Qualification Accredited

Oxford Cambridge and RSA

Examiners' report

A LEVEL

PHYSICS A

OCR Level 3 Advanced GCE in Physics A

H556

For first teaching in 2015

H556/02 Summer 2025 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 responses 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 Teach Cambridge.

Paper 2 series overview

H556/02 is one of the three assessed components of the GCE A Level Physics A specification, 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. Section B includes short-answer style questions, two Level of Response 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.

Candidates who did well on this paper generally:	Candidates who did less well on this paper generally:
• answered all of the multiple-choice questions • showed working in calculations, allowing intermediate marks to be awarded, such as in Question 22 (c) (i) • used calculators effectively with careful consideration of unit conversions, such as in Questions 18 (d) and 22 (c) (i) • demonstrated an ability with logarithms and manipulation of exponential equations, such as in Questions 18 (e) and 19 (c) • gave suitable detail and care in responses to Level of Response questions, paying particular attention to the specifics of the question • had a clear appreciation of command words • gave appropriate use of scientific language and terms, in particular in Questions 22 (c) (ii) and 23 (d) • applied consideration of significant figures in calculations, especially in Question 21 (c) (ii).	• did not attempt all of the multiple-choice questions, and this did not appear to be a timing issue • did not show suitable working in extended calculations, such as Question 21 (c) (i), which means that it was not possible to award C marks • only gave limited detail in the Level of Response questions, such as not explaining the description of both models in Question 17 • drew a poor line of best fit in Question 23 (b) (iii), assuming that the line would pass through the false origin • chose too small a range for a gradient calculation in Question 23 (c), or just used a pair of points • were unable to differentiate terms such as precision, resolution and accuracy, especially in Question 23 (d) • did not express scientific knowledge with sufficient accuracy, such as in Question 20 (c).

Section A overview

Section A has 15 multiple-choice questions 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, particularly between the responses **B** and **D**. Space is provided on the question paper for candidates' working if necessary, and they may annotate text or diagrams if it is found to be helpful. Working is not considered in the marking of the response, so candidates may make use of any notation or shortcuts to reach their answer.

Question 1

1 Which component of a gamma camera absorbs gamma rays and produces visible light?

A collimator

B computer

C photomultiplier tube

D scintillator

Your answer ☐

[1]

The majority of candidates were able to correctly recall the correct component. **A** proved a common distractor.

Question 2

2 What is a reasonable estimate for the diameter of an atom?

A 10^{-15} m

B 10^{-12} m

C 10^{-10} m

D 10^{-7} m

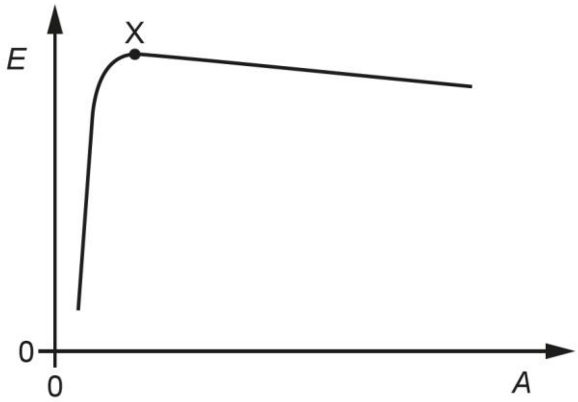
Your answer ☐

[1]

Only a few candidates were able to correctly identify the estimate for the diameter. Section 2.1.1 (b) of the specification requires candidates to be able to make estimates of physical quantities. **B** was the most common incorrect answer.

Question 3

3 The graph below shows the binding energy per nucleon, *E*, for nuclei of different nucleon number, *A*.



Which of the following statement(s) correctly describe nuclear processes?

1 Fission of nuclei to the right of X releases energy
2 Fusion of nuclei to the left of X releases energy
3 Fission of nuclei to the right of X can happen spontaneously

A Only 1

B Only 2

C Only 2 and 3

D 1, 2 and 3

Your answer

[1]

Most candidates were able to select the correct combination. Working by candidates often indicated that they knew that 1 and 2 were correct and so the only correct combination would be response **D**.

Question 4

4 The current in a copper wire of radius 2.5×10^{-4} m is 1.4A.

The number density of charge carriers (electrons) in copper is $8.5 \times 10^{28}\,\text{m}^3$.

What is the mean drift velocity of the electrons in the wire?

A $2.1 \times 10^{-4}\,\text{mm s}^{-1}$

B $0.13\,\text{mm s}^{-1}$

C $0.52\,\text{mm s}^{-1}$

D $1.9\,\text{mm s}^{-1}$

Your answer ☐

[1]

This relatively straightforward calculation, with no difficult unit conversions, was correctly answered by many candidates. The calculation does involve calculating the cross-sectional area, and many candidates showed this in working at the side, to support their calculation.

Question 5

5 An isotope has a half-life of 243 years.

One sample of this isotope has activity A_1.
A second sample of the same isotope has activity A_2.

What is the ratio: $\dfrac{\text{mass of isotope in first sample}}{\text{mass of isotope in second sample}}$?

A $243\,\dfrac{A_1}{A_2}$

B $\dfrac{A_1}{243}$

C $\dfrac{A_1}{A_2}$

D $\dfrac{A_2}{243}$

Your answer ☐

[1]

Most candidates were able to correctly identify the ratio. Many candidates worked the answer from first principles, clearly showing that the factor 243 would cancel in their calculation.

Question 6

6 A student wants to determine the count-rate from a **beta-emitting** source in the laboratory.

Which procedure would be the best to determine the count-rate?

A Measure the counts over a long period of time

B Place the radiation detector (Geiger tube) about 1 metre away from the source

C Place the source close to a very strong magnet

D Place the source inside a lead box when measuring the counts

Your answer ☐

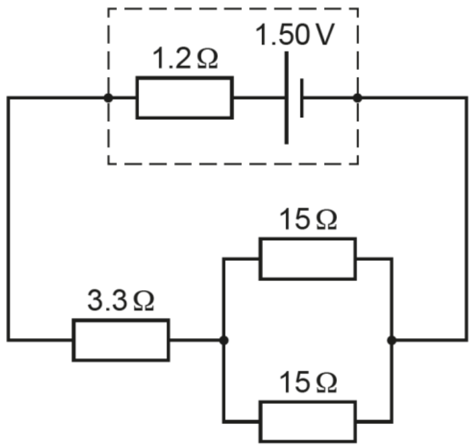
[1]

Correctly identifying the best procedure proved challenging for candidates. Many incorrect responses were given as **B.**

Question 7

7 A cell has electromotive force (e.m.f.) 1.50 V and internal resistance 1.2 Ω. It is connected in a circuit as shown below.

What is the terminal potential difference (p.d.) of the cell in this circuit?



A 0.15 V

B 1.35 V

C 1.50 V

D 1.65 V

Your answer

[1]

Most candidates were able to correctly identify the terminal p.d. Notably, many answers which did not show the correct response showed no, or little relevant, working.. Some candidates chose **D**, possibly showing an issue understanding of the relationship between e.m.f. and terminal p.d..

Question 8

8 A student uses a tube closed at one end to determine the speed of sound. A stationary wave is formed within the tube.

Which of the following quantities can be used to determine the speed of sound in air?

A length of air column in tube, number of antinodes

B length of air column in tube, resonant frequency

C number of nodes, number of antinodes

D number of nodes, resonant frequency

Your answer ☐

[1]

Most candidates gave the correct response. Many candidates drew helpful diagrams of a standing wave in a tube to help them identify relevant quantities.

Question 9

9 The radius R of the nucleus of an unknown isotope with nucleon number is calculated using the formula

$R = r_0A^{1/3}$, where r_0 is a constant.

The percentage uncertainty in r_0 is ±5%.

The percentage uncertainty in A is ±3%.

What is the percentage uncertainty in R?

A ±2%

B ±4%

C ±6%

D ±8%

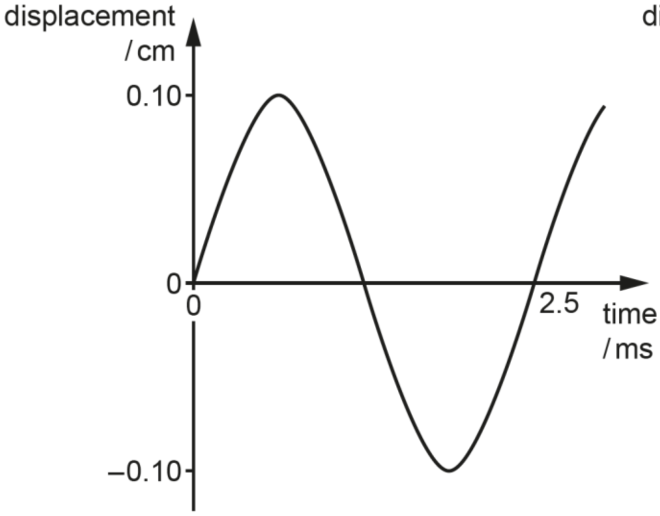
Your answer ☐

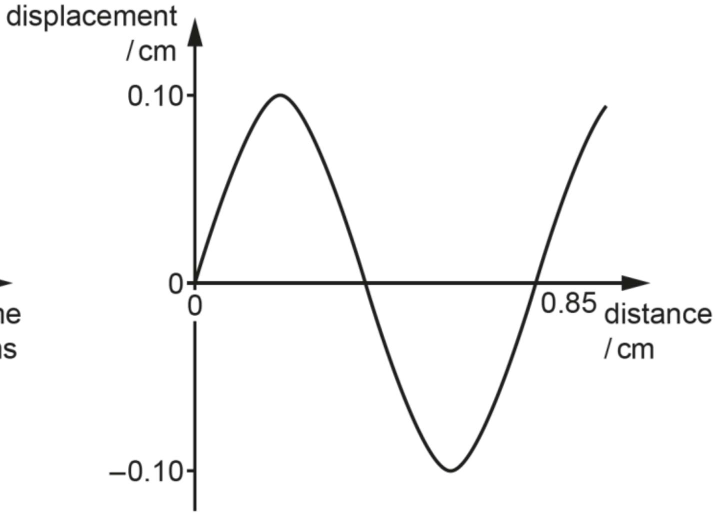
[1]

Most candidates were able to calculate the correct percentage uncertainty even though uncertainty questions can be challenging. Response **D** was the most common incorrect response.

Question 10

10 The diagrams show representations of a progressive wave.





Which row of the table correctly identifies its properties?

	Amplitude / cm	Frequency / Hz
A	0.10	400
B	0.85	2500
C	0.85	400
D	0.10	2500

Your answer

[1]

This relatively straightforward property of wave question was accessible to most candidates, with almost all candidates obtaining the correct answer. Candidates quite often cross incorrect responses and many put a cross against response **B** and **C**, as the correct amplitude was relatively simple to identify.

Question 11

11 A proton with kinetic energy 1.6×10^{-17} J is travelling at right angles to a magnetic field. The magnetic flux density is 0.050 T.

What is the magnitude of the force on the proton?

A 8.0×10^{-19} N

B 1.1×10^{-15} N

C 2.8×10^{-6} N

D 6900 N

Your answer ☐

[1]

Many candidates were able to correctly complete this two-stage calculation. Most candidates showed clear working although several attempted to use a centripetal force equation. Many of the candidates who did not select the correct response did set up the equations correctly but seemed unable to recall the charge on the proton.

Question 12

12 The intensity of the Sun's radiation at the surface of the Earth is 1400 W m^{-2}.

The distance between the centre of the Sun and the surface of the Earth is 1.5×10^{8} km.

How much mass is converted into radiant energy in the Sun in one second?

A 3.5×10^{8} kg

B 1.1×10^{9} kg

C 4.4×10^{9} kg

D 1.3×10^{18} kg

Your answer ☐

[1]

A little under half of candidates were able to correctly calculate the mass. While many were able to appreciate that $I = \frac{P}{A}$ should be used, it was common not to be able to correctly calculate the area. **A** was the most popular incorrect response.

Question 13

13 Some physical quantities are scalars and some are vectors.

Which row of the table is correct?

	Vector	Scalar
A	Current	Electric field strength
B	Power	Electric potential
C	Electric field strength	Current
D	Electric potential	Power

Your answer ☐

[1]

This was a challenging question. As is common in this style of question, candidates tick and cross those they know to be correct (or incorrect) but the inclusion of potential and field strength clearly made this more challenging. **D** was by far the most common incorrect response as candidates seemed to know that power was a scalar.

Question 14

14 Many types of charged particles can be created in particle accelerators.

The charge on an unknown particle is measured in four different experiments.

Which experimental result for the charge on the particle is impossible?

A 1.6×10^{-19} C

B 2.1×10^{-19} C

C 6.4×10^{-19} C

D 9.6×10^{-19} C

Your answer ☐

[1]

Most candidates appreciated that the change should be a multiple of the elementary charge and many were able to calculate the correct response. **D** was the most common incorrect response.

Question 15

15 Ultrasound scanning uses waves of a particular type and frequency.

Which row of the table is correct for these waves?

	Type	Frequency range
A	Longitudinal	Up to 20 kHz
B	Longitudinal	Above 20 kHz
C	Transverse	Up to 20 kHz
D	Transverse	Above 20 kHz

Your answer ☐

[1]

Many candidates were able to correctly identify the pair. The most common incorrect response was **D** which suggested that there is uncertainty between which type of wave ultrasound is.

Section B overview

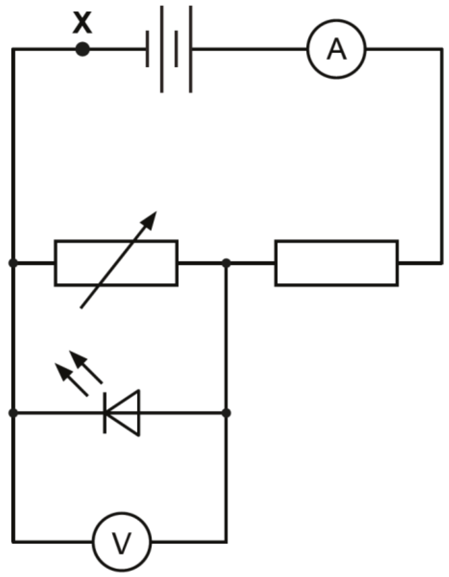
Section B consists of 8 short-answer style questions containing problem solving, calculations and practical style questions; it also includes two Level of Response questions each of has a maximum of 6 marks. This section is worth a total of 85 marks and candidates are expected to spend about 1 hour 45 minutes on this.

There was no evidence of candidates having time issues on this paper; while there were a very small number of questions not answered by some candidates, these tended to be on the more challenging questions and were spread throughout the paper.

Question 16 (a)

16 A student is investigating the behaviour of a light-emitting diode (LED).

They use the circuit below to determine the lowest potential difference (p.d.) at which the LED lights.



(a) State the name of the circuit arrangement of the battery, variable resistor and resistor in this circuit.

.... **[1]**

The anticipated response was potential divider. However, many candidates gave the response series, which is also correct. Common incorrect responses were ‘potentiometer’ and ‘parallel’, presumably thinking of the variable resistor and diode combination.

Question 16 (b)

(b) Draw an arrow on the circuit to show the direction of conventional current. **[1]**

The vast majority of candidates were able to correctly identify the direction. This was indicated in many ways, from a single arrow on a point on the circuit, to multiple loops around each separate part. Few candidates did not attempt this, which may be due to missing the question rather than a lack of understanding. Candidates are encouraged to take care to look for questions where there is no clear answer space.

Question 16 (c)

(c) State how the readings on the ammeter and the voltmeter change when the resistance of the variable resistor is increased.

Ammeter reading ....

Voltmeter reading .... **[2]**

Most candidates were able to appreciate that the voltmeter reading would increase while carrying out the described investigation. Many scripts stated that the ammeter reading would stay the same. A few attempted to justify this (although it was not required) by quoting Kirchhoff's 1st law and stating that current remained the same in a circuit.

Question 16 (d)

(d) The LED is made from two semiconducting materials.

Compare the number density of charge carriers in semiconductors, metals and insulators.

....

....

.... **[2]**

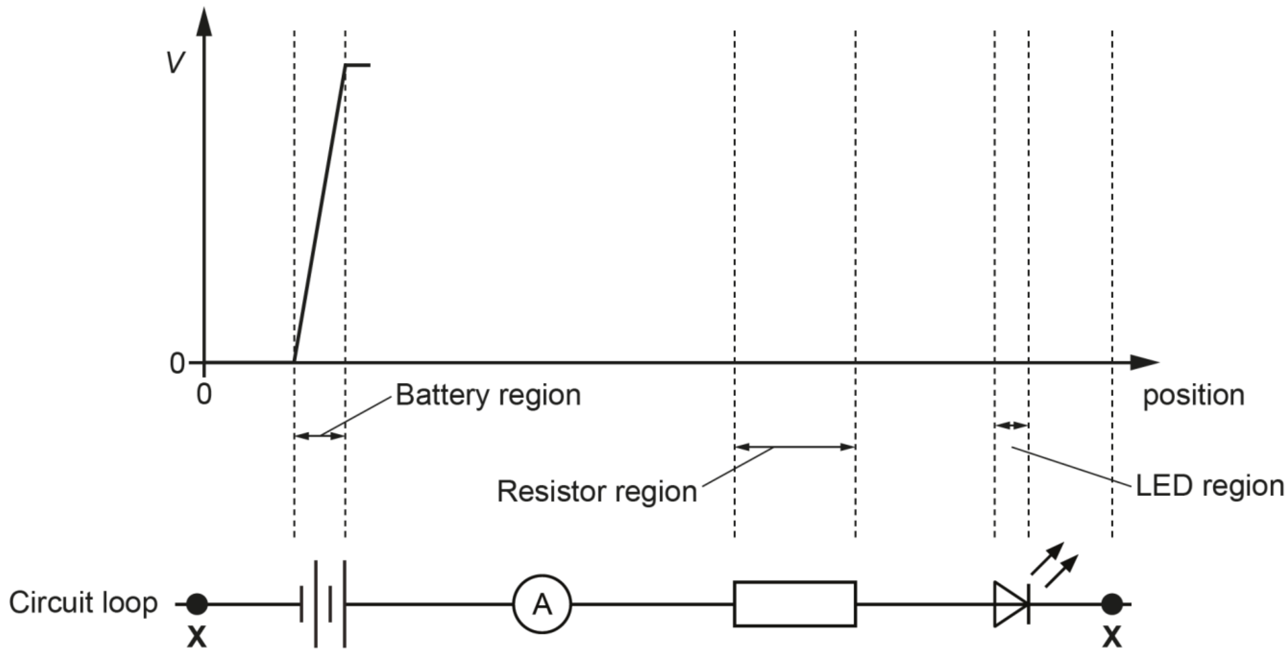
Most candidates were able to appreciate the order of number density of charge carriers. Many candidates gave numerical values to support their answer, although this was not required, and in many cases their values were accurate. Candidates should be encouraged to use comparative terms (highest, higher) rather than simple stating that values are high, as this can lead to ambiguity.

Question 16 (e)

(e) This question is about a clockwise circuit loop starting at **X**.

This loop is shown beneath the graph.

Assume the battery has negligible internal resistance. The resistance of the ammeter is also negligible.



On the axes above this loop, complete the graph to show the variation of the potential difference V relative to the point **X** with the position along this loop. **[4]**

This is a novel way of showing how the potential difference varies across components in a circuit. Many candidates were able to score all 4 marks. Common incorrect responses included having sudden jumps at the start or end of a component, having significant falling p.d. across wires, and most commonly having a non-zero p.d. after the diode. Several candidates showed a rising p.d. at some points, demonstrating a lack of appreciation of what p.d. represents in a circuit.

Question 17*

17* 'Wave-particle duality' refers to the idea that:

- particles, such as electrons, can show behaviour characteristic of waves
- waves, such as visible light, can show behaviour characteristic of particles.

Describe each model.

Describe the experimental evidence that justifies the model.

You do **not** need to describe in detail how the experiments are carried out. **[6]**

This Level of Response question was designed to assess the candidates' knowledge of various aspects of wave-particle duality, in particular each model and experimental evidence.

The key points in the description that examiners were looking for were:

- a description of a model of how particles can be described as waves, and some experimental evidece to support this
- a description of how waves can be described as particles, and some experimental evidence to support this.

To obtain Level 3, it is important that all four aspects of this are approached.

For the most part, it was clear that candidates had a general knowledge of this topic. Many were able to give some descriptions of electron diffraction and 'the gold leaf experiment', but not all gave sufficient detail in terms of the requirements of the question. Although not always required, it would be expected that candidates may use an equation in their description (the de Broglie relationship and $E = hf$) to support how the particle can be considered to act as a wave, and vice versa. More successful candidates used this in conjunction with the experimental evidence to draw their conclusions. The most common experimental evidence, which could achieve Level 3 if approached correctly, were electron diffraction through graphite and some form of the photoelectric effect.

Anticipated detail for experimental evidence would be to explain how a diffraction pattern leads to the idea of waves, and with the idea of a threshold frequency. These can only be explained by use of the correct model and would support the response.

Common weak points were to describe the electrons passing through a double slit, describing the interference pattern as fringes rather than concentric rings and explaining the photoelectric effect theoretically without any evidence. The question stated that there was no requirement to explain the experimental detail (as evidence was required) but several candidates used time doing so. Using the gold leaf electroscope (which many candidates had seen) is a good way to demonstrate the photoelectric effect, however there seemed to be some confusion about whether it was initially charged, and if so whether it was positive or negative, The statement 'one to one interaction' was common, although was often used without support and it was clearly something that had been learnt.

Most candidates used the space, including the additional space, to answer this question. It is always possible to obtain a Level 3 in the given space by carefully answering the question rather than giving superfluous information and candidates are encouraged to think a little about their response before starting.

Exemplar 1

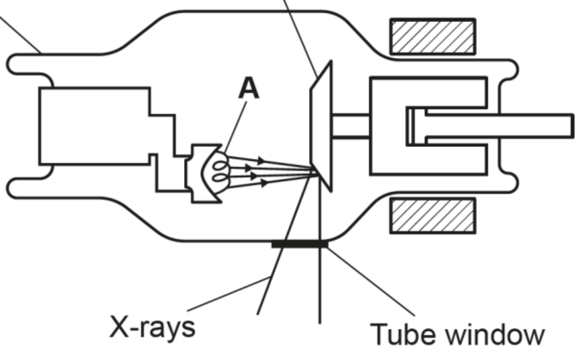
Electrons can be shown to act as particles as they have a mass and can be affected by electrical fields. In a electron gun they can show wave properties as they are fired at high speeds at a crystal and they will diffract through the gaps in the lattice. The electrons will also show interfance patterns, both of which are wave characteristics. Light can also be diffracted in a similar way showing its wave properties, however, during the photoelectric effect photons to photoelectrons are a one to one conversion impling a single photon must be incident for a single electron to be emitted. As a single photon is possible this shows particle characterits as waves cannot be a single amount.

This exemplar shows a good response, but not sufficient to reach Level 3. The candidate has given a fair, yet brief, description of the experimental evidence for electron diffraction, showing particles acting as waves. Similarly, the photoelectric effect is explained to some level of detail about how it demonstrates where a wave acts like a particle. There is little in terms of the descriptions of the model in either of these. There is a reference to diffraction for the wave model and use of the term 'photon' for the particle model. Considering the level guidance, this has some description of both model and experimental evidence so falls into Level 2. The experimental evidence has some valid details, so can be awarded the top of this level, 4 marks.

Question 18 (a)

18 X-rays are used for diagnostic imaging in a hospital.

The diagram shows the structure of an X-ray tube.



(a) Name the component labelled **A** on the diagram.

.... **[1]**

Component **A** can correctly be described by several terms, although cathode is the most appropriate. Several candidates called the component a coil, which is more a description. 'Electron emitter' and 'thermionic emitter' similarly describe its function rather than name it.

Question 18 (b)

(b) Suggest why the anode is made to rotate.

.... **[1]**

The main point of the rotation is to avoid overheating and so any statement about the heating of the anode would score a mark here. There were several vague responses to do with the anode wearing out and the electrons hitting evenly, in additional to a common response about the anode becoming negatively charged. The command word 'suggest' implies that candidates should use their knowledge to draw a possible conclusion. Only a few candidates did not attempt this question.

Question 18 (c)

(c) X-rays are produced at characteristic wavelengths which depend on the material of the anode.

Describe how the electrons from component **A** are responsible for producing X-rays.

....

....

.... **[2]**

There are two possible ways to answer this question, and most candidates chose to follow only one. The first method is to describe the production of characteristic X-rays. Many candidates explained this in terms of excitation and de-excitation rather than removal of the electrons and vacancy filling. The alternative way is to describe the production of bremsstrahlung, via slowing down and loss of kinetic energy. Detail is required in this response, such as where the deceleration occurs. Overall, it was clear that the candidates had a general understanding of one of these processes.

Question 18 (d)

(d) An electron strikes the anode. The kinetic energy of the electron changes from 150 keV to 60 keV.

Calculate the minimum wavelength, λ, of the X-ray photon emitted by the interaction of the electron with the anode.

λ = ... m **[3]**

This two-step calculation was correctly carried out by nearly three quarters of candidates. Most appreciated that the change in kinetic energy was needed, and so correctly determined 90 keV as the required energy and were able to use this in determining the wavelength. Few candidates determined the frequency first and then went on to calculate the wavelength separately. Common errors included missing that the photon energy was in keV, rather than eV, and using the wrong energy. A mark was available for correct conversion of either 150 keV or 60 keV to joules, but there could be no further credit.

Question 18 (e)

(e) A radiologist targets a uniform beam of X-rays at a tumour 4.6 cm below the skin of a patient. The beam is at right angles to the surface of the skin.

The intensity of the X-ray beam at the tumour is 30% of the incident intensity.

Calculate the attenuation coefficient, μ, of the tumour tissue in cm^{-1}.

μ = ... cm^{-1} **[2]**

This calculation was correctly done by many candidates. The ability to manipulate the exponential and take logs caused few difficulties and candidates set out the working carefully and clearly for the most part. Several candidates tried to use a value of 70%, which could not score any marks. There was occasional confusion over the units, with candidates attempting to move in or out of cm to m.

Question 19 (a)

19
(a) Describe the difference between hadrons and leptons.

....

....

.... **[2]**

The two main answers to this were either in terms of the strong force, or in terms of the composition. Several candidates gave both of these, although a wrong answer could negate a correct one. Responses in terms of mass, charge, location, etc were ignored. A few candidates confused leptons for baryons and stated that they were formed from a quark and an antiquark

Question 19 (b)

(b) An 'up' quark decays according to the equation below.

$$u \rightarrow d + {}^{0}_{+1}e + \nu$$

Give the name(s) of the lepton(s) in this equation.

.... **[1]**

Most candidates were able to correct name both leptons. A significant number called the positron an electron, and many incorrect answers only gave one particle. A small number gave the symbols which would not score the mark.

Question 19 (c)

(c) The above decay takes place within a nucleus of carbon-11. The half-life of this isotope of carbon is 1220 s.

A sample of carbon-11 has an activity of 800 Bq.

Calculate the activity, *A*, of this sample of carbon-11 after 5.0 minutes.

A = ... Bq **[3]**

The majority of the candidates were correctly able to calculate the activity. Setting out of the working was helpful to the candidates, especially with a separate calculation of the decay constant. There was little confusion over time units, and most candidate chose to work in seconds. The data is given to 2 significant figures and the expected answer should be correct to 2 significant figures also (670 Bq). With some intermediate rounding, several candidates ended up at 680 Bq which will lose the final mark. Candidate are encouraged to store any intermediate calculations in calculator memory to maintain the full significant figures.

Question 19 (d)

(d) The particle with symbol ${}^{0}_{+1}e$ can annihilate with its anti-particle.

Describe a practical use of this process in medical imaging.

....

....

....

....

....

.... **[4]**

Most candidates appreciated that the use required in this question was a PET scanner, although a small number incorrectly called it a CAT scanner. The general principles were given, but detail is required for clarity. Such as, there need to be **two** gamma photons, they need to travel in **opposite** (not different) directions and the time delay needs to be recorded at the detector. There was some confusion that the positron-electron pair were being detected.

Question 20 (a)

20 Superposition is a characteristic property of waves.

(a) Draw a diagram in the space below to show how superposition between two waves can cause destructive interference.

[2]

This question required the drawing of two transverse waves in antiphase, and a resultant shown with zero amplitude. Examiners need to use their professional judgement regarding the clarity of the diagrams and so annotations can help. Several candidates stated, but did not draw, the resultant and so could not be awarded the second mark. Some candidates drew the initial waves with different amplitudes and it was acceptable to draw a non-zero resultant, as long as it demonstrated destructive interference. A few candidates drew interference from circular wavefronts, but this was very unlikely to be awarded any marks.

Question 20 (b) (i)

(b) In an experiment to determine the wavelength λ of red light, a laser is placed in front of a double slit. The red light from the laser is incident normally at the double slits. Equally spaced light and dark fringes are visible on a distant screen.

The distance between the double slits is d and the distance between the slits and the screen is D.

A diagram of the apparatus is shown below.

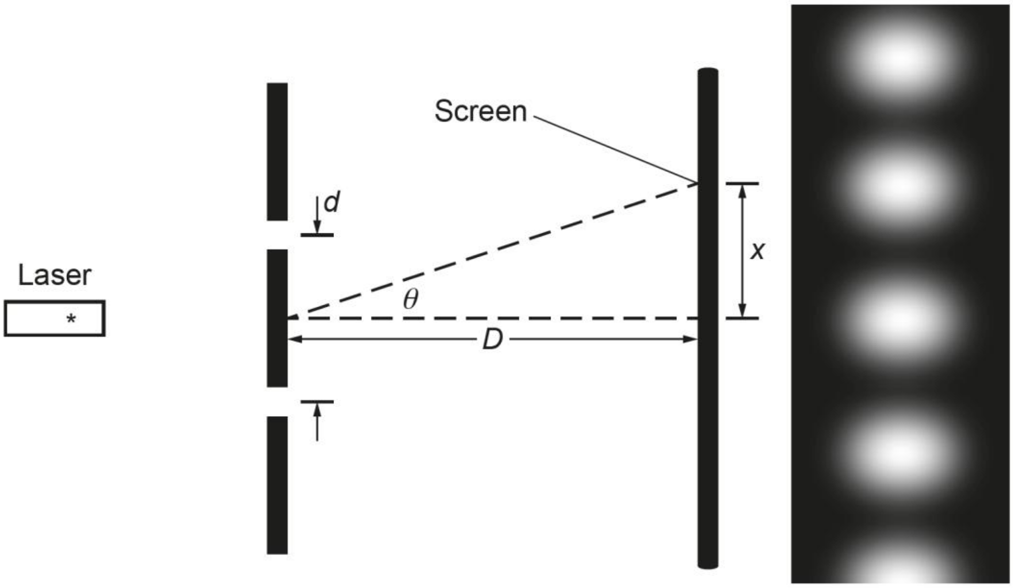


diagram not to scale

(i) Show that the fringe spacing, x, is approximately

$$x \approx \frac{D\lambda}{d}$$

State clearly any approximations you make.

Approximations .... **[3]**

This was a challenging question, using mathematical skills and requiring candidates to apply two equations, one based on path difference and one of geometry and equate them. This is demonstrated in the exemplar that follows.

The most common issue was a misapplication of geometry. The small angle approximation needed to be applied and a statement of how this was used was necessary for the approximation mark. Few candidates attempted to use Pythagoras to different degrees of success but often found the approximation difficult to express.

Exemplar 2

State clearly any approximations you make.

$d\sin\theta = n\lambda$

$n = 1$

~~dsinλ~~ $d\sin\theta = \lambda$

↓

as θ is very small

$\therefore d\theta \approx \lambda$

$\therefore \theta \approx \lambda/d$

$\tan\theta = \frac{x}{D}$

$\tan\theta \approx \theta$ approximation that 'θ' is very small angle

$\therefore \theta \approx \frac{x}{D}$

$\frac{x}{D} \approx \frac{\lambda}{d}$

$x \approx \frac{D\lambda}{d}$ //

Approximations .... **[3]**

This exemplar shows a candidate who has a clear understanding of this question and is able to set out their working clearly.

On the left is the diffraction equation, which can be found in the Data, Formulae and Relationships Booklet), with n = 1 clearly identified.

In the middle is the geometric expression for tan θ, and the approximation of tan θ is approximately θ This approximation is also shown in the booklet.

This is also used for the sin equation, linking the two clearly and then resulting in the required expression.

This gets all 3 marks, and it is evident that the candidate appreciates what they are doing at each stage.

Question 20 (b) (ii) (1)

(ii) Explain how the fringe pattern changes if

1 the laser emitting red light is replaced with a green laser

....

....

.... **[2]**

Most candidates were correctly able to give the required response to this question, however some stated that the wavelength of green light was larger than that of red. Symbols were accepted here, but it is always best to write the full words. Notation such as a lambda symbol followed by a downwards arrow is not sufficient to indicate the wavelength decreases. The M (method) mark for the wavelength meant that the candidates needed to make the link between wavelength and fringe separation, as this is the key point of the question. Care should be taken to distinguish between the fringe separation being narrower and the actual fringes being narrower.

Question 20 (b) (ii) (2)

2 the laser emitting red light is replaced with a white light **filament** lamp.

....

....

.... **[2]**

This question is asking about what happens to the fringes when white light from the filament lamp is used. The word filament is emboldened to emphasise that it is important. In the context of the question, as the light is no longer coherent, the fringes that existed with the red light will cease to be present. A fair fraction of candidates appreciated that this was the required response. Many candidates stated that there would be coloured fringes or 'a rainbow'.

Question 20 (c)

(c) Visible light can be plane polarised.

Explain why sound waves cannot be plane polarised.

....

....

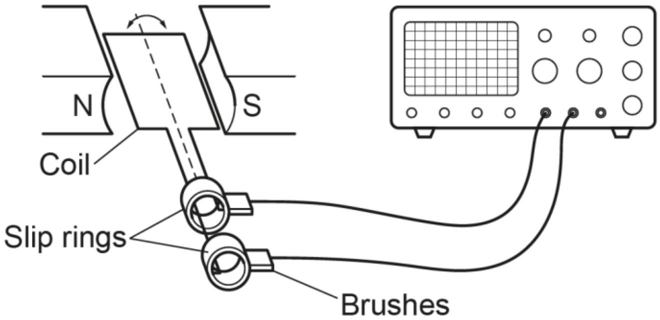
....

.... **[3]**

Few candidates were able to clearly explain polarisation in terms of oscillation, however most candidates knew that sound waves were longitudinal and could describe this type of wave. A number of candidates used movement for oscillation and this is not clear enough.

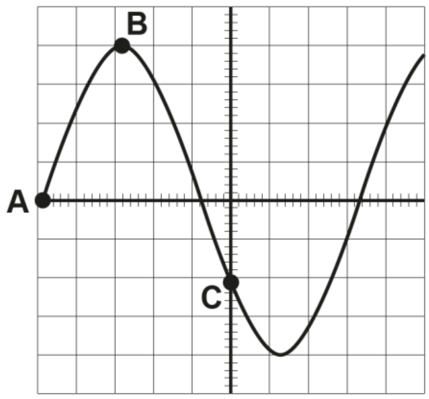
Question 21 (a)

21 The diagram shows a simple a.c. generator connected to an oscilloscope (CRO).

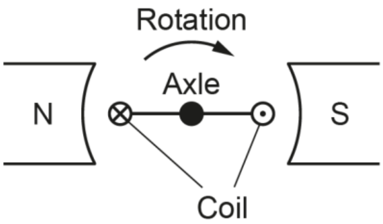


Students turn the coil at a steady rate and an a.c. signal is displayed on the oscilloscope screen, as shown in **Fig. 21.1**.

Fig. 21.1



(a) Which position on the signal, **A**, **B** or **C**, corresponds to the generator position shown below?



view from end of coil

Tick **one** box.

A	
B	
C	

[1]

A very common incorrect response was **A,** presumably confusing flux linkage with induced e.m.f.

Question 21 (b)

(b) Draw on **Fig. 21.1** to show how the signal would change if the coil is rotated at a steady, faster rate. **[2]**

The vast majority of candidates appreciated that an increased frequency results in a reduced time period and were able to show this on the graph. Not all were able to show a constant (reduced) time period, although this was not required on this occasion. Fewer candidates appreciated that the increased rate of change of flux linkage would produce a greater e.m.f. and drew the amplitude of the wave higher. The quality of wave drawing was not always good and care should be taken to aim to keep a consistent amplitude and time period in this sketch.

Question 21 (c) (i)

(c) The coil is rotated 45° clockwise from the position shown in **(a)** in a time of 0.13 s.
The magnetic field between the poles of the magnet is uniform and is 25 mT.
The coil has 120 turns.
The coil is 8.0×10^{-2} m long and 4.0×10^{-2} m wide.

(i) Calculate the change in flux linkage.

Change in flux linkage = ... Wb **[2]**

The terms flux and flux linkage can clearly be confused by candidates and they are often incorrectly interchanged. Many candidates simply calculated the flux. There were a significant number who calculated the area incorrectly, usually considering the appropriate area to be a circle. Several candidates attempted to calculate a change between two different angles, which resulted in an incorrect answer.

Question 21 (c) (ii)

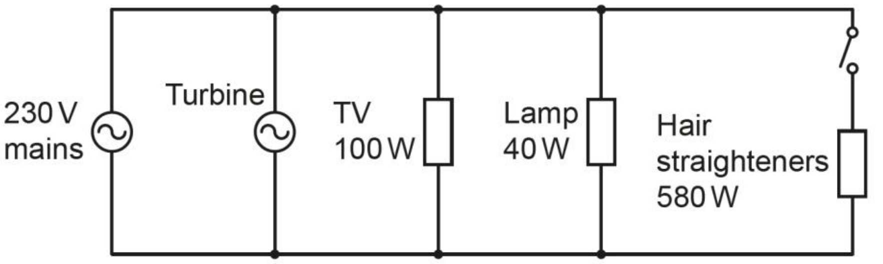
(ii) Calculate the average induced electromotive force (e.m.f.) ε across the contacts of the coil.

ε = ... V **[2]**

Those who obtained the correct response for part (c) (i) generally went on to obtain both marks in this question. Allowance of an "error carried forward" also helped many candidates, and a little over half were able to score both marks. Many candidates rounded their answer to 1 significant figure, thereby losing a mark. Candidates should always be encouraged to give their answers in keeping with the significant figures of the data provided in the question.

Question 21 (d)

(d) A larger generator is used in a wind turbine to supply electricity to a house. The house is also connected to the 230 V mains supply.



The TV and lamp are switched on.

When the turbine is providing a steady 400 W, the hair straighteners are switched on.

Calculate the current, I, drawn from the mains supply.

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

Some candidates were able to correctly calculate the current. Most incorrect answers came from adding together all the powers, including the turbine, or simply just dividing the turbine power by the mains voltage.

Question 21 (e)

(e) State the unit used to measure the electrical energy supplied to homes in the UK.

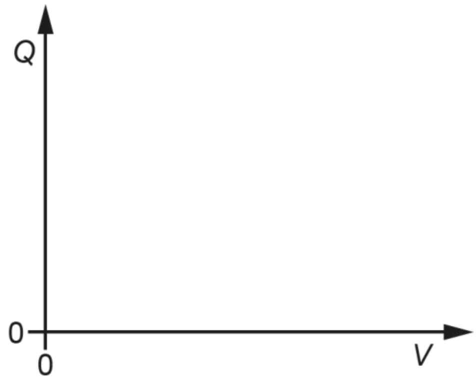
.... **[1]**

While most candidates had an awareness of the unit, some of them wrote their response as kilowatt per hour, either in words or units. Other incorrect, but not uncommon answers, were watts, joules and megawatt-hours.

Question 22 (a)

22

(a) Sketch a graph showing how the charge Q stored on a capacitor varies with the potential difference V across it.



[1]

Most candidates were able to correctly draw a straight line through the origin. It is important to draw this line with a ruler to avoid any ambiguity. The most common incorrect response was to draw a curve of decreasing gradient.

Question 22 (b)

(b) Describe how to use your graph to calculate the energy stored by the capacitor.

....

....

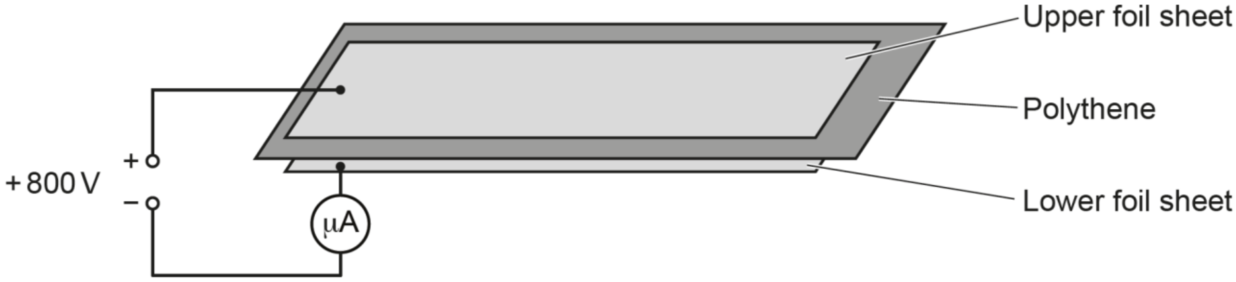
.... **[2]**

Most candidates were able to appreciate that the area under the line would produce the energy stored and that this relates to $\frac{1}{2}QV$. A reasonable number of candidates attempted to use the gradient in their explanation either by using it as a capacitance, or simply considering it was the energy stored.

Question 22 (c) (i)

(c) A teacher has built a model capacitor using sheets of aluminium and polythene. They use the model capacitor to measure the thickness of the polythene.

The foil sheets are rectangular, 30 cm wide and 50 cm long. The polythene sheet is larger to avoid the edges of the foil coming into contact with each other.



The power supply is switched on. The model capacitor is charged to 800 V in a time of 1.8 s.

The average current from the power supply during this time is 2.6 μA.

The polythene has relative permittivity 2.3.

(i) Calculate the thickness, *d*, of the polythene in mm.

d = ... mm **[3]**

Just under half of candidates were able to calculate the thickness correctly. The most common way was to calculate the capacitance and then use the parallel plate capacitor formula. This allowed clarity in setting up the calculation and generally resulted in the correct answer. Several candidates attempted to carry out the calculation in one go. This often resulted in an error, such as using 2.3 in place of the actual permittivity of the polythene. Another common error was to use the formula for the capacitance for a sphere. There seemed to be little difficulty in converting all the units correctly, either in the initial calculation or by converting to mm at the end. As always with this type of calculation, structuring it carefully allows for intermediate marks to be awarded should the final answer be incorrect.

Exemplar 3

(i) Calculate the thickness, *d*, of the polythene in mm.

$\varepsilon = 2.3$

$I = 2.6 \times 10^{-6}$

$V = 800$

$t = 1.8$

$A = 0.15$ m

$C = \frac{Q}{V}$

$C = \frac{\varepsilon_0 A}{d}$

$d = \frac{\varepsilon_0 A}{C} = \frac{((8.85 \times 10^{-12}) \times 2.3) \times \left(\frac{30 \times 50}{100}\right)}{4.68 \times 10^{-6} \div 800} = 0.2269$ mm

$Q = 1.8 \times 2.6 \times 10^{-6}$

$= 4.68 \times 10^{-6}$

$d = 0.23$ .... mm **[3]**

This exemplar shows how clear and careful setting out of a calculation can lead to C (compensatory) marks. This candidate has shown the working for (and then calculated) the charge, Q, separately on the top of the right-hand side. This gains the first mark. The candidate has then re-arranged the equation in the centre, with the capacitance in the denominator. The calculation for the capacitance is clearly shown ($4.68 \times 10^{-6} \div 800$) which is all that is required for the second C mark. It is almost always the working that gains the C mark, not the evaluation. The evaluation is required for the A (accuracy or answer) mark, and in this case there is an error leading to an incorrect final answer. However, this good structuring of the solution leads to 2 out of the 3 marks.

Question 22 (c) (ii)

(ii) Suggest how the experiment should be carried out in order to get a set of accurate and precise results.

....

....

....

....

.... **[3]**

This question was specific in asking for accuracy and precision. Most candidates only addressed one of these aspects of the question. A simple repeat and average was not considered to be of sufficient detail. A change to the experiment was required, such as using a higher voltage. Many candidates made sensible alterations, for example adding a series resistor to increase the time as 1.8 s is relatively short. Questions of this style are often challenging for candidates; however a fair number were able to obtain 2 or more marks.

Question 22 (d)*

(d)* A student creates a spreadsheet to model the discharge of a different capacitor through a resistor.

Fig. 22.1a shows part of the spreadsheet and some important values used in the modelling process.

Fig. 22.1a

	A	B	C
1	t / s	Q / μC	ΔQ / μC
2	0.0	200.00	−9.67
3	0.5	190.33	−9.20
4	1.0	128.03	−8.76
5	1.5	121.84	−8.33
6	2.0	115.94	−7.93
7	2.5	110.34	−7.55
8	3.0	148.55	−7.18
9	3.5	141.37	−6.84
10	4.0	134.53	−6.51
11	4.5	128.03	−6.19
12	5.0	121.84	−5.89
13	5.5	115.94	−5.61
14	6.0	110.34	−5.34
15			
16			
17			
18			
19			
20			
21			

time interval, Δt = 0.5 s

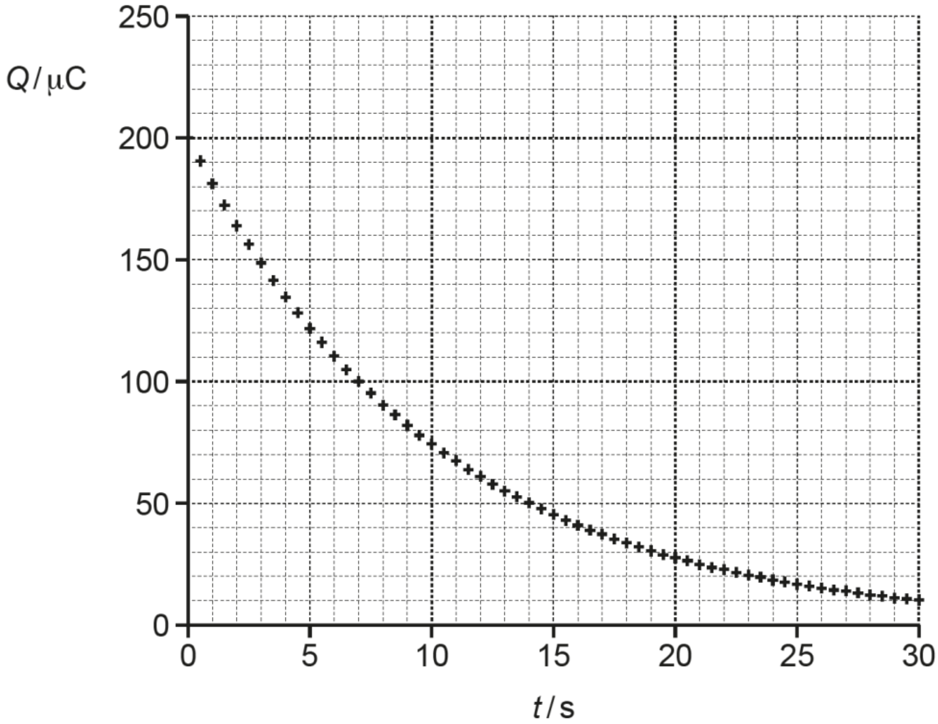
initial charge, Q_0 = 200 μC

capacitance of capacitor, C = 22 μF

resistance of resistor, R = 470 kΩ

Fig. 22.1b shows a plot of the values of t and Q from the spreadsheet.

Fig. 22.1b



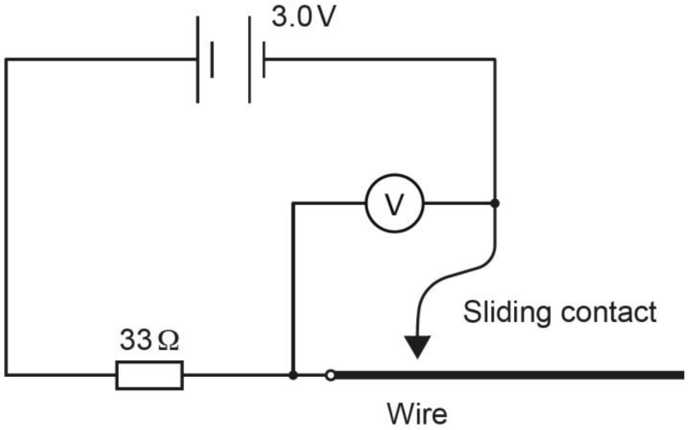
Use the data in **Fig. 22.1a** and **Fig. 22.1b** to describe how the student

- would calculate the values in columns **A**, **B** and **C** in the spreadsheet
- could confirm by calculation that the spreadsheet correctly models the discharge of the real capacitor. **[6]**

There was an error with this question which affected the candidates' ability to answer it. To make sure all candidates were treated fairly, we have awarded full marks to all candidates for this question.

Question 23 (a)

23 A student is investigating the resistance of a metal wire using the circuit shown below.



The battery has electromotive force (e.m.f.) 3.0 V and negligible internal resistance.

(a) Show that the resistance, R, of a length of this wire in terms of the p.d. across it, V, is given by the expression $R = \frac{33\,V}{3.0 - V}$.

[2]

This was a challenging question and depended on the candidate's choice of starting point. The simplest approach was to consider ratios of resistances and voltages, as long as numerical values were placed where appropriate. A majority of candidates used the potential divider as a starting point but this required a little more algebraic manipulation, as did starting with a current calculation. For the most part this calculation was completed well, although some candidates clearly could go no further with their algebra and just wrote the given expression. As always with a 'show that' question, it is very important to clearly show each stage.

Question 23 (b) (i)

(b) The student records the voltmeter reading *V* for different lengths *l* of the wire. The resistance of the wire is *R*.

***l*/cm**	***V*/mV**	***R*/Ω**
40	320	3.94
50	390	
60	456	5.92
70	519	
80	579	7.89

(i) Use the expression given in **(a)** to complete the two missing *R* values in the table. **[2]**

The vast majority of candidates were able to calculate the two numbers correctly and gave them to the required 2 decimal places. A small number of candidates calculated to the second number incorrectly (for some unknown reason).

Question 23 (b) (ii)

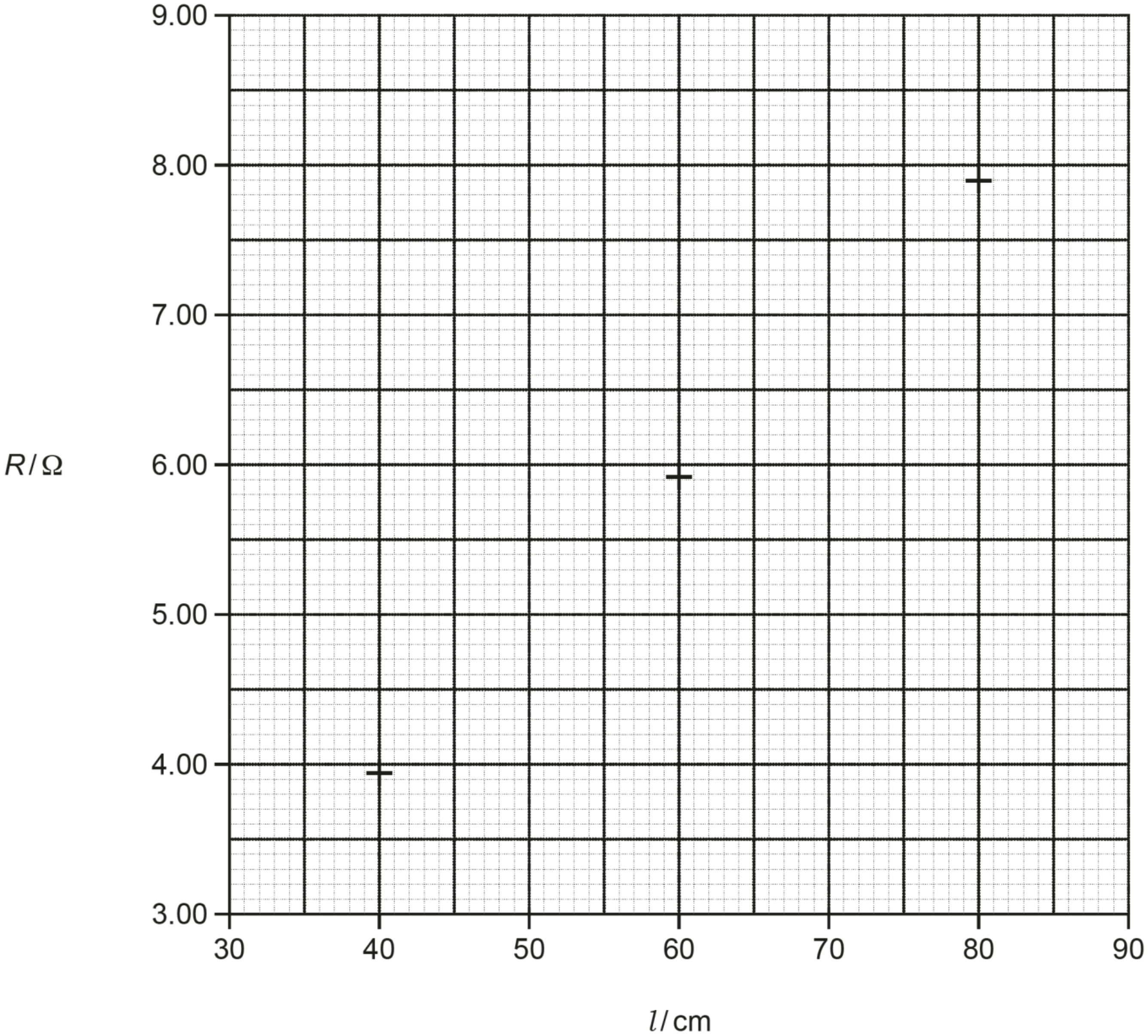
(ii) The axes below show a plot of *R* against *l*.
Three points from the table have already been plotted.

Plot the remaining points. **[1]**

The two calculated points, if calculated correctly, should lie pretty much on the straight line and therefore be relatively easy to plot within the usual tolerance of half of a small square. Almost all candidates plotted these correctly and the most common error was a mis-plot of the lower point.

Question 23 (b) (iii)

(iii) Draw on your plot a line of best fit. **[1]**



Although the points were pretty much on a straight line, only around half of the candidates drew a suitable line of best fit. Drawing a line through the false origin would likely (but not always) mean that the line missed some of the three given points by some degree. Double lines, thick lines and disjointed lines will all likely not score this mark. Candidates are encouraged to take great care in selecting and drawing their line.

Assessment for learning

Good practice for point plotting includes:

- points should be labelled in the same way as the points already plotted – this may be a dot, cross or plus
- use a sharp pencil, with a point no thicker than the thickest line on the grid
- each point needs to be plotted as carefully as possible – the tolerance is within one half small square
- check your points again after plotting
- always check again any points which do not seem to fit the pattern – they may be anomalous, or you may have mis-plotted or miscalculated
- do not forget the (0,0) point if you have been given that as a data point.

Good practice for drawing a straight line of best fit includes:

- a single straight line – have a 30cm ruler, so that a line is not drawn in two or more parts
- use a sharp pencil – once a line is drawn in pen, it is almost impossible to correct
- aim to have an equal (or similar) number of data points above and below the line – this is not always possible due to variations in the data, but this should be a general aim
- any anomalous points should not form part of the best fit
- be aware of a false origin – if present then the line should not necessarily be expected to go through this point
- drawing a line through the origin – is it possible there is a systematic error? If so, should it pass through the origin. Was the origin a taken data point?

Question 23 (c)

(c) The wire is made of constantan which has a resistivity of $5.00 \times 10^{-7}\,\Omega\,\text{m}$.

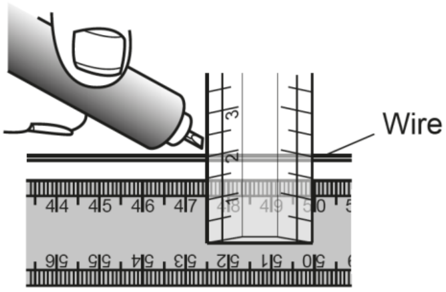
Use the gradient of the line of best fit to determine the diameter, *d*, of the wire.

d = ... m **[4]**

Two marks for this calculation were given for a correct method to calculate the gradient. The first mark is for using a pair of points – it was possible in this case to use points from the table as they lay so close to the line – however most candidate chose a pair by drawing lines on the graph. The second mark is for a sufficiently large range – at least half of the graph. Many candidates simply chose a single point or showed they had used (0,0) in their calculation, although they could not tell that it passed close to the origin. It was possible to still obtain an answer within the expected range even if a single point was used. For the most part, this calculation was done well, including the challenging area to diameter calculation. There was some occasional difficulty seen in converting the cm scale on the graph into the required m scale on the answer line. Overall, a little over half of the candidates were able to get all 4 marks.

Question 23 (d)

(d) The diagram below shows how the student uses the sliding contact to complete the circuit for a known length of wire.



Explain how this arrangement helps the student to make high-quality measurements.

....

....

....

.... **[3]**

This question required candidates to use correct terms when describing data. Answers not using these terms would not be able to score marks. Many candidates were able to use these correctly, and a good fraction were able to explain how it reduced a parallax error. The term precision was used in place of resolution on a lot of occasions and candidates are encouraged to learn the appropriate use of these terms.

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