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A LEVEL

Examiners' report

PHYSICS A

H556

For first teaching in 2015

H556/03 Summer 2022 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 are 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.

Advance Information for Summer 2022 assessments

To support student revision, advance information was published about the focus of exams for Summer 2022 assessments. Advance information was available for most GCSE, AS and A Level subjects, Core Maths, FSMQ, and Cambridge Nationals Information Technologies. You can find more information on our website.

Paper 3 series overview

H556/03, 'Unified Physics', is the third of the three examination components for GCE Physics A. It assesses all areas of the course and each question will incorporate subject matter from various different topics. In addition, a large proportion of the questions target the higher assessment objectives (AO2 and AO3). This means that candidates should expect multi-stage calculations and problem-solving questions rather than simple recall.

In general, most candidates confidently answered those questions with mathematical content. However, questions which required descriptive responses were less well answered. Centres should aim to provide more opportunities to practise this sort of question from past papers and then instruct candidates to mark them carefully using the mark schemes which can be found on the OCR website.

Candidates who did well on this paper generally did the following:	Candidates who did less well on this paper generally did the following:
• gave good descriptive responses as well as good numerical responses • used scientific ideas and terms correctly • wrote focused and clearly structured responses to the level of response (LoR) questions • accurately converted between measurements in standard form and ones using common SI prefixes • showed all stages of their working clearly	• used scientific ideas and terms imprecisely • gave incorrect values for common SI prefixes • did not show all stages of their working • drew an inaccurate line of worst fit • did not read questions carefully enough

Assessment for learning

The standard of handwriting was noticeably poorer than in previous years. Centres should be aware that candidates will invariably lose marks if large parts of their responses are illegible.

Question 1 (a)

1 The table shows some data on the planet Venus.

Mass / kg	4.87×10^{24}
Radius / km	6050
Density of atmosphere at surface / kg m^{-3}	65
Period of rotation about its axis / hours	5830

(a) Calculate the magnitude of the gravitational field strength g at the surface of Venus.

Give your answer to **3** significant figures.

g = ... N kg^{-1} **[3]**

This was a gentle start to the paper, with the formula $g = GM/r^2$ being provided in the data, formulae and relationships booklet.

Common problems in 1(a)

- omitting to convert r from km to m and so incurring a power of ten (POT) error
- using a value of G from a calculator or from memory rather than copying the 3 significant figure (3sf) value given in the formula sheet
- writing the answer to more (or less) than the 3sf specified in the question

Question 1 (b) (i)

(b) Two identical space probes, **A** and **B**, land on a flat surface on Venus.

Probe **A** lands at the north pole. Probe **B** lands on the equator.

Each probe has mass 760 kg and volume 1.7 m^3.

(i) Calculate the centripetal acceleration *a* of probe **B** at the equator due to the rotation of Venus about its axis.

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

A slightly harder question, requiring the use of two formulas (either $a = \omega^2 r$ and $\omega = 2\pi / T$, or $a = v^2/r$ and $v = 2\pi r / T$).

Some marks were available for calculating either ω or v correctly.

Common problems in 1(b)(i)

- omitting to convert T from hours to seconds, or converting T incorrectly
- omitting to convert r from km to m and so incurring a POT error

Question 1 (b) (ii)

(ii) The atmosphere exerts the same upthrust on each probe.

Using your answer to **(a)**, calculate the upthrust acting on each probe.

upthrust = ... N **[3]**

Unfortunately, many candidates did not know how to calculate upthrust, often confusing it with the normal contact force. This may be because upthrust forms a small part of the syllabus and is therefore easily overlooked.

Upthrust = weight of fluid (atmosphere) displaced by the probe. The volume of the atmosphere displaced by the probe is identical to the volume of the probe itself.

Common problems in 1(b)(ii)

- using the value g = 9.81 rather than the value of g on Venus calculated in (a)
- using the mass of the *probe* instead of calculating the mass of the *atmosphere* using the formula mass = density of atmosphere × volume of probe

Question 1 (b) (iii)

(iii) Explain which probe will experience the greater normal contact force from the surface of Venus.

....

....

....

....

....

.... **[3]**

Candidates often struggle to demonstrate a clear understanding of circular motion, and this year was no exception.

Most candidates understood that probe **B** on the equator was acted on by centripetal force whereas probe **A** at the pole was not. However, some thought that the centripetal force acted outwards, away from the surface. Many thought that the centripetal force was a separate force acting on probe **B** in addition to its weight. These candidates wrongly concluded that this would increase the force towards the centre, resulting in an increased normal contact force. Whereas the opposite is actually the case; part of the probe's weight must be used to provide the centripetal force, and so the normal contact force would be smaller.

A very common mistake was to ignore the effect of upthrust acting on the probe. Although the upthrust would be the same both at the equator and at the pole, it was worth a mention. Upthrust = 980N (from b(ii)) whereas the centripetal force was only 760 × 5.42 × 10^{-7}N (from b(i)).

Assessment for learning

The author of the examination paper structures questions to support candidates in writing their responses. 1(b)(i) is a calculation of the centripetal acceleration and 1(b)(ii) is a calculation of the upthrust. These provide a logical progression to 1(b)(iii) which involves both centripetal acceleration and upthrust (and not, say, the shape of Venus or its magnetic field).

Question 2 (a)

2 A student investigates the oscillations of a uniform rod of length L which is pivoted at the top, as shown in **Fig. 2.1**.

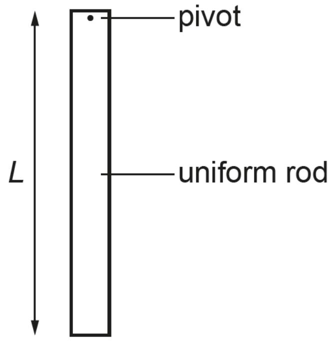


Fig. 2.1

(a) Describe how to determine accurately the period T of oscillations of this rod.

....

....

....

.... **[2]**

When asked to describe how to measure a physical quantity, it is important to include the correct measuring instrument as part of the response. A stopwatch or stop clock is the simplest, but any method is acceptable as long as a timer is mentioned. For example, 'I measured the time using my phone' would not be accepted, but 'I used my phone to record the event with a timer in view and then played it back/viewed it frame by frame' would be fine.

Measuring the number of oscillations in a fixed time period (10 seconds, say) and then calculating T from the frequency was not accepted as it is a less accurate method than the one described in the mark scheme.

Question 2 (b) (i)

(b) The relationship between the frequency f of the oscillations of the rod and its length L is

$$f = \frac{1}{2\pi}\sqrt{\frac{3g}{2L}},$$

where g is the acceleration of free fall.

The student varies the length L of the rod and determines the period T for each length.

The student plots a graph of T^2 against L, shown in **Fig. 2.2**. A line of best fit has already been drawn.

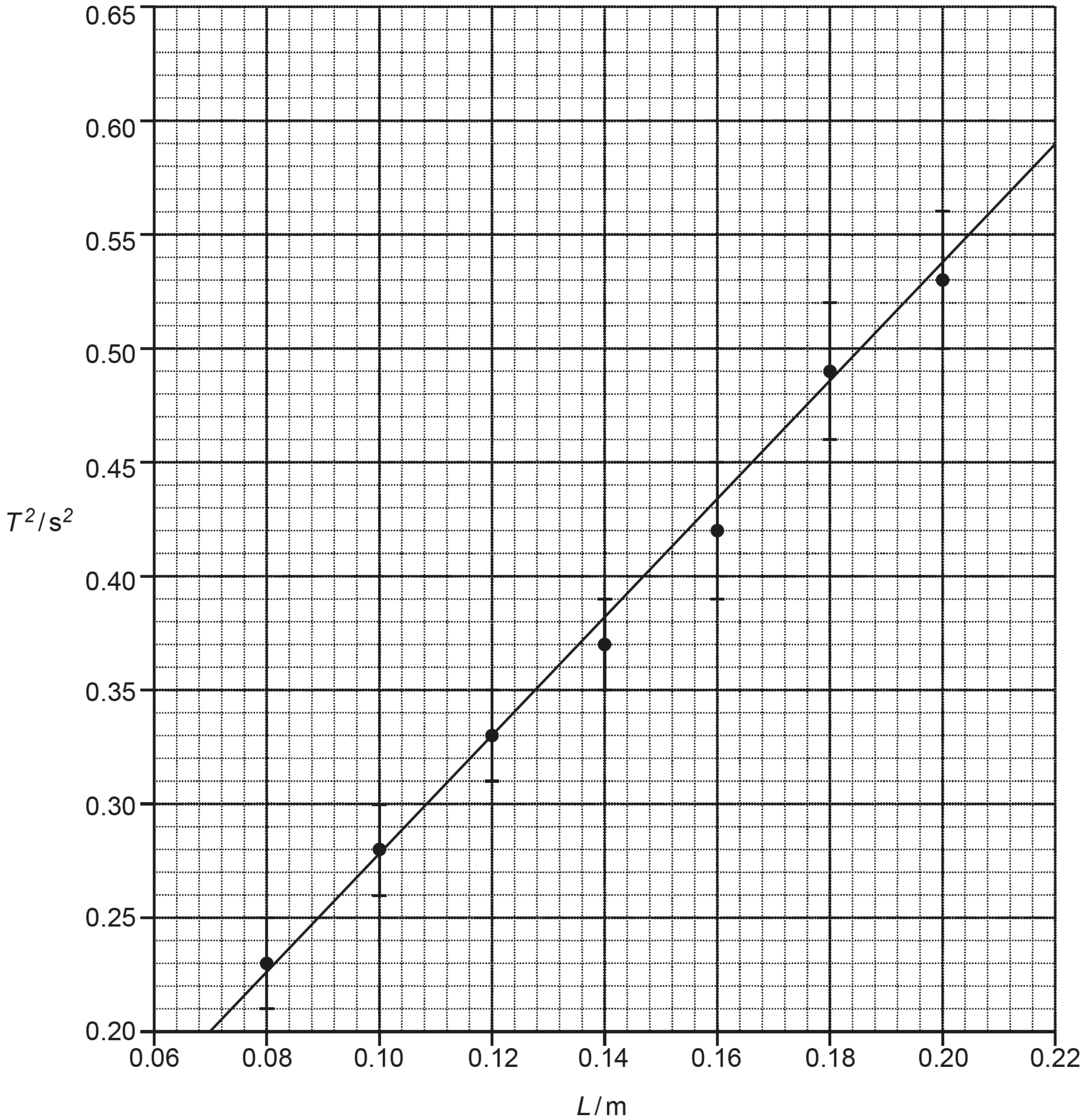


Fig. 2.2

(i) Show that the gradient of the graph is given by the equation

gradient = $\dfrac{8\pi^2}{3g}$

[2]

The expected response here was to start from the given relationship $f = \dfrac{1}{2\pi}\sqrt{\dfrac{3g}{2L}}$ and then use $T = 1/f$ to manipulate the expression into the form $y = mx + c$.

Candidates who recognised this generally had sufficient skill in algebra to arrive at the correct answer.

Question 2 (b) (ii)

(ii) The gradient of the line of best fit on **Fig. 2.2** is 2.64 $s^2\,m^{-1}$.

Use this value to determine g.

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

Candidates needed to substitute gradient = 2.64 into the formula $g = \dfrac{8\pi^2}{3 \text{ x gradient}}$.

This was arguably the easiest question on the paper. Although almost all candidates scored both marks, a few lost a mark through thinking that 9.97 = 10.0 to 3sf.

Question 2 (b) (iii)

(iii) Draw a line of worst fit on **Fig. 2.2**. **[1]**

A line joining the top of the furthest right hand error bar to the bottom of the furthest left hand error bar (or vice versa) passed through all the error bars. Either was accepted. A tolerance of ±½ small square was allowed at either end.

The most common misconception was that the worst fit line joined the top of the right hand error bar to the top of the left hand error bar (or vice versa).

Question 2 (b) (iv)

(iv) Use your line of worst fit to calculate the percentage uncertainty in *g*.

percentage uncertainty = ... % **[3]**

It is important to show all working in this type of question.

Firstly, in checking the gradient of the worst fit line, the examiner needs to determine whether a large triangle has been used in the calculation. Therefore it is helpful if candidates draw the triangle they intend to use and write down all their read-offs.

Secondly, the working to find the percentage uncertainty in *g* has to be shown in full because the correct answer is $\frac{\text{worst value of } g - 9.97}{9.97}$ and not $\frac{\text{worst value of } g - 9.97}{\text{worst value of } g}$.

Although the percentage uncertainty in the gradient was not exactly the same as the percentage uncertainty in *g*, both methods were accepted.

Question 2 (b) (v)

(v) Use the true value of *g* ($9.81\,\mathrm{m\,s^{-2}}$) to evaluate the accuracy of the student's value of *g* from this experiment. Include a calculation in your answer.

....

....

....

....

.... **[2]**

Most candidates were able to calculate either the absolute or the percentage difference between the experimental result (9.97) and the true value of *g* (9.81). Many candidates wrongly called this the percentage uncertainty or the percentage error in the result, but their calculation was accepted anyway.

A common misconception was that the relatively small percentage difference (1.6%) between the experimental result and the true values meant that the experiment was accurate. However, this is not necessarily the case. A result is only accurate if it is close to the true value and, unless we know the *uncertainty* in our result, we cannot judge whether or not this is the case.

For example, suppose that the uncertainty in our result was 1% i.e. we found that $g = 9.97 \pm 0.10$. Then our result for *g* would *not* be accurate. Our result must be somewhere between 10.07 and 9.87, and the true value of *g* (9.81) lies outside this range.

Question 3 (a)

3 (a) In beta-plus decay, a proton decays into three other particles.

Write a nuclear equation for this process.

[2]

The question did not specify what type of equation was needed, and the simple word equation

proton → neutron + positron + neutrino

was sufficient for full marks.

Common problems in 3(a)

- using the symbol N instead of n for neutron (N is the symbol for nitrogen)
- using incorrect A/Z values such as ${}^{0}_{1}n$ for neutron and/or ${}^{0}_{-1}e$ for positron
- using an incorrect symbol for the neutrino

Question 3 (b)*

(b)* A student, supervised by their teacher, carries out an experiment with three unlabelled radioactive sources.

The student is told that each source emits only one type of radiation. One emits gamma rays, one emits beta-minus particles and one emits beta-plus particles.

The student has the following equipment:

- a selection of materials with different thicknesses
- a strong magnet
- a radiation counter (GM tube and counter).

Explain how the student can use this equipment to determine safely which radiation each source emits.

You may use the space below to draw a diagram. **[6]**

When marking a LoR question, the examiner first decides the level of response (1, 2 or 3) by considering the quality of the physics. The examiner then decides whether to award the top of the level (for a well-structured and relevant response) or the bottom of the level (for a poorly structured and mostly irrelevant response).

In this LoR question, responses in Level 1 often contained insufficient key physics. The experiment described was extremely safe and painstaking but, at the end of the day, the three sources were not clearly distinguishable. Low level responses frequently included instructions on how to test for an alpha source. The magnet was often used either to pick up the sources or to attract/repel charged particles.

In a typical top level response, the thickness of aluminium used to block beta (but not gamma) was specified. A perpendicular magnetic field was used to separate the charged particles and the direction of their travel was predicted using an accurate diagram and Fleming's left hand rule.

There were three possible approaches:

1. Investigate the range in air. Gamma has the largest range and beta-plus the smallest (due to annihilation). (The answer 'both beta-plus and beta-minus have a similar range in air' was also accepted).

2. Investigate the path through a perpendicular magnetic field. Gamma is undeflected; beta-plus and beta-minus would deflect in opposite directions.

3. Investigate the penetrative power. Since the materials and thicknesses available were not specified, it was easiest to keep increasing the thickness and density of the materials until all but one of the sources was blocked, thus identifying the gamma source.

Many candidates were unable to distinguish clearly between the two beta sources because they did not understand how beta-plus and beta-minus particles would travel in a magnetic field. Many candidates erroneously thought that a magnet had a positive pole (which would attract beta-minus) and a negative pole (which would attract beta-plus).

Misconceptions

- A bar magnet does not have positive and negative poles – it has north and south poles
- A magnet does not attract or repel charges – it exerts a force on charged particles moving at right angles to its magnetic field

Question 4 (a)

4 Astronomers can detect microwave background radiation coming from space in every direction.

The temperature of this microwave radiation is 2.7 K and its **total** intensity is about $3 \times 10^{-6}\ \mathrm{W\,m^{-2}}$.

(a) Describe the origin of the microwave background radiation.

....

....

....

.... **[2]**

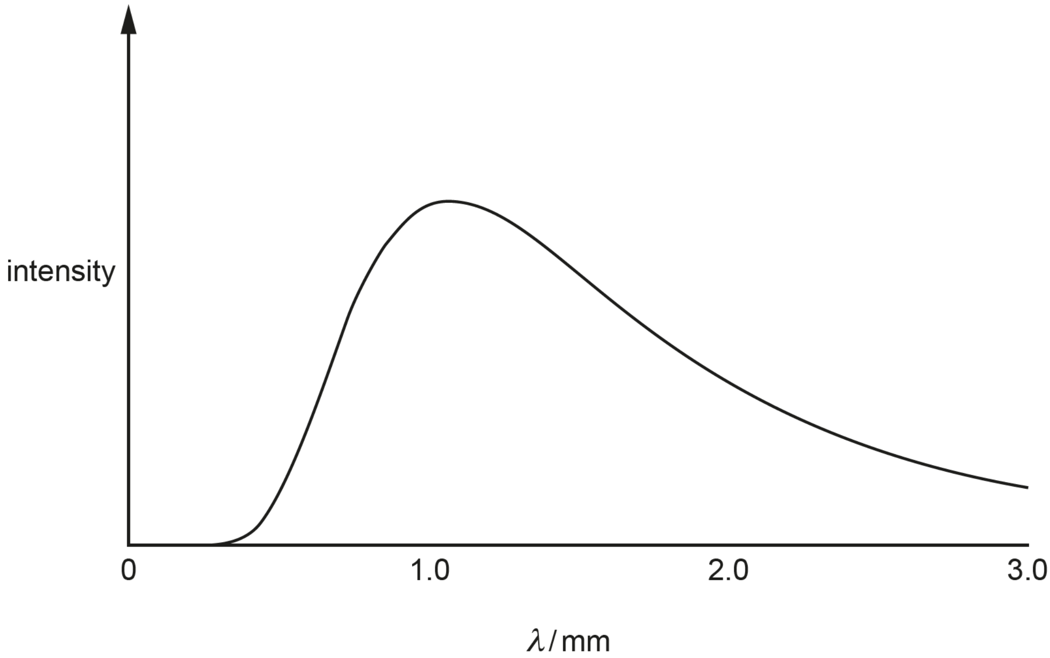
Most candidates knew that the microwave background radiation originated in the Big Bang, although one common misconception was that it formed as microwaves which then spread through space. A few candidates thought that it came from black holes or supernovas.

Precision in scientific language was important here. The photons themselves have not expanded or cooled since the Big Bang, and it is their <u>wavelength</u> that has increased / stretched / been red-shifted.

Question 4 (b) (i)

(b) The figure below shows how the intensity of the microwave background radiation varies with its wavelength λ.

The **peak** intensity is at a wavelength of 1.1 mm.



This spectrum of microwave background radiation changes with temperature according to Wien's displacement law.

(i) Suggest and explain how the spectrum might have looked in the distant past. You may draw on the figure to support your answer.

....

....

....

.... **[2]**

The mention of Wien's displacement law gave a clue that it would be useful in answering the question. A mark was given for stating the law. Note that the law is $\lambda_{MAX} \propto 1/T$ rather than $\lambda \propto 1/T$ or $\lambda_{MAX} = 1/T$.

Candidates who did not draw on the diagram to illustrate their response sometimes missed the second B1 mark because they said that the wavelength (rather than the peak wavelength) would have been smaller. If an examiner says, 'You may draw on the diagram', it is generally a beneficial approach.

Question 4 (b) (ii)

(ii) Calculate the energy of a photon which has a wavelength of 1.1 mm.

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

This was a straightforward question and most candidates correctly chose and applied the formula $E = \frac{hc}{\lambda}$

Common problems in 4(b)(ii)

- not converting mm to m
- trying to convert the answer to or from MeV

Question 4 (b) (iii)

(iii) Estimate the number of photons of microwave background radiation incident per second on the back of your hand.

Assume that all emitted photons have the energy calculated in **(ii)**, and that the back of your hand has a surface area of 150 cm^2.

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

This is a complex, multi-stage calculation. A good approach was to use:

number of photons per second × energy of each photon = amount of energy per second

= power

= intensity × area

The total intensity of the microwave background radiation was given at the start of the question as 3×10^{-6} $W\,m^{-2}$.

Converting cm^2 into m^2 proved difficult for many.

Question 4 (b) (iv)

(iv) A scientist suggests that the microwave background radiation could be used as an energy source.

The scientist proposes using large tanks of water to absorb the microwave radiation.

Estimate the maximum rise in temperature that could be produced per second for a large cylindrical tank of depth 5.0 m. Assume that all microwave radiation incident on the top of the tank is absorbed.

density of water = $1000\,\text{kg}\,\text{m}^{-3}$
specific heat capacity of water = $4200\,\text{J}\,\text{kg}^{-1}\,\text{K}^{-1}$

maximum rise in temperature per second = ... $°\text{C}\,\text{s}^{-1}$ **[3]**

This too was a complex, multi-stage calculation.

Most candidates correctly found their way into the question by writing down the formula $E = mc\Delta\theta$ and realising that they needed to use the formula $\rho = m/V$ in order to calculate the mass. The volume V of the cylindrical tank could be found using V = depth × cross-sectional area. However, although the depth was specified in the question, the cross-sectional area was not.

Successful candidates realised that, if the cross-sectional area was not given, then it must cancel out later in the calculation. Some used algebra and called the cross-sectional area A. Others simply made up a value for A ($A = 1\,\text{m}^2$ is the easiest).

Question 5 (a) (i)

5 A student experiments with microwaves emitted from a transmitter. The frequency *f* of the microwaves from the transmitter can be adjusted.

(a) The microwaves are produced by an alternating current in the transmitter.

In one experiment, *f* is 11 GHz. In a wire in the transmitter, the magnitude of the **maximum** alternating current is 20 mA. The wire has cross-sectional area $1.4 \times 10^{-8}\,\mathrm{m}^2$ and is made of a metal with free electron number density $8.0 \times 10^{28}\,\mathrm{m}^{-3}$.

(i) Show that the maximum drift velocity of each free electron in the wire is about $0.1\,\mathrm{mm\,s^{-1}}$.

[3]

Since the answer is given here and candidates are being asked to show where it comes from, it is important to show every stage in the working. The following steps were necessary to gain full marks:

write down the correct formula

substitute the given values <u>and</u> the values of any physical constants (such as *e*)

work out the answer to more significant figures than given in the question

Exemplar 1

20×10^{-3} A

$I = AneV$

$= 1.4\times10^{-8} \times n \times 1.6\times10^{-19} \times V$

$\quad\quad\downarrow 8\times10^{28}$

$V = \dfrac{20\times10^{-3}}{1.4\times10^{-8} \times 8\times10^{28} \times 1.6\times10^{-19}} = 1.116\times10^{-4}\,\mathrm{m/s} = 0.116\,\mathrm{mm/s}$

$\approx 0.1\,\mathrm{mm/s}$ **[3]**

0.01 cm

0.0001 m/s

The exemplar above shows the type of response that gained full marks.

Question 5 (a) (ii)

(ii) The student models the average motion of the free electrons in the wire as simple harmonic motion.

Use your answer to **(i)** to calculate the amplitude *A* of this motion.

A = ... m **[3]**

The formula sheet gives $v = \pm\omega(A^2 - x^2)^{½}$ as a starting point.

The maximum velocity of the electrons has been given in (i) as 0.1 mm s^{-1}. The electrons are moving in simple harmonic motion, and so their maximum velocity occurs as they pass equilibrium i.e. when $x = 0$. This simplifies the formula to $v_{MAX} = \omega A$.

Equal marks were given for using either the given value for v_{MAX} of 0.1 mm s^{-1} or the candidate's own value from (a)(i).

Exemplar 2

$V_{max} = 2\pi f A$ $= 1.5915... \times 10^{-15}$ m

$A = \frac{V_{max}}{2\pi f}$

$A = \frac{1.1\times10^{-4}}{2\pi \times 11\times10^{9}}$

A = 1.6×10^{-15} m **[3]**

The exemplar above shows the type of response that gained full marks.

Question 5 (a) (iii)

(iii) Without further calculation, explain how the maximum acceleration of a free electron varies as the frequency *f* is adjusted, provided that the maximum alternating current remains constant.

....

....

....

.... **[2]**

This was a difficult question; hard to visualise and involving some challenging algebra.

Most candidates did not notice that the question specified the <u>maximum</u> acceleration of a free electron. Therefore the most common response was that $a = (2\pi f)^2 x$, showing that $a \propto f^2$. This gained no marks.

Other candidates went further and said that the maximum acceleration occurs when $x = A$. This means that $a_{MAX} = (2\pi f)^2 A$ and so $a_{MAX} \propto f^2$, since A is constant.

However, the amplitude A of the oscillation is itself dependent on the frequency. If the maximum current remains constant then the maximum velocity v_{MAX} of the electron must also remain constant. In (a)(ii), we used the fact that $v_{MAX} = 2\pi fA$, so fA must remain constant. $a_{MAX} = (2\pi f)^2 A = (2\pi)^2 fA \times f$ = constant $\times f$. So we conclude that $a_{MAX} \propto f$.

An easy way to see this algebraically is:

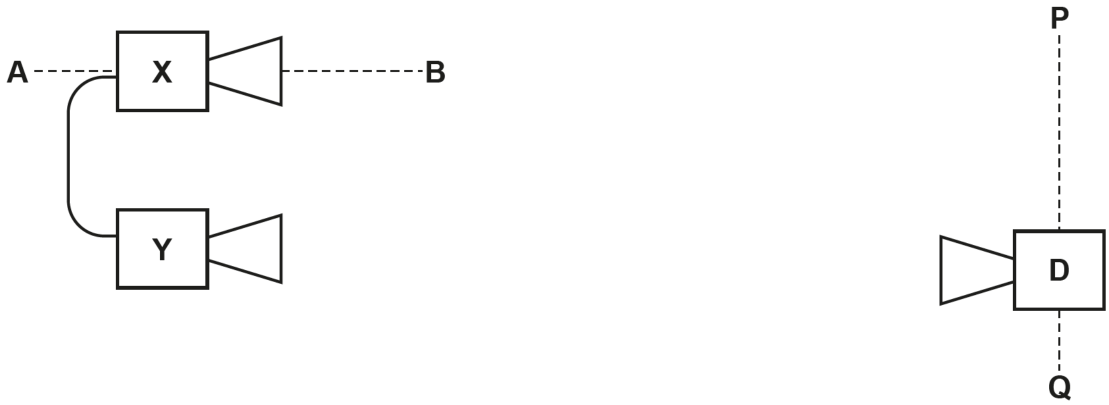
$a_{MAX} = (2\pi f)^2 A$ and $v_{MAX} = 2\pi fA$

Therefore $a_{MAX} = (2\pi f)\, v_{MAX}$

v_{MAX} remains constant and so $a_{MAX} \propto f$

Question 5 (b) (i)*

(b) The student connects two microwave transmitters **X** and **Y**, and places them in front of a microwave detector **D**, as shown in the diagram below.



The transmitters **X** and **Y** produce **coherent** vertically polarised microwaves with the same frequency *f*.

The detector **D** is sensitive to vertically polarised microwaves only.

When the detector **D** is moved along the line **PQ**, a pattern of maximum and minimum intensity is observed. Adjacent maxima are separated by a distance *x*.

(i)* Explain:

- why this pattern of intensity occurs
- the expected relationship between the frequency *f* and the distance *x*
- how to verify this relationship experimentally. **[6]**

There were three parts to this LoR question and all needed to be addressed to access the top level.

Candidates were first asked to explain why a pattern of maximum and minimum intensity was observed. Marks were given to candidates who used precise scientific wording, e.g. destructive interference occurs when waves are in antiphase (rather than merely out of phase) or when the path difference is an odd number of half wavelengths (rather than merely an odd number of wavelengths). Fewer marks were given to candidates who wrote about waves 'cancelling out' or 'amplitudes subtracting'.

In the second part, the expected relationship between the frequency *f* and the distance *x* is that *f* and *x* are inversely proportional. Most candidates were able to explain this, either algebraically ($\lambda = ax/D$ and $c = f\lambda$ so $x = cD/af$) or descriptively in terms of the waves overlapping more closely as *f* increased.

The third part of the question required an explanation of how to verify this inversely proportional relationship. The question stated that the frequency *f* of the microwaves could be adjusted. So the experimental procedure involved varying *f* and measuring *x* (over several maxima for accuracy). If a graph of *f* against $1/x$ gives a straight line through the origin then the relationship is verified.

Exemplar 3

To prove this relationship the distance between adjacent maxima (x) should be measured as the frequency of the microwaves changes. f should be measured from readings on the transmitter

Additional answer space if required

or using an oscilloscope ($f \propto \frac{1}{T}$); ~~and~~ x should be measured using a ruler*. Plotting a graph of $\frac{1}{x}$ against f should produce a straight line that passes through the origin with a gradient equal to $\frac{a}{vD}$.

* The maxima can be identified as points of the greatest amplitude, a marker should be placed at each maxima. Measure the distance between multiple maxima and divide by the number of maxima to obtain a more accurate value of x.

The exemplar above shows a successful response for the third part of the question. It makes it clear what to vary, what to measure, what measuring instruments to use, and what to do graphically with the results.

Assessment for learning

Only use the words node and antinode in the context of stationary waves.

Question 5 (b) (ii)

(ii) Transmitter **X** is rotated about the line **AB** and the experiment is repeated at different orientations until it has been rotated by 180°.

Describe and explain the observed patterns of maximum and minimum intensity.

....

....

....

....

....

.... **[3]**

This question was misread by many candidates, who described the variation in *overall* intensity instead of the variation in the *interference pattern*. Some candidates thought that transmitter **X** was rotating away from **Y**, rather than about the **AB** axis.

Only a few candidates correctly explained the change in pattern in terms of the change in the amount of interference between the waves from **X** and **Y**. Many said detector **D** was receiving less of a signal from **X**, rather than interference was lessening because of a reduction in the vertical component from **X**.

Question 6 (a)

6 (a) Define the **time constant** of a circuit containing a capacitor of capacitance C and a resistor of resistance R.

....

.... **[1]**

To find the time constant of a capacitor, we look at the time taken for the charge on a discharging capacitor to fall from any initial value to 37% ($1/e$) of that value. We could also take values of current or voltage. However, it is not the time taken for the <u>capacitance</u> to fall from C_o to C_o/e – the capacitance remains constant.

Care is needed with wording here. Either the charge falls <u>to</u> 37% of its initial value, or it falls <u>by</u> 63% from its initial value.

Misconception

Capacitance × resistance is not the <u>definition</u> of the time constant; it is one way of calculating the time constant if the values of capacitance and resistance are known.

Question 6 (b) (i)

(b) The capacitor circuit shown in **Fig. 6.1** can be used to smooth oscillating electrical signals.

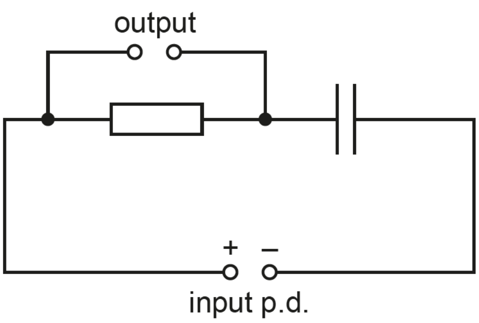


Fig. 6.1

(i) **Fig. 6.2** shows the input signal of potential difference (p.d.) V against time t.

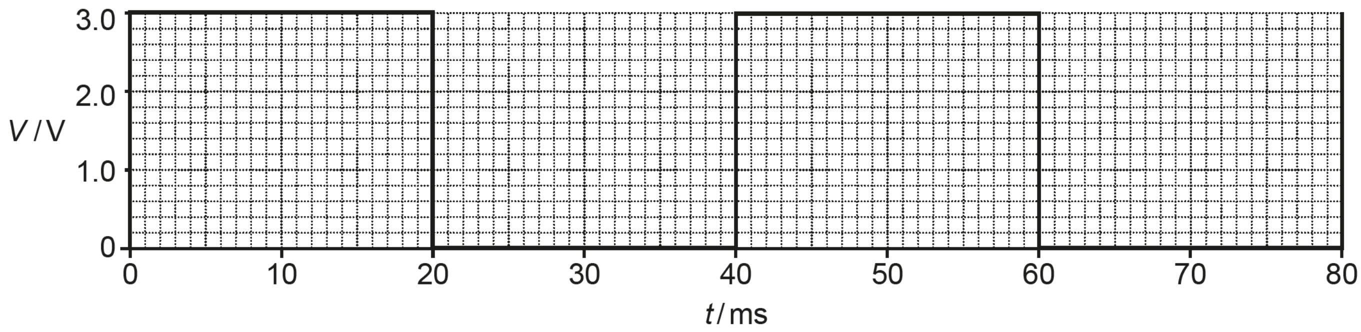


Fig. 6.2

Calculate the frequency f of this input signal.

f = ... Hz **[2]**

It is important to show how the information from the graph has been used to calculate the frequency. The correct answer did not score full marks unless some working had been shown.

Question 6 (b) (ii)

(ii) **Fig. 6.3** shows the variation of the charge Q on the positive plate of the capacitor with time t.

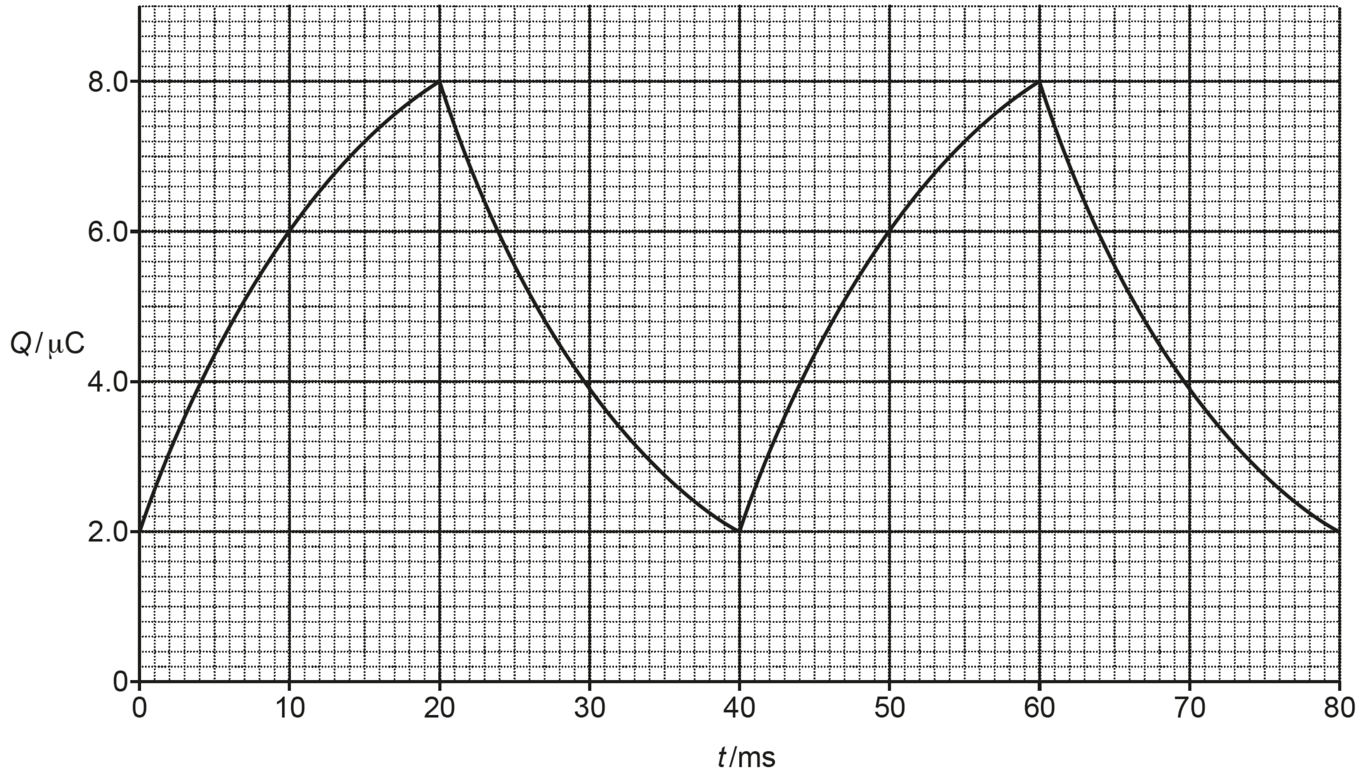


Fig. 6.3

Use a discharging section of the graph in **Fig. 6.3** to determine the time constant of the circuit. Give your answer in ms.

time constant = ... ms **[2]**

The question specifies using the discharging section of the graph. Some candidates tried to use the charging section, but this proved more difficult.

Using the definition of the time constant, we need to find how long it takes for the charge to fall from any initial value to 37% (1/e) of that value. Many candidates chose 8μC for their initial value, but this is not vital.

37% of 8μC is 2.9μC. The charge is 8μC at 20ms and 2.9μC at 34ms, so the time taken is 34 – 20 = 14ms.

A common alternative approach was to insert values from the graph into the equation $Q = Q_o\, e^{-t/CR}$. This gave the same result, but sometimes resulted in a POT error because of the need to give the answer in milliseconds.

Question 6 (b) (iii)

(iii) By drawing a suitable tangent to the graph in **Fig. 6.3**, calculate the maximum current in the resistor.

maximum current = ... A **[2]**

Many candidates lost marks here because they did not realise that, to calculate the *maximum* current in the resistor, they had to draw the steepest possible tangent to the graph.

Question 6 (b) (iv)

(iv) **On Fig. 6.4** below, sketch the variation of the current I in the resistor with time t. Include an appropriate label and scale on the vertical axis.

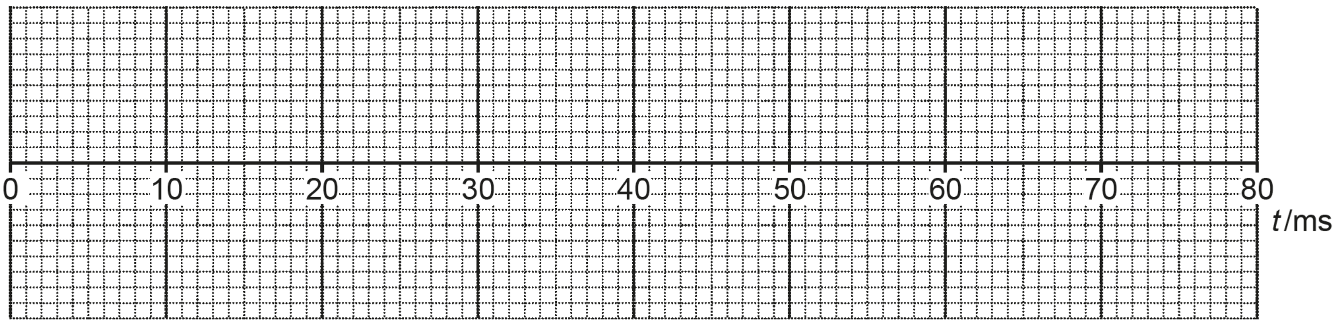


Fig. 6.4

[3]

Since $I = \Delta Q/\Delta t$, the graph of I against t can be found from the gradient of the graph of Q against t. The gradient is positive from 0 – 20 ms and negative from 20 – 40ms; this represents the current flowing one way around the circuit while the capacitor charges and then the opposite way while it discharges. Since the gradient is never zero, the value of the current is never zero either.

Tasks that caused problems in 6(b)(iv)

- drawing an exponential decay, particularly in the negative section of the graph (most drew a sinusoidal curve).
- converting the maximum current into mA or μA.
- labelling the vertical axis and drawing on a sensible scale.

Assessment for learning

Centres should consider providing more practice in drawing graphs without the aid of graph-plotting software.

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