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A LEVEL

Examiners' report

PHYSICS A

H556

For first teaching in 2015

H556/03 Summer 2024 series

Version 1

Contents

Introduction

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

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

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

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

Paper 3 series overview

H556/03, 'Unified Physics', is the third of the three examination components for the GCE Physics A qualification. Compared to papers H556/01 and H556/02, a larger proportion of the questions in H556/03 target the higher assessment objectives (AO2 and AO3). For example, candidates can be asked to analyse and interpret experimental data, as in Question 2, or to design their own experiment, as in Question 5(c). Questions may be set on any part of the specification, including practical skills. The paper is synoptic, and any individual question often covers material from several different topics. For example, Question 4 brings together topics from Forces in Action (3.2), Materials (3.4), Oscillations (5.3) and Electromagnetism (6.3). Candidates must be able to apply their knowledge and understanding in unfamiliar contexts in order to gain high marks.

Candidates who did well on this paper generally:	Candidates who did less well on this paper generally:
• showed clear working, especially on 'show that' questions • provided detailed and well-structured written answers • had legible handwriting (or used a word processor) and formed every digit clearly • used a sharp pencil and a 30cm rule for graphs and diagrams • carefully read the instructions on the two LoR questions and so answered them fully • were confident in using their knowledge in unfamiliar contexts.	• missed out steps in their working • wrote rushed answers that lacked structure and detail • wrote illegible answers and formed their digits hastily, making their work difficult to interpret • used a pen to plot graphs and a rule that was too short to draw a continuous line of best fit • did not answer every aspect of the two LoR questions • lost unnecessary marks by making POT errors.

Assessment for learning

Centres should be aware that candidates will invariably lose marks if large parts of their responses are illegible. This applies to calculations as well as to written responses.

Question 1 (a)

1 A flute is a musical instrument made from a long tube that is open at both ends.

A stationary sound wave in the tube produces a musical note.

The lowest frequency note that a standard flute produces in air is 262 Hz.

The speed of sound in air at a temperature of 20 °C is 340 m s^{-1}.

(a) Show that a standard flute has an approximate length of 0.65 m.

[3]

This is a 'show that' question and so every step of the calculation needs to be made clear. It is not enough to point out that 340 / (2 x 262) = 0.65: the examiner needs to know why the data is being combined in this particular way.

The step that was most often omitted was saying that, for the fundamental (lowest) frequency, half a wavelength fits inside the flute. This could be demonstrated using a diagram, showing an open tube containing half a wavelength with antinodes at both ends. However, a written statement (length is half of a wavelength) or a mathematical statement ($L = \lambda/2$) are just as good.

Question 1 (b) (i)

(b) In an ideal gas, the speed v of sound is given by

$$v = \left(\frac{\gamma RT}{M}\right)^{1/2}$$

where

γ is a dimensionless constant that depends on the gas

R is the molar gas constant

T is the absolute temperature

M is the molar mass of the gas.

The table below shows values of γ and M for both air and helium.

Gas	**γ**	**M / g mol^{-1}**
Air	1.40	29.0
Helium	1.67	4.00

(i) The kinetic model of an ideal gas assumes that there are a large number of particles in rapid, random motion.

State **two** further assumptions for the kinetic model of an ideal gas.

1 ....

....

2 ....

.... **[2]**

Most candidates confidently wrote two correct assumptions. Errors most often came about through careless wording, such as 'the time between collisions is negligible' (rather than the time of collisions) or 'the particles take up negligible space' (rather than volume).

Question 1 (b) (ii)

(ii) A standard flute is placed inside a sealed chamber.

The chamber is filled with helium at a temperature of –10 °C.

Calculate the lowest frequency that the flute could produce inside the chamber.

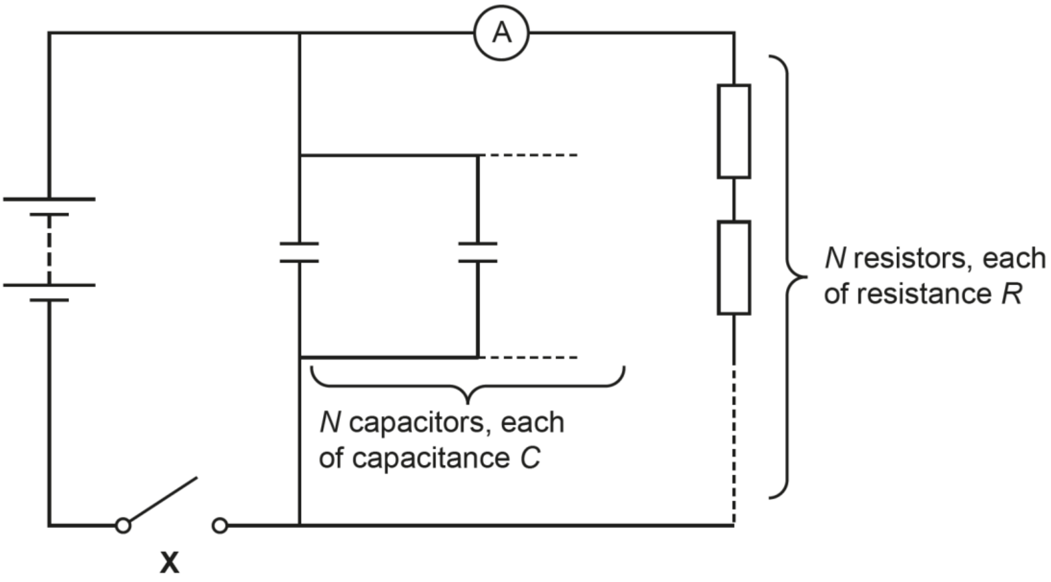
frequency = ... Hz **[4]**

Common problems in 1 (b) (ii)

- failing to convert the molar mass *M* into units of kg mol^{-1}
- substituting the length of the flute (0.65m) instead of 1.30m for the wavelength.

Question2(a)

2 A group of students investigate the circuit shown in the figure below.



There are *N* capacitors, each of capacitance *C*, connected in parallel.

There are *N* resistors, each of resistance *R*, connected in series.

Initially, the students close the switch **X**. They then note the reading on the ammeter.

The students then open the switch. They record the time *T* for the reading on the ammeter to fall to half of its initial value.

The table below shows the students' results.

N	***T* / s**			
	1	**2**	**3**	**Mean**
1	14.7	14.1	14.3	....
2	50.3	49.6	50.1	....
3	126.6	126.3	125.2	126.0
4	224.4	224.3	225.9	224.9
5	356.1	354.3	345.6	352.0
6	500.4	512.7	499.5	504.2

(a) Show that $T = (\ln 2)N^2RC$.

[2]

The initial step in this question is to use the equation $I = I_o e^{-t/RC}$ together with the fact that *N* resistors in series have a total resistance of *NR* and *N* capacitors in parallel have a total capacitance of *NC.T* is the time taken for I_o to fall to $I_o/2$ *and so* ½ = $e^{-T/NR.NC}$. Many candidates were able to navigate the tricky mathematics and were aware that ln(½) = -ln(2)

It is important in this question to distinguish clearly between *t*, the general variable for time, and *T*, the time taken for I_o to fall to $I_o/2$. The statement ½ = $e^{-t/NR.NC}$ is not generally true; it is only true when *t* = *T*.

Question 2 (b)

(b) The students write in their lab books, "Our data is precise".

Evaluate this statement.

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....

....

....

.... **[2]**

There is still a common misconception that data given to 3s.f. is more precise than data given to 2s.f. However, most candidates were able to describe a precise data set in terms of a narrow spread, or a small percentage uncertainty. Unfortunately, these candidates were often vague in their evaluation of the given data, giving statements that were too general such as 'the data is fairly close together' or 'it gets less precise as *N* increases'. Some candidates made statements such as 'For *N* = 1, the range is 0.6s', and they were given credit, but a better answer would go on to compare this to the mean value of 14.4s saying, for example, that this gives a percentage uncertainty of 4.2%

Question 2 (c)

(c) The results table is repeated below.

Complete the last column for N = 1 and N = 2 in the table below.

N	***T* / s**			
	1	**2**	**3**	**Mean**
1	14.7	14.1	14.3	....
2	50.3	49.6	50.1	....
3	126.6	126.3	125.2	126.0
4	224.4	224.3	225.9	224.9
5	356.1	354.3	345.6	352.0
6	500.4	512.7	499.5	504.2

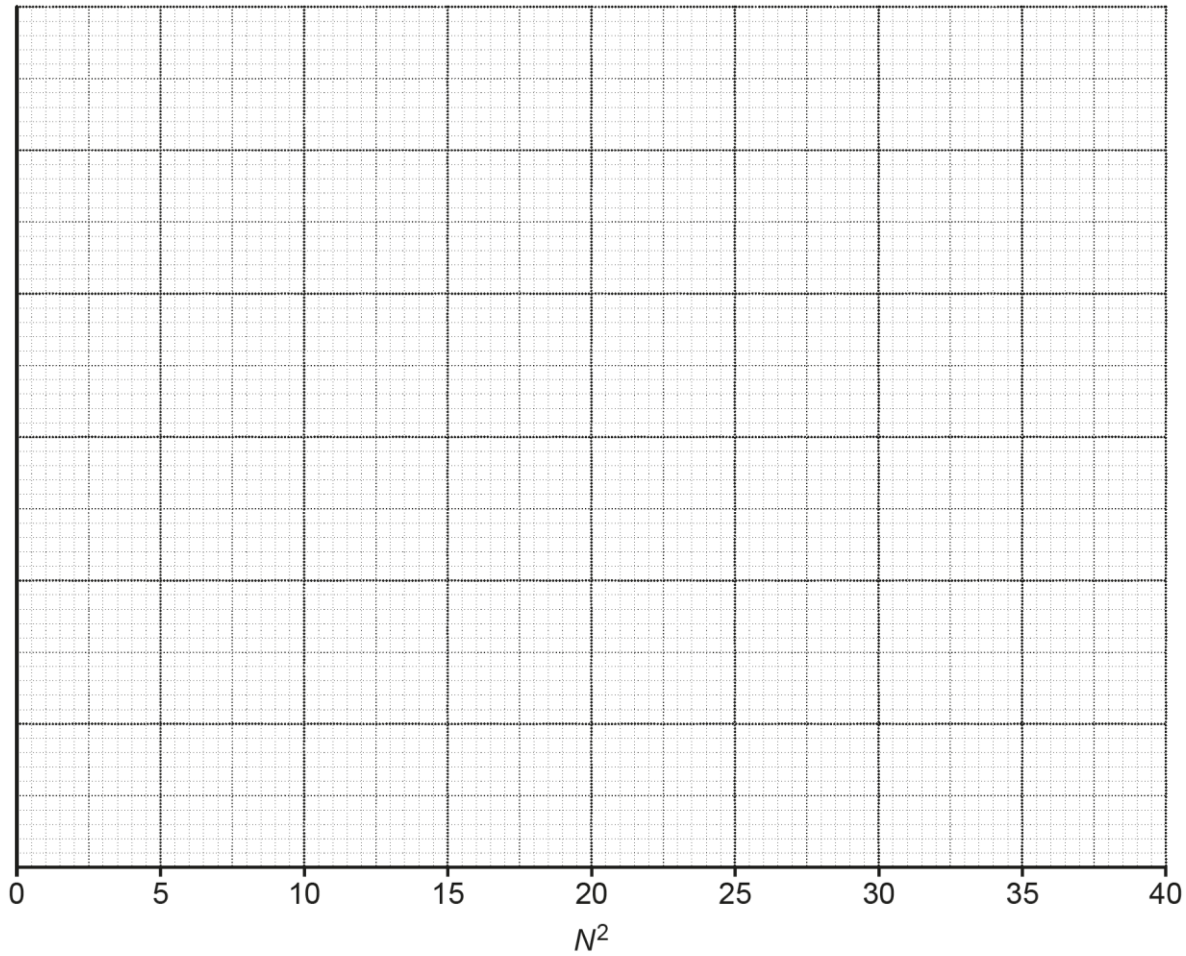
[1]

It is good practice to give all values in a column of a table to the same number of decimal places.

Question 2 (d) (i)

(d) The students begin to plot a graph of T (y-axis) against N^2 (x-axis).

(i) Complete the graph below and plot the 6 results from the table. You are **not** expected to include error bars. **[4]**



It was easy to put a scale onto this graph, and very few candidates used a non-linear scale or one with a poor choice of intervals. Some candidates, however, forgot to add units to their time axis. Most plotted the points easily, although the first point often proved tricky.

Question 2 (d) (ii)

(ii) Draw a straight line of best fit on the graph. **[1]**

Almost all candidates were able to draw a best fit line with an even scatter of points above and below the line

Question 2 (d) (iii)

(iii) Calculate the gradient of the straight line of best fit.

gradient = ... s **[2]**

Again, this was well done, with most candidates choosing a large triangle to calculate their gradient and drawing it onto the graph.

Note that it is important to use points on the line of best fit to calculate a gradient (which are not necessarily points from the table).

Question 2 (d) (iv)

(iv) The value of C is known to be 1000 μF ± 5%.

Use your gradient value from **(iii)** to find a value for R, in units of kΩ, including an **absolute** uncertainty.

R = ... ± .... kΩ **[2]**

Common problems in 2(d)(iv)

- giving the value of R in Ω rather than kΩ.
- giving the value and its absolute uncertainty to a different number of decimal places.

Question 2 (e) (i)

(e) Following the investigation, the students discovered that the sixth 1000 μF capacitor connected to the circuit was actually two 470 μF capacitors connected in parallel.

(i) State the type of error caused by this mistake.

.... **[1]**

This was a systematic error, since it would affect all the results for *N* = 6 (and for larger values of *N*, if taken) in the same way

Question 2 (e) (ii)

(ii) Explain the effect that this error would have had on the calculated value of *R*.

....

....

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.... **[1]**

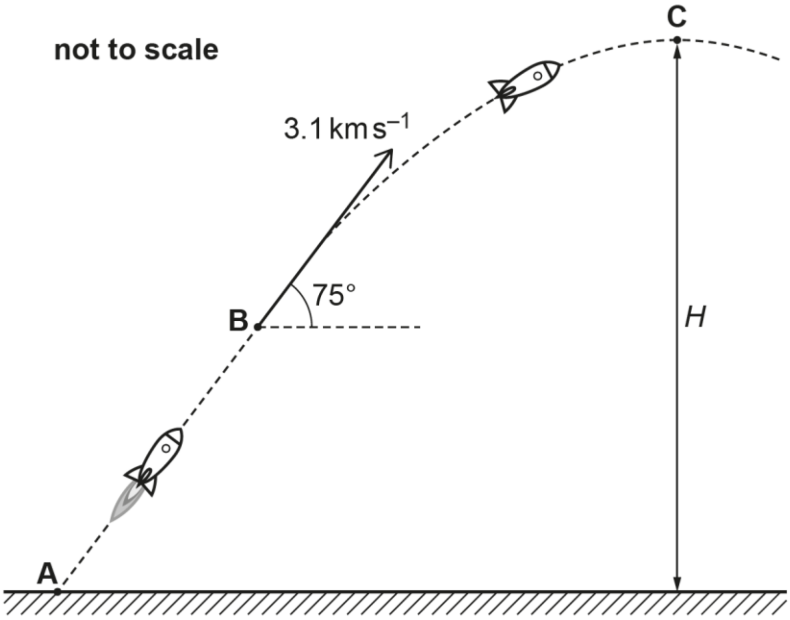
The students calculated their value for *R* by using the formula *R* (in kΩ) = ln (2) / gradient. If their sixth capacitance was too small then their gradient would also have been too small (because their point for *N* = 6 (N^2 = 36) would have been slightly lower). This means that their calculated value for *R* would have been too small.

Question 3 (a)

3 A scientist uses a rocket to study the Earth's atmosphere.

The scientist launches the rocket from rest at the point **A** at t = 0 seconds. The force produced by the rocket's engine causes it to accelerate.

At t = 50 seconds, the rocket's engine no longer produce an accelerating force as all of the fuel has been used. The rocket has reached point **B**. Its velocity is now 3.1 km s^{-1} at an angle of 75° to the horizontal.



(a) The rocket engine works by expelling hot gas backwards.

Explain, using Newton's laws of motion, how the engine causes the rocket to accelerate between t = 0 and t = 50 s.

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.... **[3]**

It was expected that candidates would use, rather than simply state, Newton's laws of motion in order to explain why the rocket accelerates. Most candidates were able to state, 'for every action there is an equal and opposite reaction' or even 'if A exerts a force on B, then B exerts and equal and opposite force on A'. However, few extended that to 'if the rocket exerts a force on the gas (backwards) then the gas will exert a force on the rocket (forwards)'. Even fewer went on to explain that, in order for the rocket to accelerate, this force must be greater than the weight of the rocket in order for there to be a resultant force (forwards).

Question 3 *(b)

***(b)** The rocket reaches its maximum height at point **C**.

- Estimate the vertical displacement *H* between **A** and **C**. Assume that $g = 9.81\,\text{m}\,\text{s}^{-2}$ throughout.
- Clearly state any other assumptions required at each stage in your calculations.
- Evaluate the assumption that $g = 9.81\,\text{m}\,\text{s}^{-2}$ between **A** and **C**, supporting your discussion with a calculation. Assume that the radius of the Earth ≈ 6400 km.

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.... **[6]**

Level 3 candidates set out a correct calculation of *H*¸ together with the assumptions required at each stage, plus an evaluation of the assumption that *g* remains constant at 9.81 ms^{-2} throughout.

Level 2 candidates missed out one or more of these three parts, usually the evaluation at the end, which they found quite difficult.

Level 1 candidates were often unable to calculate *H,* or the value of g at height *H,* correctly

Common problems in 3 (b)

- omission of sin 75° (or using cos 75°) when calculating velocity
- not converting from m to km correctly
- not squaring the r term in the calculation for *g*

Exemplar 1

• from A to B: s = __ u = 0 v = 3100 ms⁻¹ a = __ t = 50
So ~~v²-u²=~~ s = ½(u+v)t = ½(3100)×50 = 77500 m
So vertical height between A and B = 77500 × sin75° = 74859 m
~~At~~ from B to C: s = __ u = 3100 sin75° v = 0 a = −9.81
So v² − u² = 2as (3100 sin75°)² = 2×9.81×s t = __
s = 456995 m = 457000 m
So total height H = 456995 + 74859 = 532000 m above Earth's surface.
• the other assumptions include the assumption that the force output of the rocket, ~~on~~ its mass, and its acceleration all remain constant during A to B, ~~and~~ and the assumption that no frictional / air resistance forces act on the rocket from ~~A~~ A to C.

Exemplar 1 demonstrates good practice in answering a LoR question. The candidate has made sure they have answered each part of the question by using bullet points. Their calculations are clearly set out and so easy to follow, and their handwriting is legible. Instead of just calculating a value for *g* at height *H*, they have also given an explicit evaluation: 'The assumption that *g* remains constant is not reasonable'. Other candidates went on to say that this means that the rocket would reach an even greater height.

OCR support

OCR has a Guide to Level of Response Questions. This includes guidance on communication and the use of bullet points (page 5).

Question 4 (a)

4 The length of an unloaded spring is approximately 4 cm.

The force constant *k* of the spring is 0.62 N cm^{-1}.

(a) Describe how you could determine *k* using an appropriate experiment.

....

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.... **[3]**

In general, when asked to describe an experiment, it is good practice to describe which variables are being measured and what instruments are being used to measure them. In this case, we are measuring force (using a newton meter, or a top pan balance for mass plus F = mg) and extension (using a rule or tape measure). It is important to define extension, since it involves two measurements (extended length – initial length).

It is also good practice to describe a graphical method for measuring *k* rather than just carrying out a simple calculation.

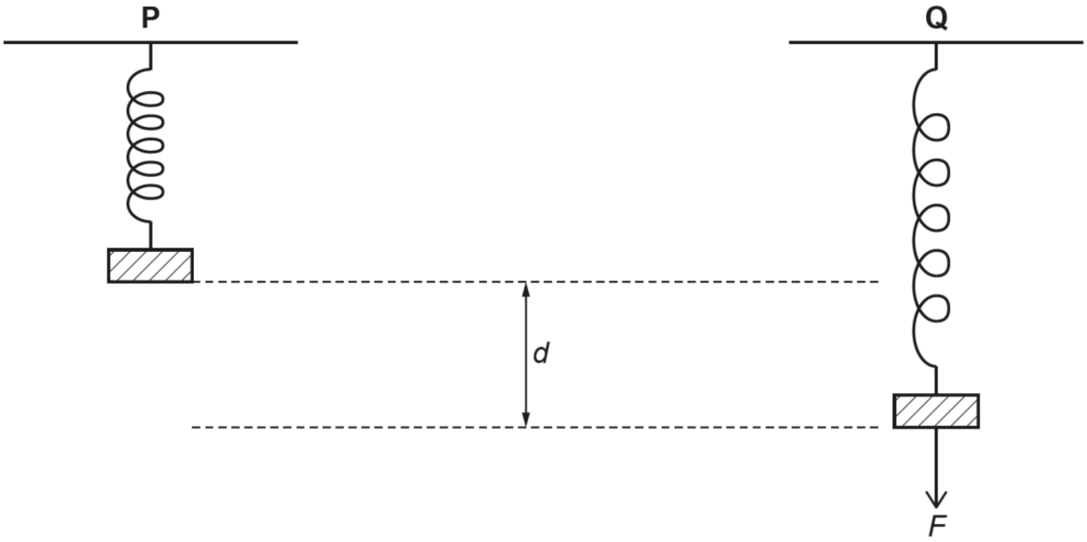
Candidates who said, 'I would plot a graph of F against x' or 'I would divide F by *x'* (without stating what F and x represented in terms of this experiment) gained no credit.

Question 4 (b) (i)

(b) The figure below shows a block of mass 0.20 kg attached to one end of the spring. The other end of the spring is attached to a fixed support vertically above the block.

In position **P** the block rests in equilibrium. The extension of the spring is 3.2 cm.

In position **Q** a downwards force *F* has been applied to the block, so that it now rests a distance *d* below its position at **P**. The extension of the spring is now 8.5 cm.



The force *F* is removed.

(i) Calculate the magnitude of the block's initial acceleration at the instant that the force *F* is removed.

Assume that the spring is not extended beyond its limit of proportionality.

acceleration = ... $m\,s^{-2}$ **[3]**

There are two measurements for extension given here: an extension of 3.2cm under a load of (0.2 x 9.81) N and an extension of 8.5cm under a force of F + (0.2 x 9.81)

The easiest way to approach the question is to recognise that the extension due to *F* alone must be (8.5 – 3.2) = 5.3cm. *F* = *kx* then becomes *F* = 0.62 x 5.3 (since *k* is given in N cm^{-1}) and so we can use *F* = *ma* with *m* = 0.2kg to find the acceleration *a*.

However, other valid methods were also given credit.

Question 4 (b) (ii)

(ii) The block now moves with simple harmonic motion.

Calculate the frequency of this motion.

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

The answer to this question is frequency = 2.8Hz, since ω depends only on k and m ($\omega^2 = k/m$).

However, most candidates used the formula $a = (-)\omega^2 x$ together with appropriate values for a and x.

Question 4 (c) (i)

(c) The block is replaced by a strong magnet **L** of slightly greater mass.

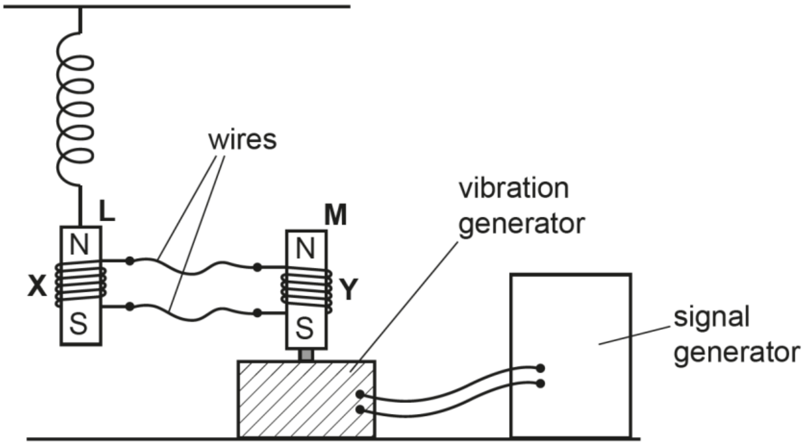
The oscillation frequency of this new arrangement is 2.5 Hz.

The magnet **L** is placed inside a coil **X** of insulated copper wire.

The coil **X** is connected with long wires to a second, identical coil **Y**.

A second strong magnet **M** is placed inside **Y** and attached to a vibration generator.

The vibration generator is then forced to oscillate with a frequency of approximately 2.5 Hz by adjusting the signal generator.



(i) As magnet **M** oscillates, it moves in and out of coil **Y**.

The magnet **L** also begins to oscillate.

Explain why **L** oscillates.

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....

....

....

.... **[3]**

Clarity in explanation was important here, as there are two magnets, M and L, plus two coils, X and Y. It is a change in flux linkage *in coil* Y which leads to an induced alternating current *in coil X.* This current creates an alternating magnetic field *in coil X* which interacts with the field *of magnet L* to create an alternating force on L.

Assessment for learning

Many explanations were too generalised: 'Faraday's Law states that there must be an induced emf which is proportional to the rate of change of flux linkage' or 'Fleming's left hand rule states there must be a force on the magnet' were often seen. Candidates should be encouraged to write in less general terms and to focus their answer on the specific question.

Question 4 (c) (ii)

(ii) The frequency of the vibration generator is now varied between 0.5 Hz and 5.0 Hz.

Suggest how the amplitude and frequency of the oscillations of **L** will change as the frequency of the generator is varied.

You may draw a diagram to support your answer.

[3]

Many candidates did not realise that this was a question about resonance, presumably because of the unfamiliar context of the question.

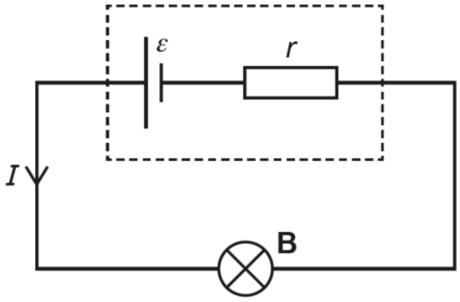
Common problems in 4(c)(ii)

- not answering every part of the question: most candidates forgot to describe how the frequency varied as well as the amplitude
- not realising that the vibration generator is driving the oscillation of L, and that this is a question about resonance
- not labelling the scales on the graph of amplitude against frequency (or just using letters such as *A* and *f*)
- failing to mark the resonance frequency as 2.5Hz (instead calling it f_o)

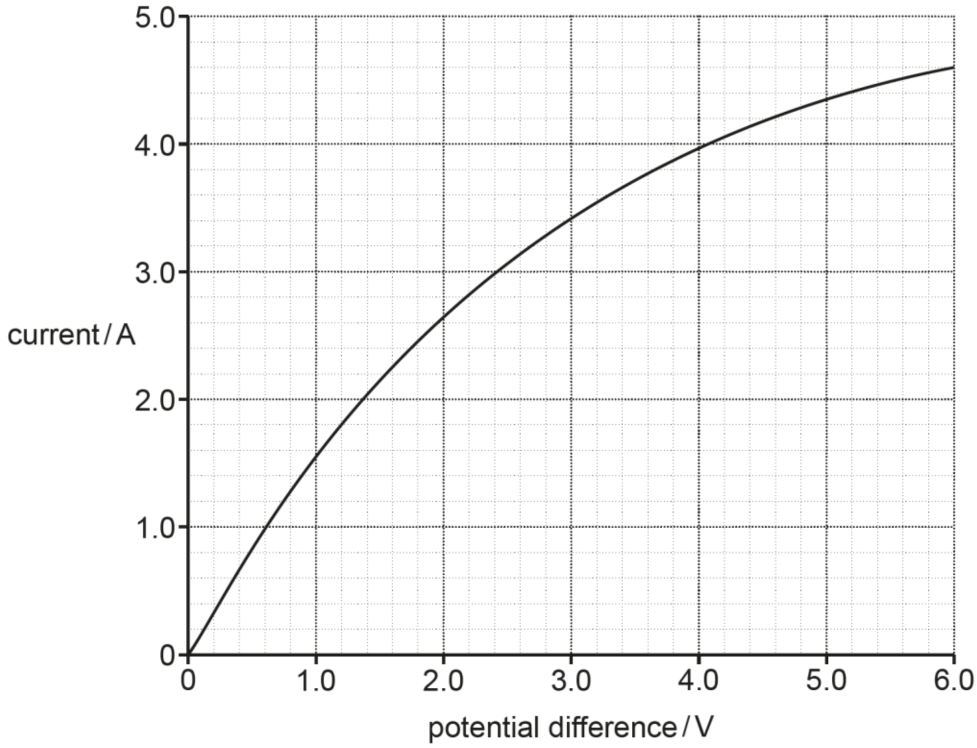
Question 5 (b)

(b) A cell has internal resistance $r = 1.2\,\Omega$ and e.m.f. $\varepsilon = 5.6\,V$.

When the cell is connected to a filament lamp **B**, as shown in the circuit diagram below, the current in the circuit is I.



The I-V characteristic for **B** is shown in the figure below.



Determine the current I in the circuit.

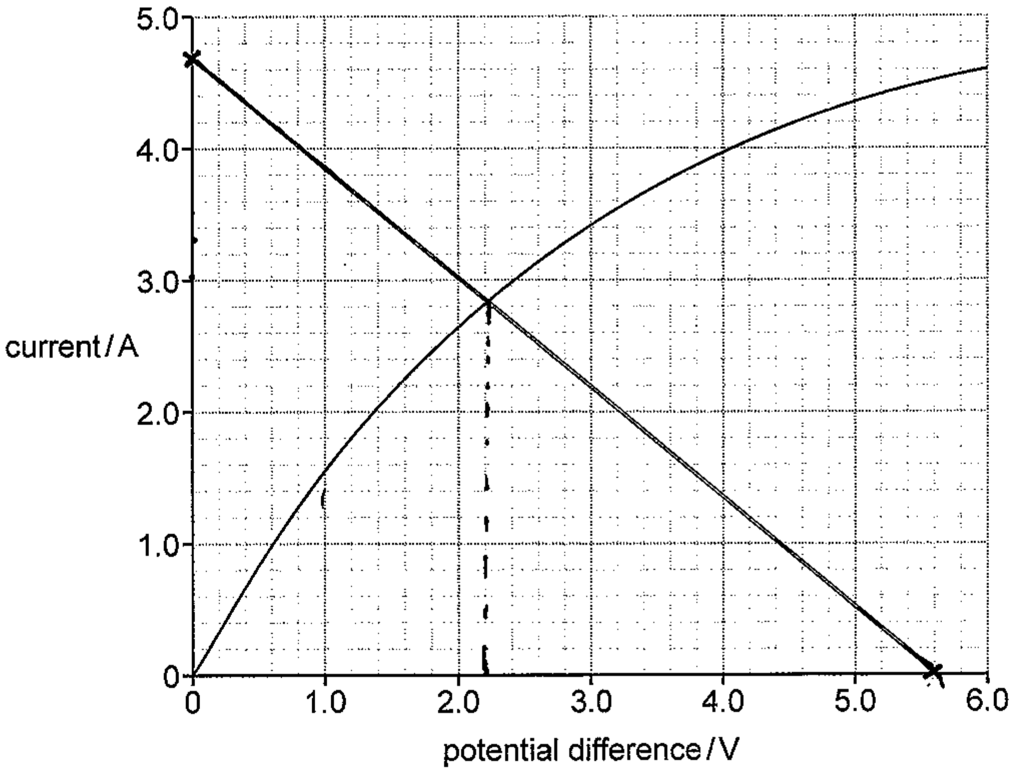
current = ... A **[3]**

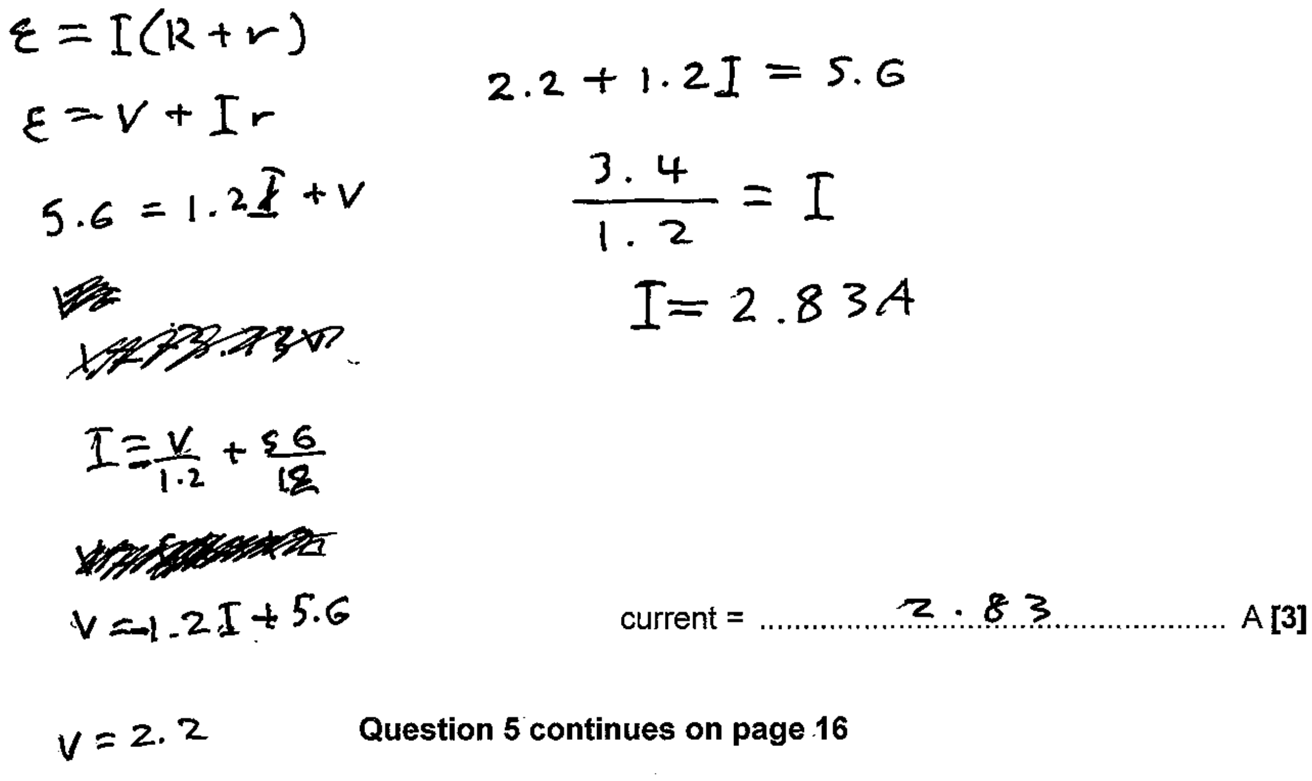
5 (b) (ii) was a question aimed at stretch and challenge level candidates with good problem-solving abilities..

Voltage V and current I are related through the formula ε = V + Ir so, given the values in the question, 5.6 = V + 1.2I. The relationship between V and I is also shown graphically. The problem is to find a pair of corresponding values for V and I which match both relationships.

One way of solving this problem is to draw the relationship 5.6 = V + 1.2I onto the graph. This can be done by arranging it into a y = mx + c form i.e. $I = 4.7 - 0.83V$. The solution to the problem can then be found where the two lines cross, which is the point (2.2, 2.8). So, the values I = 2.8A (and V = 2.2V) fit both relationships. This method of solution is shown in Exemplar 2.

Exemplar 2





An alternative method of solution is trial and improvement.

Pick a point on the V-I graph; say (1.2, 1.8). Calculate ε = V + 1.2I = 1.2 + 2.16 = 3.36V. This is lower than the 5.6V we need for the emf.

So, try a point higher on the graph: say (3.0, 3.4). Calculate ε = = 3.0 + 4.08 = 7.08V. This value is too high.

In this way we can eventually reach the correct point at (2.2, 2.8).

There are, of course, other methods of solving this problem.

The majority of candidates attempted to work out the resistance of an arbitrary point on the graph (often by finding the gradient, or 1/gradient, at a tangent) and then evaluated a current using 5.6 = I(R + 1.2). If they ended up with I = 2.8A, it was usually by luck rather than by good judgment.

Misconception

If you are given the I-V characteristic of a non-Ohmic device, you should never try to evaluate the resistance of the device using 1/gradient; this is incorrect physics. The gradient of the graph gives ΔI/ΔV, which is not the same as I/V.

For example, for the graph in this question, when V = 4.0V, the gradient of the graph is approximately 0.5 Ω^{-1}, but I/V = 4.0/4.0 = 1.0 Ω^{-1}

Question 5 *(c)

***(c)** A student wants to determine the internal resistance *r* and the e.m.f. ε of a different cell.

The student knows that the internal resistance is approximately 0.1 Ω.

The only other **electrical** equipment available is as follows:

- one voltmeter
- one ammeter
- one sensitive thermistor, known to have resistance of approximately 0.1 Ω at 20 °C
- several connecting wires and crocodile clips.

Describe how the student can determine *r* and ε for the cell.

Include how the student should:

- collect and analyse the data
- determine the uncertainties in the values of *r* and ε.

....

....

....

....

....

.... **[6]**

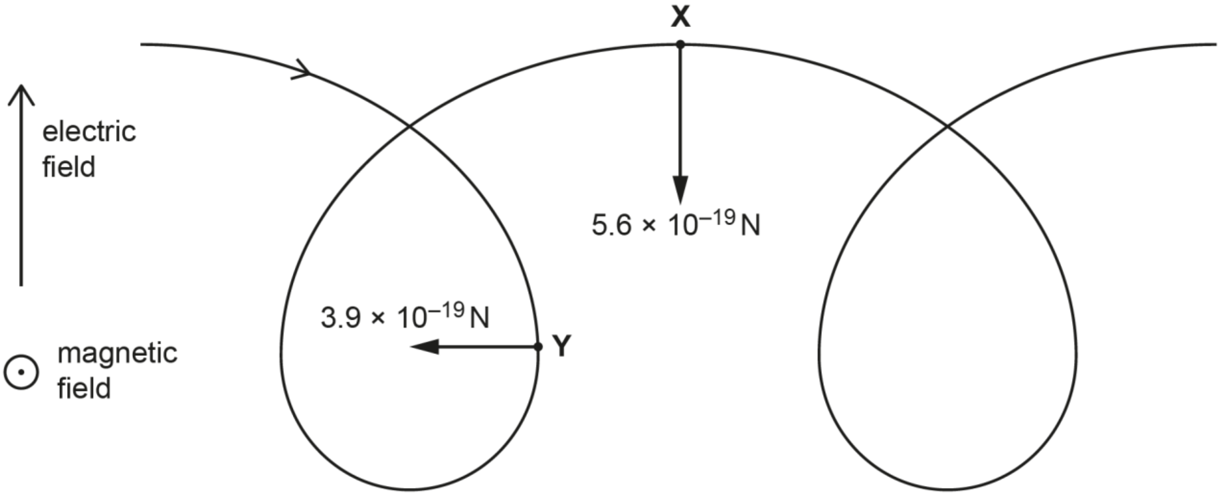
Although it was clear that many candidates had performed an experiment to determine *r* and ε for a cell, they were sometimes thrown by the need to use a thermistor rather than a variable resistor. Many candidates drew the symbol for a variable resistor anyway instead of a thermistor, and others put the variable resistor into the circuit alongside the thermistor. Some suggestions for varying the temperature of the thermistor were impractical.

Although it would be practically difficult to take several values of V and I at exactly the same temperature, candidates were allowed to use error bars found from half the range of repeated values, rather than by using the resolution of the ammeter and voltmeter. Often candidates were rather vague when trying to describe how to determine the uncertainties; 'Use the worst fit line' was often all the instruction that was given.

Question 6 (a)

6 The figure below shows the path of a proton moving in a region occupied by both an electric field and a magnetic field.

The direction of the electric field lines is perpendicular to the direction of the magnetic field lines.



The uniform electric field is directed upwards, with electric field strength $E = 0.90\,\text{N}\,\text{C}^{-1}$.

The uniform magnetic field is directed out of the plane of the paper, with magnetic flux density $B = 5.0 \times 10^{-5}\,\text{T}$.

At point **X** the proton is moving horizontally to the right. The magnitude of the **magnetic** force at **X** is 5.6×10^{-19} N.

At point **Y** the proton is moving vertically downwards. The magnitude of the **magnetic** force at **Y** is 3.9×10^{-19} N.

The **electric** forces acting on the proton at **X** and **Y** are **not** shown in the figure.

(a) Show that the magnitude of the constant **electric** force acting on the proton is about 10^{-19} N.

[1]

This was an easy introduction to the question, which used the definition of electric field strength; $E = F_E / Q$. Being a 'show that' question, candidates needed to show their working in full, including writing the value for the electronic charge (rather than simply 'e') and giving the answer to at least 2 s.f.

Question 6 (b) (i)

(b)
(i) Suggest why the **magnetic** force acting on the proton has a different magnitude at **X** than at **Y**.

....

....

.... **[1]**

The force on a charged particle moving at right angles to a magnetic field is given by the formula $F_{mag} = BQv$. Since B and Q are constants in this case, the reason for the different magnitude of F must be that the proton has a different velocity, v.

Common problems in 6(b)(i)

- using the formula $F = BIl\sin\theta$ and suggesting that the proton might be travelling at a different angle to the field, not realising that the proton is always travelling at right angles to the magnetic field in this question
- suggesting that the proton may be in a weaker (or stronger) field at X than at Y, not realising that the magnetic field is uniform and so its field strength is constant throughout

Question 6 (b) (ii)

(ii) At **X**, the motion of the proton is instantaneously equivalent to motion in a circle at a constant speed.

Calculate the radius of this circular motion.

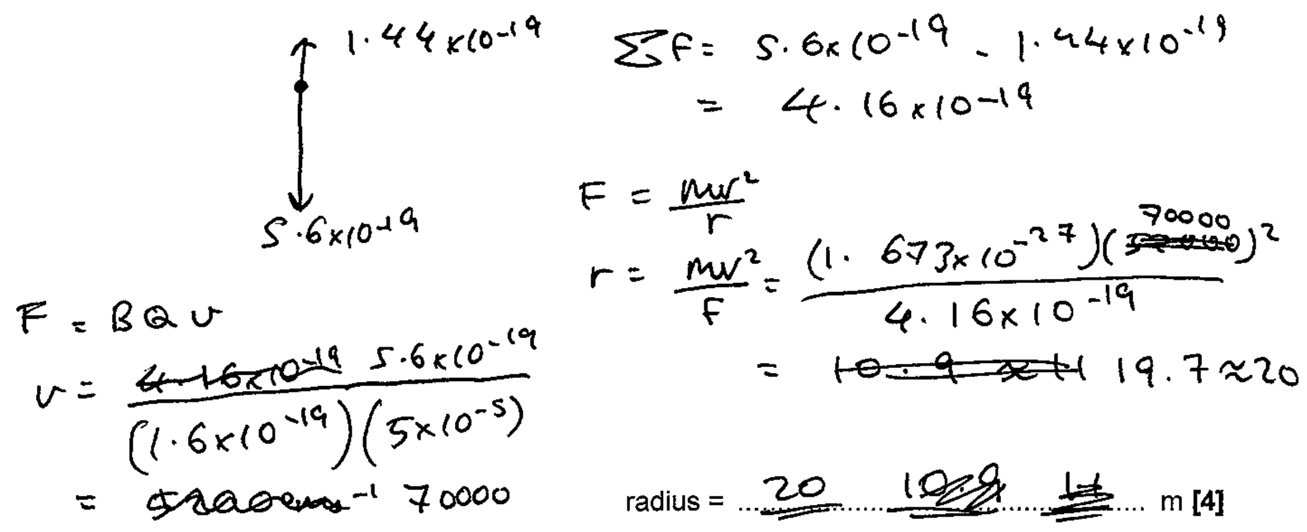
radius = ... m **[4]**

This question could not be done in one step, by equating the magnetic force to the centripetal force. This is because, at X, the centripetal force is being provided by a combination of forces from both the electric and the magnetic field.

The easiest approach is to find the velocity of the proton using $F_{mag} = BQv$ (the value for F_{mag} is given in the diagram as 5.6 x 10^{19} N). This velocity v can then be used in the formula $F = mv^2/r$ *in order* to calculate the radius, r. F here is the *resultant* force towards the centre of the circle, which is found from magnetic force downwards – electric force upwards (the electric force having been calculated in part (a)).

Exemplar 3 is an example of a correct answer, clearly written to show each stage in the calculation:

Exemplar 3



Question 6 (b) (iii) 1

(iii) 1 Calculate the magnitude of the resultant force on the proton at **Y**.

resultant force = ... N **[2]**

There are two forces acting on the proton at Y: an electric force upwards (given in (a)) and a magnetic force to the left (shown on the diagram). These two forces act at right angles to each other, and so the magnitude of their resultant can be found using Pythagoras's Theorem.

Credit was given for using a value for the electric force to 1, 2 or more significant figures.

Question 6 (b) (iii) 2

2 Explain why the motion of the proton at **Y** is **not** instantaneously equivalent to motion in a circle at a constant speed.

....

....

....

.... **[2]**

At Y, the proton is moving downwards, with a resultant force being the combination of an electric force upwards and a magnetic force to the left (calculated in part 1). The resultant force cannot be at right angles to the velocity, so we cannot have circular motion.

The component of the resultant force acting in the direction of the proton's motion will do work on the proton and change its speed. So, the proton cannot be travelling at a constant speed.

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