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A LEVEL

Examiners' report

PHYSICS A

H556
For first teaching in 2015

H556/02 Summer 2019 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. 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 can be downloaded from OCR.

Paper 2 series overview

H556/02 is one of the three assessed components of GCE Physics A. The component is worth 100 marks and is split into two sections. It assesses modules 1, 2, 4 and 6 of the specification. 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 (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 forms 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 duration of the examination paper is 2 hours 15 minutes.

H556/01 Component has weighting 37%. It assesses material from modules 1, 2, 3 and 5.

H556/03 Component has weighting 26% and is synoptic. It assesses material from all modules (1 to 6).

Overview of performance

The positive attributes of the candidates in this component were:

- Answering most of the multiple choice questions and making good use of the spaces provided to do any rough analysis and calculations.
- Good use of calculators, especially handling powers of ten and logarithms.
- Well-structured solutions with clear manipulation of equations, good substitution and expressing the final answers to appropriate significant figures.
- Good comprehension of command terms such as *describe*, *explain*, *show* etc.
- Good recall of key definitions.

There were some missed opportunities in this component. Candidates are reminded that they can maximise marks in future examinations by following the advice below:

- Underline key data or terms in the text of the question which are necessary to answer the questions.
- In level of response (LoR) Questions, **16(d)** and **22(c)**, a significant number of candidates gave partial answers. This was particularly noticeable in **22(c)**, where many candidates either ignored, or gave less importance, to the variables that had to be controlled in the experiment. Those who were successful, had underlined the key terms *describe*, *relationship*, *identify*, *variables* and *control*.
- In questions requiring extended writing, candidates are allowed to use bullet points. Doing this often avoids repetition and prevents making contradictory statements.
- Make good use of technical and scientific vocabulary in descriptions and explanations.
- Do not round up, or down, numbers in the middle of long calculations. Retain all the digits on your calculator for subsequent stages of a calculation. Truncating numbers in the middle of calculations may result in the loss of marks.
- Do not spoil answers requiring knowledge of proportionality and inverse proportionality by using incorrect symbols. For example, in **22(b)(ii)**, instead of finishing the analysis off with the statement $Q \propto \frac{1}{d}$, a significant number of candidates had written $Q = \frac{1}{d}$.
- Finally, be aware of the information available on the Data, Formulae and Relationship Booklet. In some questions, you need data from this booklet. For example, in Question **19(c)**, you need the values of speed of light *c*, the Planck constant *h* and the electronvolt eV. There is no need to remember these values.

Note

From this series students have been provided with a fixed number of answer lines and an additional answer space. The additional answer space will be clearly labelled as additional and is only to be used when required. Teachers are encouraged to keep reminding students about the importance of conciseness in their answers. Please follow this link to our SIU - https://www.ocr.org.uk/administration/support-and-tools/siu/alevel-science-538595/

Section A overview

Section A has 15 multiple choice questions (MCQs) from modules 1, 2, 4 and 6.

Space is provided on the question paper for any analysis or scribbling. It is important for candidates to insert their correct response in the square box provided.

All questions showed a positive discrimination, and the less able candidates could access the easier questions. MCQs require careful inspection. Candidates are allowed to annotate text and diagrams if it helps to get to the correct answer. No detailed calculations are expected on the pages, so any shortcuts, or intuitiveness, can be employed to get to the correct answers.

Questions **1**, **2**, **3**, **4** and **8** proved to be particularly straightforward, allowing most of the candidates to demonstrate their knowledge and understanding of physics. At the opposite end, Questions **5**, **6** and **13**, proved to be more challenging, and as such, were only accessible to the top end candidates.

Question 1

1 Which law indicates that charge is conserved?

A Lenz's law

B Coulomb's law

C Kirchhoff's first law

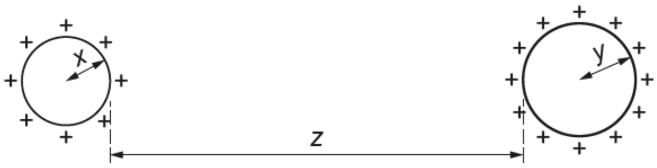
D Faraday's law of electromagnetic induction

Your answer ☐ **[1]**

This was a well-answered question with most candidates correctly recalling that charge is conserved according to Kirchhoff's first law. A significant number of candidates distracted towards **B**; perhaps because of the unit of charge is the coulomb.

Question 2

2 The diagram below shows two uniformly charged spheres separated by a large distance z.



The radius of the small sphere is x and the radius of the large sphere is y.

Which is the correct distance to use when determining the electric force between the charged spheres?

A z

B $x + z$

C $y + z$

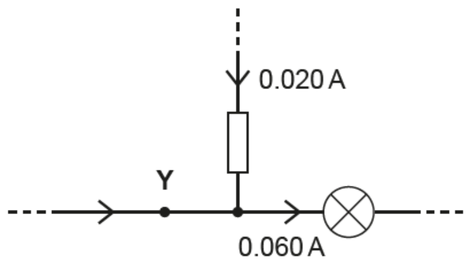
D $x + y + z$

Your answer ☐ **[1]**

This question was assessing the simple learning outcome 6.2.1b from the specification – *modelling a uniformly charged sphere as a point charge at its centre.* The correct key is **D**. The most popular distractor was **A** with distance being measured between the two surfaces of the sphere.

Question 3

3 Part of an electric circuit is shown below.



The direction of all the currents and the magnitude of two currents are shown.

How many electrons pass through the point **Y** in 10 s?

A 1.25×10^{18}

B 2.50×10^{18}

C 3.75×10^{18}

D 5.00×10^{18}

Your answer **[1]**

This was not an easy question, but most candidates did extremely well in this multi-step calculation. The directions of the currents are important. The current at **Y** and the current in the resistor, must add up to 0.060 A. The charge passing point **Y** in a time of 10 s can be calculated using $\Delta Q = I\Delta t$ and finally the number of electrons can be determined by dividing the charge passing through **Y** by the elementary charge *e*. Therefore

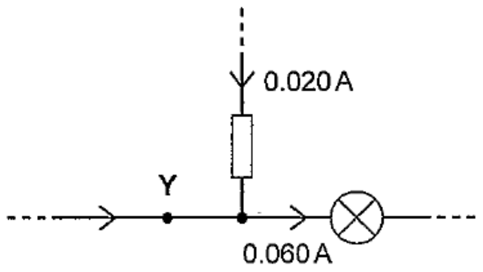
$$\text{number of electrons} = \frac{(0.060 - 0.020) \times 10}{1.60 \times 10^{-19}} = 2.50 \times 10^{18}$$

The key, correct answer, is **B**. The most popular distractor was **C**, in which a current of 0.060 A is assumed; the rest of the distractors were equally favourable. **A** was the answer for a current of 0.020 A and **D** was the answer for a current of 0.080 A. It is worth mentioning that most of the candidates just wrote down the correct answer in the box, without any calculations. On the surface, this looks reckless, but it is an excellent strategy if the numbers are being punched into the calculator correctly.

The exemplar 1 below shows a typical correct answer, with numbers jotted down for visual help.

Exemplar 1

Part of an electric circuit is shown below.



The direction of all the currents and the magnitude of two currents are shown.

How many electrons pass through the point **Y** in 10 s?

A 1.25×10^{18} 0.4

B 2.50×10^{18}

C 3.75×10^{18}

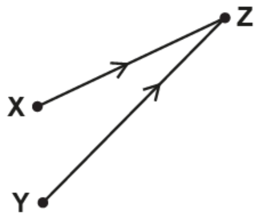
D 5.00×10^{18}

Your answer B **[1]**

The candidate has the correct current at **Y.** Without the 0.040 A, the answer would have led to one of the distractors. It is worth pointing out that the final step of the calculation must have been done directly on the calculator. An excellent time-saving approach.

Question 4

4 Coherent radio waves from transmitters **X** and **Y** are emitted in phase. The waves interfere **constructively** at point **Z**.



The distance **XZ** is 16.0 m and the distance **YZ** is 20.0 m.
The radio waves have wavelength λ.

Which value of λ is **not** possible?

A 1.0 m

B 2.0 m

C 3.0 m

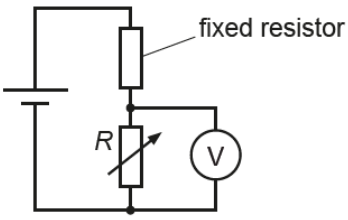
D 4.0 m

Your answer **[1]**

This question was assessing knowledge and understanding of path difference and constructive interference. The path difference is 4.0 m. With the waves in phase at **X** and **Y**, this means that the distance of 4.0 m must be equal to a multiple of wavelengths. This condition is satisfied by all but **C**. You cannot get 4.0 m by multiplying 3.0 m by an integer. The majority of the candidates effortlessly picked up 1 mark here.

Question 5

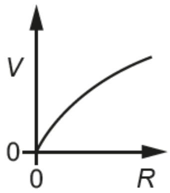
5 A potential divider circuit is shown below.



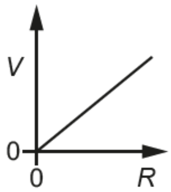
The resistance of the variable resistor is R. The potential difference across the variable resistor is V.

Which graph shows the correct variation with R of V?

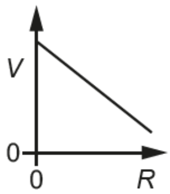
A



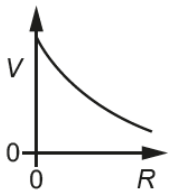
B



C



D



Your answer **[1]**

This is a question on a potential divider circuit and a sketch of the correct *V*-*R* graph. Unfortunately, the distractor **B** was a bit too strong. **A** is the correct sketch. When R = 0, V had to be zero too. Most candidates did write down the correct potential divider expression for V, but then did not acknowledge that V cannot be directly proportional to R – the straight-line graph through the origin could not be the correct answer. It was a choice between **A** or **B**, and by the brief reasoning above, the answer had to be **A**.

Question 6

6 Wires **P** and **Q**, made from the same metal, are connected in **parallel** across a cell of negligible internal resistance.
The table shows some data.

Wire	Length of wire	Diameter of wire	Mean drift velocity of electrons in the wire / mm s^{-1}
P	*L*	*d*	0.60
Q	3*L*	2*d*	*v*

What is the mean drift velocity *v* of the electrons in wire **Q**?

A 0.15 mm s^{-1}

B 0.20 mm s^{-1}

C 0.30 mm s^{-1}

D 0.60 mm s^{-1}

Your answer [ ] **[1]**

This was a question on combining together three important expression in the topic of electricity; $V = IR$, $R = \rho L/A$ and $I = Anev$. On top of this, there was the additional information that **P** and **Q** were in parallel and hence the potential difference across each wire was the same.

The mean drift velocity *v* of the electrons is given by the expression $v = \frac{V}{ne\rho L} \propto \frac{1}{L}$. The cross-sectional area *A*, and hence the diameter *d* of the wire has no effect on *v.* The relationship above implies that for wire **Q**, $v = \frac{1}{3} \times 0.60 = 0.20$ mm s^{-1}. The correct answer is **B**.

All the distractors were equally popular. About a third of the candidates, mostly from the very top end of the ability range, were successful in this very demanding question.

Question 8

8 The electric field strength at a distance of 2.0×10^{-8} m from a nucleus is 3.3×10^{8} N C^{-1}.

What is the charge on the nucleus?

A 1.6×10^{-19} C

B 1.5×10^{-17} C

C 7.3×10^{-10} C

D 3.8×10^{-9} C

Your answer **[1]**

This question required knowledge of the equation $E = \frac{Q}{4\pi\varepsilon_0 r^2}$, which is in the Data, Formulae and Relationship Booklet. The key, the correct answer, is **B**. The most common mistake made by candidates was not squaring *r*, or the equivalent where the electric potential *V* equation was used instead. This gave the incorrect answer of 7.3×10^{-10} C for the most recurrent distractor **C**. The exemplar 2 below shows a plausible method for getting to the correct answer.

Exemplar 2

The electric field strength at a distance of 2.0×10^{-8} m from a nucleus is 3.3×10^{8} N C^{-1}.

What is the charge on the nucleus?

A 1.6×10^{-19} C

B 1.5×10^{-17} C

C 7.3×10^{-10} C

D 3.8×10^{-9} C

$$E = \frac{Q}{4\pi\varepsilon_0 r^2}$$

$$E 4\pi \varepsilon_0 r^2 = Q$$

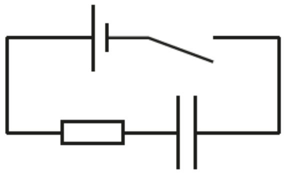
$$(3.3\times10^{8})(4\pi)(8.85\times10^{-12})(2\times10^{-8})^2$$

Your answer B **[1]**

This middle-grade candidate has shown all the working. A significant number of candidates wrote down the correct expression, circled the key data in the question and did the rest of the work on their calculators. A variety of techniques were use.

Question 13

13 A capacitor is charged through a resistor.



The cell has electromotive force (e.m.f.) 1.50 V and negligible internal resistance.
The time constant of the circuit is 10 s. The switch is closed at time $t = 0$. At time t, the potential difference across the resistor is 0.60 V.

Which expression is correct?

A $0.60 = 1.50e^{-0.10t}$

B $0.90 = 1.50e^{-0.10t}$

C $0.60 = 1.50e^{-10t}$

D $0.60 = 1.50(1-e^{-10t})$

Your answer [ ] **[1]**

All the key equations for capacitor-resistor circuits are in the Data, Formulae and Relationship Booklet. As the capacitor charges, the potential difference *V* across the resistor will fall exponentially with respect to time. The time constant of the circuit *CR* is 10 s. Therefore, according to the equation $V = V_0e^{-t/CR}$, the correct expression after substitution will be $0.60 = 1.50e^{-0.10t}$. The correct answer is **A**. Just on the knowledge of time constant, neither **C** nor **D** can be the correct answers because of the '10' in the expression. The choice then is between **A** and **B**; as demonstrated above, **A** is the answer. All the distractors were equally popular.

Section B overview

Section B includes short-answer style questions, problem solving, calculations and practical. It also includes two level of response (LoR) questions. In each LoR question you can score a maximum of 6 marks. This section is worth 85 marks and you are expected to spend about 1 hour 45 minutes.

Question 16 (a)

16 This question is about waves.

(a) The **period** of a progressive wave can be determined from Fig. 16.1. Add a correct label to the horizontal axis so that the period can be found. **[1]**

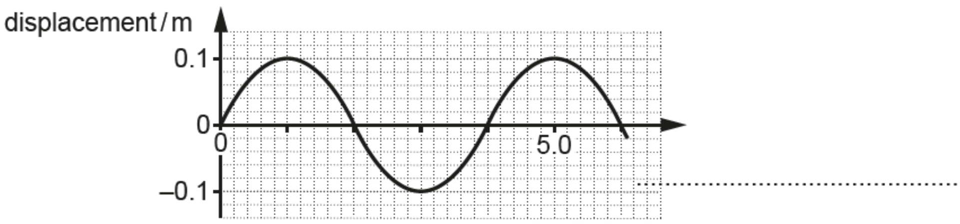


Fig. 16.1

Almost all candidates did well here by correctly labelling the horizontal axis. Most answers also included the unit, e.g. time / s. A very small number of candidates had *distance*, *time period*, *frequency* and *velocity* for the label.

Question 16 (b)

(b) A progressive wave has wavelength λ, frequency f and period T.

Show that the speed v of the wave is given by the equation $v = f\lambda$.

[2]

For maximum marks, it was important for candidates to clearly show all the steps leading to the wave equation. Supportive text always helps with the clarity of answers. The vast majority of the candidates produced flawless answers in terms of λ, f and T. A significant number of candidates used t or *d,* which made their working ambiguous. Some tried their luck with 4.0 s from **Fig. 16.1**, which led to no marks.

The exemplar 3 below shows a model response supported by equations and text and exemplar 4 shows that even top end candidates make mistakes.

Exemplar 3

A progressive wave has wavelength λ, frequency f and period T.

Show that the speed v of the wave is given by the equation $v = f\lambda$.

distance travelled in one period = λ
time = T

$\therefore$ speed of wave = $\frac{\text{distance}}{\text{time}} = \frac{\lambda}{T}$

$T = \frac{1}{f}$ so $f = \frac{1}{T}$ $\therefore$ speed, $v = \underline{\underline{f\lambda}}$.

[2]

This is a model response for a show-type question. The text provides continuity and supports the derivation of the wave equation. A perfect solution.

Exemplar 4

(b) A progressive wave has wavelength λ, frequency f and period T.

Show that the speed v of the wave is given by the equation $v = f\lambda$.

$f = {}^1/_T$

$f = s^{-1}$

${}^1/_{{}^1/_T}$

$\lambda = m$

$v = ms^{-1}$
$T = s$
$f = {}^1/_T = s^{-1}$
$\lambda = m$
$\therefore v = f\lambda$
(ms^{-1})

[2]

This was a high scoring candidate overall who misunderstood the question here. The focus is on S.I. units of the various quantities and not on a derivation of $v = f\lambda$ from first principles.

Question 16 (c) (i)

(c) A scientist is investigating the interference of light using very thin transparent material.
A sample of the transparent material is placed in a vacuum.
Fig. 16.2 shows the path of two identical rays of light **L** and **M** from a laser.

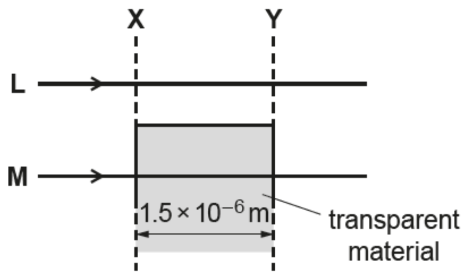


Fig. 16.2

The refractive index of the material is 1.20. The thickness of the material is 1.5×10^{-6} m.
The wavelength of the light in vacuum is 6.0×10^{-7} m.

(i) Show that the difference in time t for the two rays to travel between the dashed lines **X** and **Y** is 1.0×10^{-15} s.

t = ... s **[3]**

Generally, candidates answered this question extremely well and most scoring full marks

In **(c)(i)**, the solutions ranged from being well-structured to an assortment of equations and substitutions filling the entire answer space. Equations for refractive index and speed were easily used to show the answer to be 1.0×10^{-15} s.

In **(c)(ii)**, candidates either calculated the frequency of 5.0×10^{14} Hz and then used $T = f^{-1}$ or calculated T directly using $T = \frac{6.0 \times 10^{-7}}{3.0 \times 10^{8}} = 2.0 \times 10^{-15}$ s.

(c)(iii) provided some discrimination with middle and top candidates getting the correct answer of 180°. As always, error carried forward (ECF) rules apply in calculations. This helped those candidates who got an incorrect answer of 2.4×10^{-15} s in **(c)(ii)** to score a mark for 150°.

?	**Misconception**	There were some missed opportunities, with some candidates making the following mistakes. • In **(c)(i)** calculating the difference in the time for the two rays by halving the period of 2.0×10^{-15} s. • In **(c)(ii)** using the wavelength in vacuum of 6.0×10^{-7} m but the incorrect speed of 2.5×10^{8} m s^{-1} to calculate the period. This gave an answer of 2.4×10^{-15} s; examiners allowed 1 mark for this method. • In **(c)(iii)**, a small number of candidates, mainly at the low-end, confused the symbol ϕ for phase difference to be work function. This produced some bizarre answers.

Question 16 (c) (ii)

(ii) Calculate the period T of the light wave.

T = ... s **[2]**

Question 16 (c) (iii)

(iii) The rays of light are in phase at the dashed line **X**.

Use your two answers above to state the phase difference ϕ in degrees between the light rays at **Y**.

ϕ = ... ° **[1]**

Question 16 (d)

(d)* The speed v of surface water waves in shallow water of depth d is given by the equation $v = \sqrt{gd}$, where g is the acceleration of free fall.

The speed v is about $1\,\text{m}\,\text{s}^{-1}$ for a depth of about 10 cm.

You are provided with a rectangular plastic tray, supply of water and other equipment available in the laboratory.

Describe how an experiment can be conducted in the laboratory to test the validity of the equation above and how the data can be analysed to determine a value for g. **[6]**

This level of response (LoR) question was designed to assess practical skills of planning, implementation, analysis and evaluation from module 1 of the specification, together with the mathematical skills of graphs from Section M3. The context of the question was waves and the relationship between wave speed v and depth d of the water.

A holistic approach to marking is used, with marks given according answers matching the descriptors for the various levels. There is no one perfect answer for this question, examiners were expecting an eclectic approach. The key things examiners were looking for were:

- A plausible technique for creating the waves on the surface of the water.

- Method for determining the speed of the waves.

- Instruments used for measurements.

- Techniques used to produce reliable results.

- The graph plotted, and how the acceleration of free fall g is determined from the data.

On occasions, the methods used for determining the speed of the waves and creating the waves were a bit creative, but perhaps plausible in the hands of very competent physicists. For examples, light-gates were often used to determine the speed of the waves. The intricacies of this method were often omitted, but given lots of time, the technique could be made to work. There were some interesting suggestions about using a motion-sensor above a floating ball to determine the frequency of the waves. Examiners were not looking for perfection. Most candidates either dropped objects into the water or struck the side of the tray to create the waves. The speed was often determined by dividing the distance travelled by the wave by the time it took to travel a known distance.

Candidates either plotted v^2 against d or v against $\sqrt{d}$ to determine g. Across the ability range, the analysis sections of the answers were generally better than the descriptions.

The exemplar 5 shows a response that scored Level 3 (L3) and exemplar 6 shows a response that missed out on a top score because of lack of detail in the description.

Exemplar 5

* Fill the plastic tray with a supply of water, up to ~~depth of 30 cm~~ a shallow depth.
* Measure the depth of water using a ruler with a mm scale, this can be placed in the plastic tray. Record the depth reading.
* Using a ripple machine (a rod connected to a vibration generator) surface water waves can be produced by the repeated motion of the rod on the water.
* ~~Connect the vibration generator to~~ Adjust the frequency of the vibration generator until water waves are present on the surface of the water. These may be hard to spot at first.
* Using a ruler, measure the distance between the rod and the end of the tray, then, using a

Additional answer space if required.

Stopwatch ~~record~~ measure the time taken for the wave from the rod to reach the end of the tray. Now, alter the depth at regular intervals.
* Calculate the speed using distance travelled / time.
* Calculate v^2 by squaring this answer.
* Plot a graph of v^2 against d (depth of water) this should produce a straight line through the origin.

* Gradient of this line = g.

$\rightarrow V = \sqrt{gd}$

$v^2 = g d$

$y = m x$

This exemplar shows that examiners are not expecting perfection with the practical skills or the analysis. The description here is clear, as is the analysis. This response met all the requirements of a Level 3 score.

Exemplar 6

Using the plastic tray, changing the depth of the water while not adjusting ~~speed~~ oscillator the frequency driver or wave inducer with keeping f constant ~~the~~ ~~depth~~ the wavespeed will change only based on depth. Measure wavespeed by measuring time for wave to travel full length of tray or a set distance. Using v^2 against d. change the depth to have a varied range of wave speed. using v^2 against d will result in the gradient of graph being equal to value of g. The relationship will be conferming by a constant gradient through origin since g is a constant value. A mechanical driver would be prefered to keep ~~speed~~ frequency constant, meaning the speed of water waves will only change because of depth of water.

Additional answer space if required.

Using $1 = v$ and $10 \times 10^{-2} = d$

a value of $10\ \text{Nkg}^{-1}$ can be calculated.

Measure a range of values for depth with resulted speed of waves to plot data and graph.

This exemplar shows a Level 2 response. You will notice that the description is not as robust at that shown in exemplar 5. The analysis in both is similar. There are small margins between the levels.

Question 17 (a) (i)

17 (a) Fig. 17.1 shows the variation with distance of the displacement of a **stationary** wave at time $t = 0$.

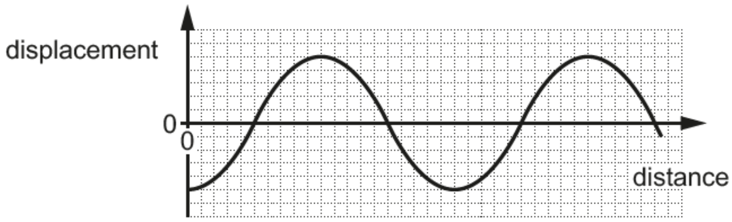


Fig. 17.1

The period of the wave is T.

(i) On Fig. 17.1, sketch a graph to show the variation of the displacement at time $t = \frac{T}{2}$. **[1]**

The majority of the candidates drew the correct variation of the displacement after a time of half a period. In **(a)(ii)**, it was good to see the nodes clearly marked with the letters **N**. The most common mistake was to draw a curve with a different period with nodes at all the points where the displacement was zero.

Question 17 (a) (ii)

(ii) On Fig. 17.1, show the positions of **all** the nodes. Label each node **N**. **[1]**

Question 17 (b)

(b) Stationary sound waves are formed in a tube closed at one end.
Fig. 17.2 shows three stationary wave patterns formed in the air column of the tube.

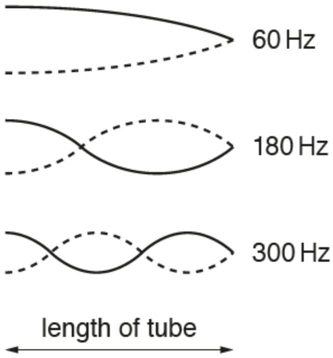


Fig. 17.2

The frequency *f* of the oscillations for each stationary wave is shown in Fig. 17.2.

Use Fig. 17.2 to explain how the frequency *f* of the sound wave depends on the wavelength λ.

[3]

The majority of the candidates scored 1 mark for either mentioning that the *wavelength was inversely proportional to the frequency* or identifying the correct relationship between the length of the tube and the wavelength. Generally, the explanations lacked cohesion and showed poor comprehension of stationary waves formed within a fixed column of air. The common errors are highlighted below.

?	**Misconception**	There were some missed opportunities, with some candidates making the following mistakes. • **wavelength** = $\lambda/4$, $3\lambda/4$ and $5\lambda/4$, instead of **length of tube** = $\lambda/4$, $3\lambda/4$ and $5\lambda/4$. • Correctly identifying the relationship between *L* and λ, but then confusing *L* and λ, and stating that the $f \propto \lambda$. • Using an equal sign instead of the proportionality symbol, e.g. *frequency is inversely proportional wavelength, hence* $f = 1/\lambda$.

Question 18 (a)

18 (a) State Kirchhoff's second law **and** the physical quantity that is conserved according to this law.

....

....

....

.... **[2]**

Many candidates jumbled up the first and second laws, but most candidates gave perfect answers. It was quite common to see hybrid statements such as '*sum of e.m.f.s at a point = sum of p.d.s coming out of the same point'*. Most did know that energy was conserved, but other incorrect suggestions were *charge*, *current* and *voltage*. The question discriminated well and rewarded those candidates that had learnt their definitions.

Question 18 (b)

(b) The S.I. base units for the ohm (Ω) are $\text{kg}\,\text{m}^2\,\text{s}^{-3}\,\text{A}^{-2}$.

Use the equation $R = \frac{\rho L}{A}$ to determine the S.I. base units for resistivity ρ.

base units for ρ .... **[2]**

The majority of the candidates effortlessly showed the base units for resistivity to be kg m^3 s^{-3} A^{-2}. The structure from most was immaculate. It was good to see shortcuts being used too. Some candidates went straight to the units for resistivity (Ω m), and then multiplied the units given for resistance multiplied by m.

?	**Misconception**	The most common misconception, mainly at the lower end, was that the *A* in the resistance equation was the unit for current, the ampere A. This led to the incorrect answer kg m s^{-3} A^{-1}.

Question 18 (c) (i)

(c) Fig. 18.1 shows a circuit used by a student to determine the resistivity of the material of a wire.

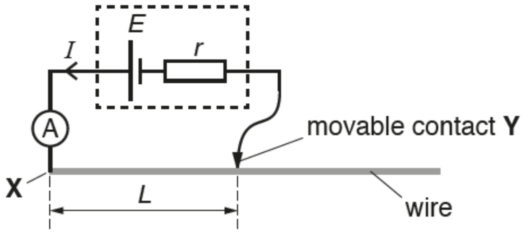


Fig. 18.1

The wire is uniform and has diameter 0.38 mm. The cell has electromotive force (e.m.f.) *E* and internal resistance *r*. The length of the wire between **X** and **Y** is *L*.

The student varies the length *L* and measures the current I in the circuit for each length.

Fig. 18.2 shows the data points plotted by the student.

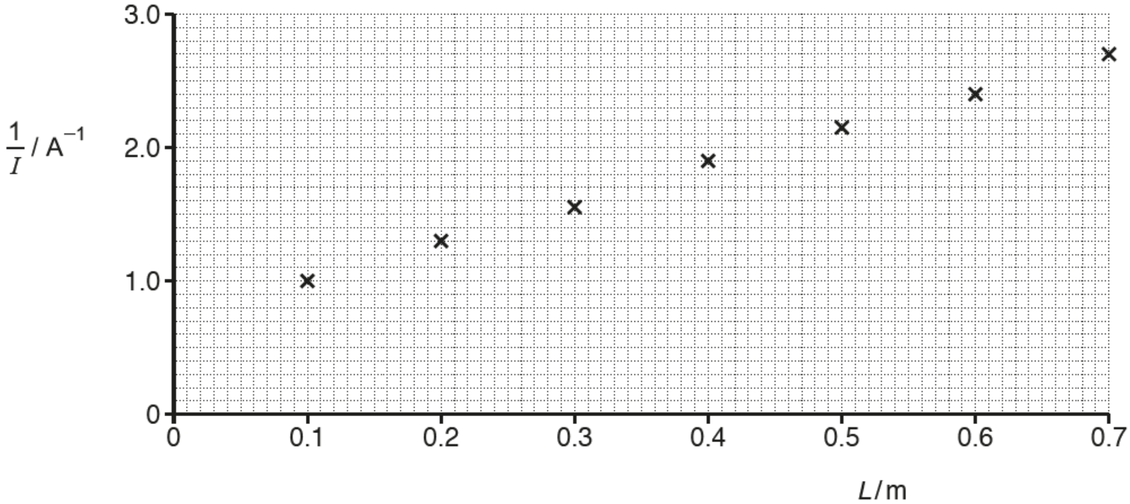


Fig. 18.2

(i) On Fig. 18.2 draw the straight line of best fit. Determine the gradient of this line.

gradient = ... $A^{-1}\,m^{-1}$ **[2]**

In **(c)(i)**, the lines of best fit were generally very good, as were the gradient calculations with most candidates getting values in the range 2.60 to 3.00. Only a small number of candidates calculated the inverse of the gradient.

Question 18 (c) (ii)

(ii) Show that the gradient of the line is $\frac{\rho}{AE}$, where ρ is the resistivity of the material of the wire, A is the area of cross-section of the wire and E is the e.m.f. of the cell.

[2]

Most candidates struggled with **(c)(ii)**. Less than 1 in 10 candidates successfully used the equations $E = V + Ir$ and $R = \frac{\rho L}{A}$ to derive the expression $\frac{1}{I} = \frac{\rho}{AE}L + \frac{r}{E}$, and then identified the gradient as $\frac{\rho}{AE}$ by comparison with the equation for a straight-line $y = mx + c$.

Question 18 (c) (iii)

(iii) The e.m.f. E of the cell is 1.5 V. The diameter of the wire is 0.38 mm.

Use your answer to **(i)** and the equation given in **(ii)** to determine ρ.

ρ = ... Ω m **[2]**

Most candidates in **(c)(iii)** did exceptionally well to calculate the resistivity using the equation for the gradient. Calculations were generally well-structured, and the final answer showed good use of powers of ten and significant figures.

Question 18 (iv)

(iv) Fig. 18.3 illustrates how the student had incorrectly measured all the lengths L of the wire.

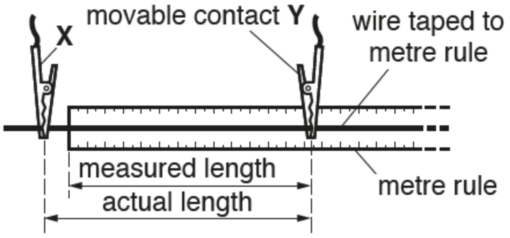


Fig. 18.3

According to the student, re-plotting the data points using the **actual** lengths of the wire will not affect the value of the resistivity obtained in **(iii)**.

Explain why the student is correct.

....

....

....

.... **[2]**

Finally, **(c)(iv)** provided good discrimination with many of the top end candidates realising the gradient of the line was unaffected, the line was just shifted horizontally. 'Systematic error' and 'zero error' were allowed as alternative answers for the horizontal translation of the line.

?	**Misconception**	There were some missed opportunities, with some candidates making the following mistakes. • In **(c)(ii)**, ignoring the internal resistance *r* of the cell shown in the circuit of **Fig. 18.1** to get the wrong expression $\frac{1}{I} = \frac{\rho}{AE}L$. • In **(c)(iii)**, a small number of candidates either used 0.38 mm as the radius of the wire to get a resistivity of 1.9×10^{-6} Ω m or forgot to convert the millimetres into metres to get a value of 0.48 Ω m. • In **(c)(iv)**, a significant number of low-end candidates, mentioned that resistivity of the wire did not depend on its physical dimensions, and therefore the resistivity value calculated will be the same. There was no reasoning in terms of gradient = $\frac{\rho}{AE}$.

Question 19 (a)

19 Fig. 19.1 shows an electric circuit.

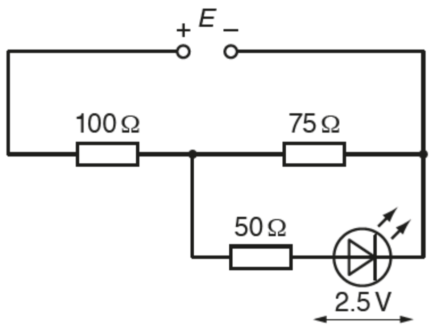


Fig. 19.1

The power supply has electromotive force (e.m.f.) *E* and negligible internal resistance.

The resistance values of the resistors are shown in Fig. 19.1. The *I*–*V* characteristic of the light-emitting diode (LED) is shown in Fig. 19.2.

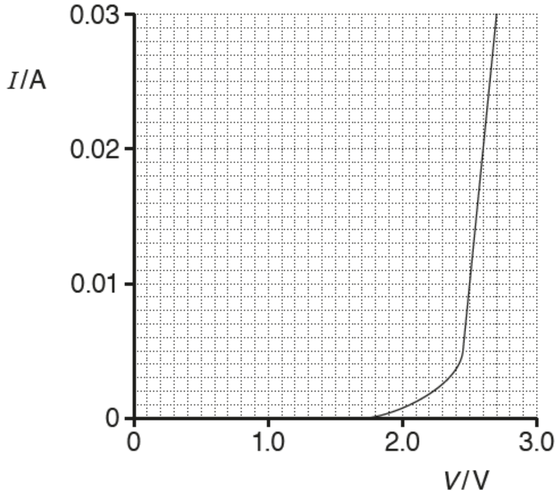


Fig. 19.2

The potential difference (p.d.) across the LED is 2.5 V.

(a) Use Fig. 19.2 to show that the p.d. across the 50 Ω resistor is 0.50 V.

[2]

This was an accessible question on determining the p.d. across the LED using the data from **Fig. 19.2**. The universal approach was short and precise: $V = 0.01 \times 50 = 0.50$ V. However, a significant number of candidates used a longer route involving the potential divider rule and the 250 Ω resistance of the LED.

Question 19 (b)

(b) Calculate the e.m.f. *E* of the power supply.

E = ... V **[3]**

The analysis of the circuit proved to be problematic with most of the candidates getting as far as calculating either the resistance of the LED as 250 Ω or the p.d. across the LED-50 Ω resistor combination as 3.0 V. The stages thereafter demonstrated all the usual misconceptions; these are summarised later. About a quarter of the candidates produced flawless solutions using a range of techniques from Kirchhoff's two laws to potential dividers. The simplest solution had the correct current of 0.050 A in the 100 Ω resistor, followed by the correct value of the e.m.f. of 8.0 V. This type of solution is shown in exemplar 7.

?	**Misconception**	These were the most common errors made in calculating the e.m.f. of the power supply. • Calculating the total resistance of the parallel network by omitting the resistance of the LED. • The current in the 100 Ω resistor was the same as the current of 0.010 A in the LED. • The current in the 100 Ω resistor was the same as the current of 0.040 A in the 75 Ω resistor. • Using the potential divider equation by completely omitting the LED-50 Ω resistor series network.

Exemplar 7

(b) Calculate the e.m.f. *E* of the power supply.

~~2.5 + 0.5 7V~~

$R = \frac{2.5}{0.01} = 250\Omega$

$50 + 250 = 300$

$\frac{300}{75} = 4$

$4 \times 0.01 = 0.04$

$0.04 + 0.01 = 0.05$

$100 \times 0.05 = 5V$

$0.5 + 2.5 + 5 = 8V$

E = ...8.......................... V **[3]**

This exemplar shows a perfect response from a middle-grade candidate. The response should have been written to 2 SF. However, because the answer was 8.0 V, a 1 SF response was allowed without incurring any penalty.

Question 19 (c) (i)

(c) The LED emits blue light of wavelength 4.7×10^{-7} m.

(i) Estimate the number of blue light photons emitted from the LED per second.

number of photons per second = ... s^{-1} **[3]**

This question required knowledge of both power and energy of photons. It discriminated well with many of the top end candidates getting the correct of 5.9×10^{16} s^{-1}. A significant number of candidates scored 1 mark for the energy of the photons. Using the power of 0.025 W in the final step of the calculation proved to be the main obstacle in this calculation. Alternative answers using the energy of a photon as 2.5 eV were allowed. This gave the rate of photons emission to be 4.0×10^{16} s^{-1}.

?	**Misconception**	The most common mistake was to calculate the energy of the photon in joule, but to write the frequency 6.4×10^{14} on the answer line. This wayward answer can perhaps be explained by frequency and the rate of photon emissions having the same units – s^{-1}.

Question 19 (c) (ii)

(ii) The light from the LED is incident on a metal of work function 2.3 eV.

Explain, with the help of a calculation, whether or not photoelectrons will be emitted from the surface of the metal.

....

....

.... **[2]**

Most candidates showed excellent knowledge and understanding of electronvolts and the photoelectric equation. A variety of answers were accepted. The most common approach was to calculate the energy of the photon in eV, and then either show that this was greater than the work function of the metal or to calculate the kinetic energy of the emitted photoelectron. A lot of confidence in the topic of quantum physics was evident in the answers from the candidates. This is illustrated by exemplar 8 below from a middle-grade candidate.

Exemplar 8

(ii) The light from the LED is incident on a metal of work function 2.3 eV.

Explain, with the help of a calculation, whether or not photoelectrons will be emitted from the surface of the metal.

$E = \phi + KE_{max}$

$2.3 \times 1.6 \times 10^{-19} = 3.68 \times 10^{-19}$ J

$4.23 \times 10^{-19} = 3.68 \times 10^{-19} + KE_{max}$

photoelectrons will be ~~emm~~ emitted as the work function (3.68×10^{-19} J) is less than the energy of a photon (4.23×10^{-19}) [2]

This exemplar shows the right blend of calculations and scientific text to support the response. Good command of quantum physics earned this candidate full marks.

i	**OCR support**	Being aware of the contents of the data, formulae and relationship booklet and its layout will support candidates, alleviating the need to recall numerical values of constants and allowing retrieval of correct formulae, or giving assurance that the student has recalled correctly.

Question 20 (a)

20 Fig. 20 illustrates a device used to determine the relative abundance of charged rubidium ions.

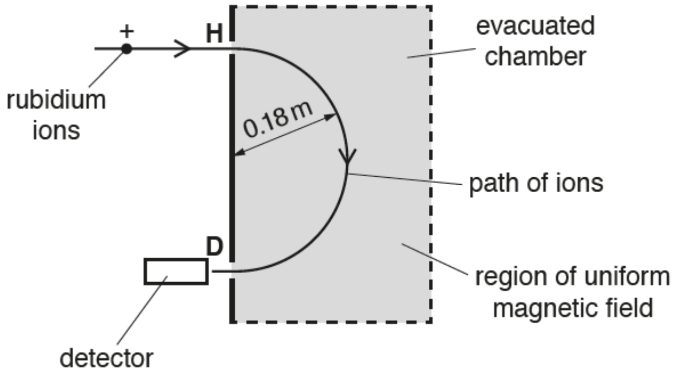


Fig. 20

A uniform magnetic field is applied to an evacuated chamber. The direction of the magnetic field is perpendicular to the plane of the paper.

A beam of positive rubidium ions enters the chamber through a hole at **H**. The ions travel in a semi-circular path in the magnetic field. The ions are detected at point **D**.

(a) Each rubidium ion has charge $+1.6 \times 10^{-19}$ C and speed 4.8×10^{4} m s^{-1}.
The radius of the semi-circular path of the ions is 0.18 m.
The mass of a rubidium ion is 1.4×10^{-25} kg.

Calculate the magnitude of the magnetic flux density B of the magnetic field.

B = ... T **[3]**

This question on the circular motion of charged particles in a uniform magnetic field was answered with confidence and flair. Most candidates got the correct answer of 0.23 T for the magnetic flux density. A small number of candidates, mainly at the low-end, were using incorrect equation for the magnetic force experienced by the ions. Some of these equations were hybrids of the **electric** force experienced by charged particles.

Question 20 (b) (i)

(b) The chemical composition of ancient rocks found on the Earth can be used to estimate the age of the Earth.
Nuclei of rubidium-87 ($^{87}_{37}$Rb) decay spontaneously into nuclei of strontium-87 ($^{87}_{38}$Sr).
The half-life of rubidium-87 is 49 billion years.

(i) Name the two leptons emitted in the decay of a rubidium-87 nucleus.

1. ....

2. .... **[1]**

The majority of the candidates scored a mark for electron and antineutrino as the two leptons. The most common incorrect answers were *neutrino*, *positron*, *proton* and *neutron*. The pairing of electron and positron also appeared on some scripts.

Question 20 (b) (ii)

(ii) The percentage of rubidium **left** in a sample of an ancient rock is 95%.

Estimate the age of the Earth in billion years.

age = ... billion years **[3]**

Many of the top-half candidates demonstrated how the age of the Earth could be calculated in just a few lines. The use of natural logs (ln) was faultless. Most candidates calculated the decay constant and then used the equation 0.95 = $e^{-\lambda t}$, or its equivalent ln0.95 = $-\lambda t$, to calculate the age *t*. Candidates are reminded not to round numbers in long calculations – it is good practice to keep all the digits on your calculator. A significant number of candidates rounded the decay constant to 2 SF (0.014 billion y^{-1}), and this gave an answer of 3.7 billion years. The correct answer, without rounding ln2/49, was 3.6 billion years. On this occasion, examiners allowed the 3.7 billion years answer.

The command term 'estimate' in the question made a small number of candidates to use the equation $\frac{\Delta N}{\Delta t} \approx -\lambda t$. This was allowed, and it gave an estimated age of 3.5 billion years.

?	**Misconception**	These were some common errors being made in this question, these are summarised below. • Incorrect conversion of billion years into seconds. (Most candidates calculated the decay constant in billion year^{-1}, which easily led to the correct answer in billion years.) • Using ln0.05 instead of ln0.95 when calculating the age of the Earth.

Question 21 (a) (i)

21 (a) Fig. 21 shows stable and unstable nuclei of some light elements plotted on a grid. This grid has number of neutrons *N* on the vertical axis and number of protons *Z* on the horizontal axis.

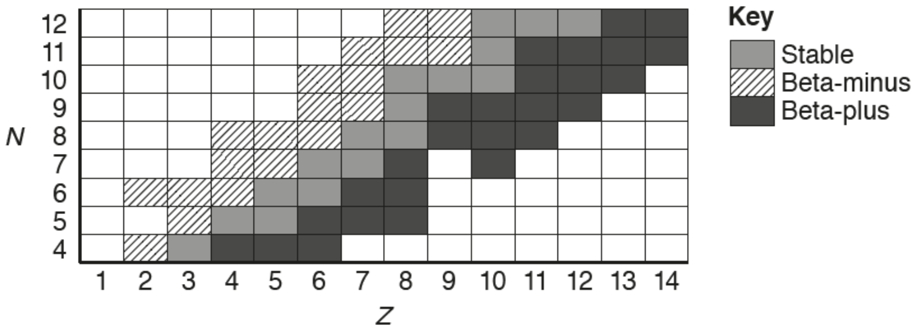


Fig. 21

The key on Fig. 21 shows whether a nucleus is stable, emits a beta-plus particle or emits a beta-minus particle to become stable.

For $Z = 7$, suggest in terms of *N* why an isotope may emit

(i) a beta-minus particle

....

.... **[1]**

This question required analysis of the information provided in **Fig. 21**. Most candidates scored a mark for either recognising that the isotope had too many neutrons or a neutron had to decay into a proton in order to provide stability.

Question 21 (a) (ii)

(ii) a beta-plus particle.

....

.... **[1]**

A range of answers were allowed in this question requiring analysis of **Fig. 21**. Most candidates scored a mark for either recognising that the isotope had too few neutrons or a proton had to decay into a neutron in order to provide stability.

Question 21 (b) (i)

(b) Inside a nuclear reactor, fission reactions are controlled and **chain reactions** are prevented. A typical fission reaction of the uranium-235 nucleus ($^{235}_{92}U$) is illustrated below.

$$^{1}_{0}n + ^{235}_{92}U \longrightarrow ^{141}_{55}Cs + ^{93}_{37}Rb + 2^{1}_{0}n$$

The neutron triggering the fission reaction moves slowly. The neutrons produced in the fission reaction move fast.

(i) Describe what is meant by **chain reaction**.

....

....

....

.... **[2]**

Most candidates scored 1 mark for the general idea of a chain reaction, but the important role played by the neutrons was often omitted in the descriptions. Only a small number of candidates misunderstood fission as a reaction in which the Cs and Rb nuclei themselves were responsible for triggering subsequent reactions of the uranium nuclei.

Question 21 (b) (ii)

(ii) Explain how chain reactions are prevented inside a nuclear reactor.

....

....

.... **[2]**

The mechanism of preventing uncontrolled chain reaction within a nuclear reactor was generally well understood. Having given perfect answers with control rods absorbing the excess neutrons, a significant number of candidates confusing their answers by also mentioning the moderator. It many cases it was impossible for examiners to decide from the candidates response if the control rods, or the moderators, were responsible for preventing chain reactions. Some candidates mentioned 'boron rods', this was an acceptable alternative for the 'control rods'.

Question 21 (b) (iii)

(iii) The energy released in each fission reaction is equivalent to a decrease in mass of 0.19 u.
A fuel rod in a nuclear reactor contains 3.0% of uranium-235 by mass.

Estimate the total energy produced from 1.0 kg of fuel rod.

molar mass of uranium-235 = 0.235 kg mol^{-1}
1 u = 1.66 × 10^{-27} kg

energy = ... J **[4]**

This proved to be an excellent discriminator with top end candidates showing excellent skills to get to the correct answer of 2.2 × 10^{12} J. The majority of the candidates correctly converted the 0.19u into kilograms, and then successfully used Einstein's mass-energy equation to calculate the equivalent energy of 2.8 × 10^{-11} J. The main obstacle in this question was the determination of the number of uranium nuclei in the fuel rods. Avogadro constant, given in the data booklet, was either omitted or the incorrect mass used to determine the number of uranium nuclei.

?	**Misconception**	There were some missed opportunities, with some candidates making the following mistakes when determining the number of uranium nuclei in the 1.0 kg fuel rod. • Using 0.235 × N_A. to calculate the number of uranium nuclei. • Using the rest masses of neutrons and protons. • Omitting the 3.0%.

Question 22 (a) (i)

22 (a) Fig. 22.1 shows two horizontal metal plates in a vacuum.

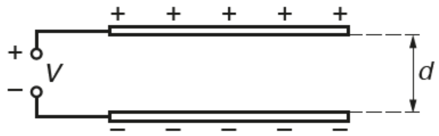


Fig. 22.1

The plates are connected to a power supply. The potential difference *V* between the plates is constant. The magnitude of the charge on each plate is *Q*. The separation between the plates is *d*.

Fig. 22.2 shows the variation with *d* of the charge *Q* on the positive plate.

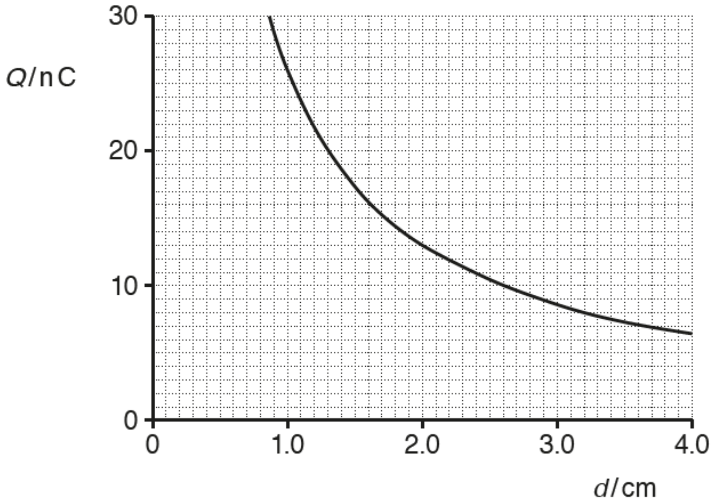


Fig. 22.2

(i) Use Fig. 22.2 to propose and carry out a test to show that *Q* is inversely proportional to *d*.

Test proposed:

....

....

Working:

[2]

The question was not carefully examined by most candidates, because the reference to use **Fig. 22.2** was totally ignored. A significant number of candidates focused either on superfluous practical details or the proof of the relationship between *Q* and *d* – which was required in the next question. About a third of the candidates used at least two points on the graph to show that *Qd* = constant. The powers of ten were overlooked by examiners. A small number of candidates, mainly at the lower-end, calculated the gradient of the curve at arbitrary points to provide support for their incorrect reasoning.

Question 22 (a) (ii)

(ii) Use capacitor equations to show that *Q* is inversely proportional to *d*.

[2]

Most candidates successfully, and elegantly, provided the proof for the relationship. Correct answers ranged from the whole space filled with algebra to a couple of succinct lines. A small number of candidates finished off their working by writing $Q = \frac{1}{d}$ instead $Q \propto \frac{1}{d}$ - the 'equal' and the 'proportionality' symbols are not equivalent.

Question 22 (b) (i)

(b) Fig. 22.3 shows a negatively charged oil drop between two oppositely charged horizontal plates in a vacuum.

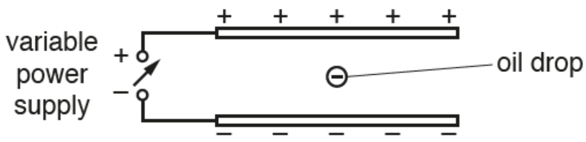


Fig. 22.3

The plates are fixed and connected to a variable power supply. The weight of the oil drop is 1.8×10^{-14} N.

(i) The power supply is adjusted so that the potential difference between the plates is 200 V when the oil drop becomes **stationary**.

State the magnitude of the vertical electric force F_E acting on the charged oil drop.

F_E = ... N **[1]**

This question was designed to support candidates with the next question. The majority scored 1 mark for quoting the weight of the oil drop. A significant number of candidates, about 1 in 5, focused incorrectly on the term **stationary** in the question, and wrote 0 N on the answer line.

Question 22 (b) (ii)

(ii) The potential difference between the plates is now increased to 600 V.
The oil drop accelerates upwards.

Calculate the acceleration a of the oil drop.

a = ... m s^{-2} **[3]**

This was a perfect question for the higher and middle ability candidates. Securing full marks was very much dependent on candidates' understanding of **resultant force**. The majority of the candidates scored 1 mark for calculating the weight of the oil drop in kg. Subsequent steps required the electric force on the oil drop to be 3 times the weight, or the resultant force being twice the weight. The key to getting the correct answer of 2g, or 19.6 m s^{-2}, was deducing that the resultant force was 3.6×10^{-14} N. The most common incorrect answer was 29.4 m s^{-2} because the resultant force was taken as 5.6×10^{-14} N. The exemplar 9 below shows the most common incorrect solution.

Exemplar 9

(ii) The potential difference between the plates is now increased to 600 V.
The oil drop accelerates upwards.

Calculate the acceleration *a* of the oil drop.

F

$1.8\times10^{-14}\times3 = 5.4\times10^{-14}$ N ↑

$\frac{600}{200} = 3$

$W = mg$

$\frac{W}{g} = m$

M

$\frac{1.8\times10^{-14}}{9.81} = 1.835\times10^{-15}$ kg

$F = ma$

$\frac{F}{m} = a$

$\frac{5.4\times10^{-14}}{1.835\times10^{-15}} = 29.43$

a = ...29.43...... ms^{-2} **[3]**

This exemplar from a middle-grade candidate shows how lack of knowledge of resultant force on the oil drop led to just 1 mark. The only mark given was for the mass of the oil drop. Using as 5.6×10^{-14} N as the resultant force led to the incorrect response of 3*g* or 29.43 m s^{-2}.

Question 22 (c)

(c)* Fig. 22.4 shows an arrangement used by a student to investigate the forces experienced by a small length of charged gold foil placed in a uniform electric field.

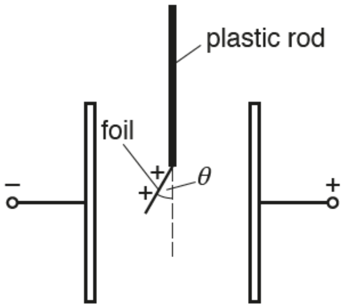


Fig. 22.4

The two vertical metal plates are connected to a high-voltage supply.

The foil is given a positive charge by briefly touching it to the positive plate.

The angle θ made with the vertical by the foil in the electric field is given by the expression

$$\tan\theta = \frac{qE}{W}$$

where q is the charge on the foil, E is the electric field strength between the plates and W is the weight of the foil.

The angle θ can be determined by taking photographs with the camera of a mobile phone.

Describe how the student can safely conduct an experiment to investigate the relationship between θ and E.
Identify any variables that must be controlled. **[6]**

This was the second level of response (LoR) question in this paper. This too was designed to assess practical skills of planning, implementation, analysis and evaluation. The context of the question was force experienced by a charged gold foil in the uniform electric field provided by two parallel plates. Candidates were not expected to have seen such an experiment, but they were expected to use their knowledge of electric field strength and practical skills to present plausible approaches. On occasions, the experimental methods showed poor appreciation of some basic ideas. Some candidates were charging the foil using large current that allegedly would cause heating issues for the foil, while others decided to use $Q = It$, ammeter and a stopwatch to determine the charge on the foil – failing to appreciate that the time constant will be too small for such a technique. However, on this occasion, such over ambitious techniques were generally overlooked by examiners.

As with **16d**, a holistic approach to marking was used, with marks given according answers matching the descriptors for the various levels. There is no one perfect answer for this question, examiners were expecting an eclectic approach. The key things examiners were looking for were:

- Methods for determining electric field strength *E*.

- Using the right instruments for the measurements.

- Plotting the correct graph to show the relationship given in the question was valid.

- Correctly identifying the variables that were being controlled (kept constant).

Access to higher level marks dependent on fully answering the question – and this included the last statement about control of variables. A significant number of candidates focused on the description and analysis of the data, without ever addressing the last sentence of the question. This question did discriminate well, with L1, L2 and L3 marks roughly distributed in the ratio 1:3:4.

Question 23 (a)

23 **(a)** Describe the basic structure of an X-ray tube and explain how X-ray photons are produced.
You may draw a labelled diagram.

....

....

....

....

....

.... **[3]**

This question comes directly from the requirements of the learning outcomes 6.5.1(a) and 6.5.1(b) of the specification. In the first outcome, the basic structure of the X-ray tube outlines the components as heater (cathode), anode, target metal and high-voltage supply. Candidates generally gave poor answers with some components missed out, and quite often getting the anode and cathode very mixed up. On many scripts a cell or a battery was being used, instead of a high-voltage supply. In contrast some candidates incorrectly had a high-voltage supply connected to the heater in order to 'supply fast moving electrons released through thermionic emission'. There were missed opportunities with the explanation of the production of X-rays. Candidates did use terms such as Bremsstrahlung, but basic notion that the kinetic energy of the electrons was being used in the production of the X-ray photons eluded many candidates.

Question 23 (b)

(b) A beam of X-rays is directed at tissues in a patient.
The X-ray photons interact with the atoms of the tissues.

Simple scatter is one of the attenuation mechanisms.

Name and describe **two** other attenuation mechanisms.

1. ....

....

....

....

2. ....

....

....

....
[4]

Most candidates correctly recalled the names of the remaining attenuation mechanisms and gave good descriptions. The mark scheme required descriptions in terms of the X-ray **photons**. The Compton effect was the most complicated mechanism, but many answers correctly described the scattering of the photon with reduced energy (or longer wavelength). A small number of candidates wrote about pair production as if it was the annihilation of an electron-positron pair. The majority of the candidates scored some marks for their answers.

Question 24 (a)

24 **(a)** Explain how an ultrasound transducer can **emit** ultrasound.
You do **not** need to describe the design of the transducer.

....

....

....

....

....

.... **[2]**

Many candidates showed good knowledge of the piezoelectric effect. A significant number of candidates incorrectly believed that the vibrations of the piezoelectric film, or the crystal, were because of a steady potential difference applied to its end; a very high frequency alternating e.m.f. is required to force the crystal to oscillate. The modal score for this question was 2 marks.

Question 24 (b)

(b) Explain how the reflection of ultrasound at a boundary between two tissues depends on the physical properties of the tissues.

....

....

....

....

....

....

....

.... **[3]**

The majority of the candidates scored a mark for mentioning acoustic impedance of the tissues. This term was confused with attenuation coefficient (from X-rays) by some of the candidates. Examiners could not give any credit if this confusion was evident in the answers. A pleasing number of candidates knew that the reflection of ultrasound at the boundary was significant when the difference in the acoustic impedances was large, or the equivalent, that there was no reflection when the acoustic impedances matched. For many candidates, it was the difference in density of the tissues, and not acoustic impedance, that governed the fraction of the reflected intensity at the boundary. Only a small percentage of the candidates omitted this question.

Supporting you

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