they are already log values. There were not many misreads, but the nature of the data meant that any could have a significant impact on their answer and would likely be penalised. Some candidates got into difficulties with time units and attempted to convert the decay constant to s^{-1} without success.

Question 22 (a) (i)

22 This question is about lightning.

(a) Sheet lightning occurs when there is an electrical discharge between the upper and lower regions of a thunder cloud.
The upper regions are positive and the lower regions are negative.

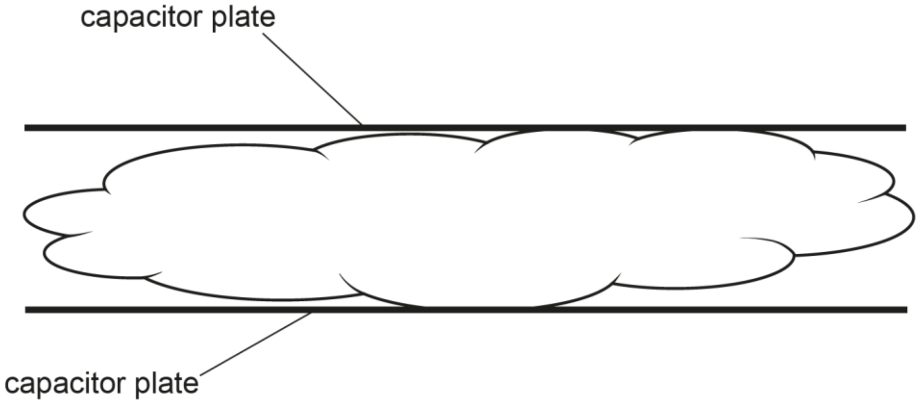
The thunder cloud can be modelled as an ideal parallel plate capacitor with circular horizontal plates.

The data for the capacitor comes from the cloud.

Diameter of cloud	24 km
Distance between upper and lower regions	3.2 km
Electric field strength between the regions	$4.0 \times 10^{5}\,\mathrm{V\,m^{-1}}$

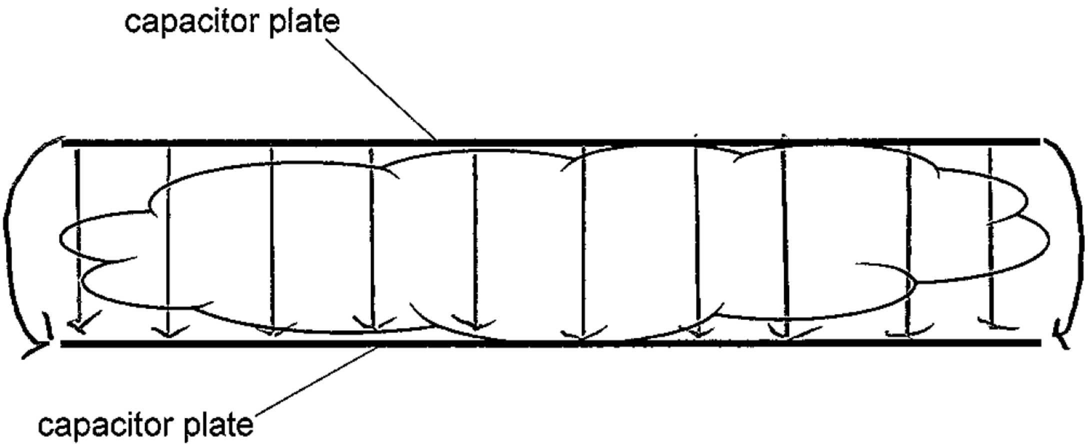
(i) The diagram shows the plates of the model capacitor superimposed on the cloud.

Draw on the diagram to show the electric field lines between capacitor plates. **[2]**



Most candidates were able to score at least 1 mark on this question. The most common loss of marks was an uneven spacing between the lines. Some candidates (helpfully) wrote on the diagram that the spacing was equal. As it is apparent that most candidates know the spacing should be regular, it would be best to do this with a ruler rather than leave it judgement. Similarly, the lines should be vertical and straight, again best done with a ruler.

Exemplar 3



Exemplar 3 only scored the second mark, as the spacing is unequal. At first glance it may look like the spacing is regular and this is possible what the candidate meant to do, but those at the right hand side (ignoring those outside of the plates) are definitely not equally spaced by eye. It would have been far better for the candidate to use a ruler to make the spacing equal.

Question 22 (a) (ii)

(ii) Suggest why the actual electric field lines of the cloud would differ from what you have drawn.

....

.... **[1]**

Although there were many ways to obtain this mark, only around half of candidates gave a suitable response. Many answers were vague such as 'the cloud is not even' or 'the cloud contains water vapour' which really needs more clarity. The best response is based on the distribution of charges, but alternatives relating to uniformity of a variety of factors are perfectly correct.

Question 22 (a) (iii)

(iii) Show that the potential difference (p.d.) *V* between the plates is about 1×10^9 V.

[1]

Again, a 'show that' question needs the calculation to be clear. Here it will involve the multiplication of two quantities using the correct powers. For example, 32k is not a suitable alternative to 32 x 10^3.

The value calculated is not the same as the 'show that' value so needs to be given to more significant figures (at least 2) to prove the calculation was carried out. The significant majority of candidates were able to correctly score this mark.

Question 22 (a) (iv)

(iv) Calculate the capacitance *C* of the model capacitor.

Assume the permittivity of the material of the cloud is the same as the permittivity of free space.

C = ... F **[2]**

Most candidates were able to select the correct formula and make an attempt at a substitution. The main error came from an incorrect calculation of the area, either by using an incorrect method for the circle or incorrectly calculating it using 24km x 3.2km. Candidates are to be reminded that if the working is correct and the calculation wrong, then marks may still be given. Without this working, there is likely to be no credit. Several candidates used the formula for charge on a sphere which gave the same answer (to 2sf) but is a physics error so scores no marks.

Question 22 (a) (v)

(v) Calculate the magnitude of the charge Q on one of the plates of the model capacitor.

Q = ... C **[2]**

This response could produce a wide variety of correct answers depending on the rounding of the numbers used, although most candidates used at least 2sf for their values, which is recommended. A noticeable number of candidates correctly evaluated the change then divided it by 2, presumably due to it asking for the charge on one of the plates.

Assessment for learning

Error carried forward.

In general, error carried forward can only be applied when the working is clearly seen and the error value is correctly used. In this question, there are two values to be used, each of which may have been incorrectly calculated. It is therefore vital that the calculation is seen, so that the credit can be given. It is, of course, good practice to always show working rather than when just an error carried forward could be applied.

Question 22 (b) (i)

(b) Fork lightning is an electrical discharge that occurs between the bottom of the cloud and the surface of the Earth.

Another cloud has a charge of 155 C and is at a height of 2.0 km.

The surface of the Earth has an electrical potential *V* of 0 V.

(i) Assume the cloud acts as a **point** charge.

Calculate the magnitude of the electrical potential *V* between the cloud and the surface of the Earth.

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

Most candidates were able to correctly select the equation and evaluate the correct answer. Some chose the field strength equation or wrote the potential equation with a r^2. Some selected the wrong value of r, giving it as the radius of the cloud. As with Question 18(b)(iii) candidates are reminded that, in general, answers should be given to the lowest number of significant figures in the question, and that an answer of 7×10^8 will incur the significant figure penalty (applied only once per paper).

Question 22 (b) (ii)

(ii) A fork lightning strike has a duration of 25 ms. The cloud discharges at a constant rate. The cloud is uncharged after the strike.

Calculate the number of electrons reaching the ground in 1.0 ms.

number of electrons in 1.0 ms = ... **[3]**

This question could be answered in several ways. Most candidates chose to calculate the current in amps and then converting back to ms at the end. Very few were confused by the need to give the answer in ms. This question polarised the candidates with the vast majority scoring 0 or 3; those who got part way to solving it generally ended up with the correct answer.

Supporting you

Teach Cambridge

Make sure you visit our secure website **Teach Cambridge** to find the full range of resources and support for the subjects you teach. This includes secure materials such as set assignments and exemplars, online and on-demand training.

Don't have access? If your school or college teaches any OCR qualifications, please contact your exams officer. You can forward them this link to help get you started.

Reviews of marking

If any of your students' results are not as expected, you may wish to consider one of our post-results services. For full information about the options available visit the OCR website.

Access to Scripts

We've made it easier for Exams Officers to download copies of your candidates' completed papers or 'scripts'. Your centre can use these scripts to decide whether to request a review of marking and to support teaching and learning.

Our free, on-demand service, Access to Scripts is available via our single sign-on service, My Cambridge. Step-by-step instructions are on our website.

Keep up-to-date

We send a monthly bulletin to tell you about important updates. You can also sign up for your subject specific updates. If you haven't already, sign up here.

OCR Professional Development

Attend one of our popular professional development courses to hear directly from a senior assessor or drop in to a Q&A session. Most of our courses are delivered live via an online platform, so you can attend from any location.

Please find details for all our courses for your subject on **Teach Cambridge**. You'll also find links to our online courses on NEA marking and support.

Signed up for ExamBuilder?

ExamBuilder is a free test-building platform, providing unlimited users exclusively for staff at OCR centres with an Interchange account.

Choose from a large bank of questions to build personalised tests and custom mark schemes, with the option to add custom cover pages to simulate real examinations. You can also edit and download complete past papers.

Find out more.

Active Results

Review students' exam performance with our free online results analysis tool. It is available for all GCSEs, AS and A Levels and Cambridge Nationals (examined units only).

Find out more.

You will need an Interchange account to access our digital products. If you do not have an Interchange account please contact your centre administrator (usually the Exams Officer) to request a username, or nominate an existing Interchange user in your department.

Need to get in touch?

If you ever have any questions about OCR qualifications or services (including administration, logistics and teaching) please feel free to get in touch with our customer support centre.

Call us on
01223 553998

Alternatively, you can email us on
support@ocr.org.uk

For more information visit

- **ocr.org.uk/qualifications/resource-finder**
- **ocr.org.uk**
- **facebook.com/ocrexams**
- **twitter.com/ocrexams**
- **instagram.com/ocrexaminations**
- **linkedin.com/company/ocr**
- **youtube.com/ocrexams**

We really value your feedback

Click to send us an autogenerated email about this resource. Add comments if you want to. Let us know how we can improve this resource or what else you need. Your email address will not be used or shared for any marketing purposes.

I like this **I dislike this**

Please note – web links are correct at date of publication but other websites may change over time. If you have any problems with a link you may want to navigate to that organisation's website for a direct search.

CAMBRIDGE
UNIVERSITY PRESS & ASSESSMENT

OCR acknowledges the use of the following content: N/A