Pearson
Edexcel

Examiners' Report
June 2025

GCE Physics 9PH0 03

ResultsPlus

Edexcel and BTEC Qualifications

Edexcel and BTEC qualifications come from Pearson, the UK's largest awarding body. We provide a wide range of qualifications including academic, vocational, occupational and specific programmes for employers. For further information visit our qualifications websites at https://www.edexcel.com or https://www.btec.co.uk.

Alternatively, you can get in touch with us using the details on our contact us page.

ResultsPlus

Giving you insight to inform next steps

ResultsPlus is Pearson's free online service giving instant and detailed analysis of your students' exam results.

- See students' scores for every exam question.
- Understand how your students' performance compares with class and national averages.
- Identify potential topics, skills and types of question where students may need to develop their learning further.

For more information on ResultsPlus, or to log in, visit https://www.edexcel.com/resultsplus. Your exams officer will be able to set up your ResultsPlus account in minutes via Edexcel Online.

Pearson: helping people progress, everywhere

Pearson aspires to be the world's leading learning company. Our aim is to help everyone progress in their lives through education. We believe in every kind of learning, for all kinds of people, wherever they are in the world. We've been involved in education for over 150 years, and by working across 70 countries, in 100 languages, we have built an international reputation for our commitment to high standards and raising achievement through innovation in education. Find out more about how we can help you and your students at: https://www.pearson.com/uk.

June 2025

Publications Code 9PH0_03_2506_ER

Introduction

This paper comprises short, open-response, calculation and extended writing questions worth a total of 120 marks.

The questions draw on a range of the topics in the specification and include synoptic questions drawing on two or more different topics.

The paper also includes questions that assess conceptual and theoretical understanding of experimental methods (indirect practical skills), some of which draw on candidates’ experiences of doing the core practicals.

When preparing for the exam, candidates should be encouraged to work with mark schemes, however, it is important that they understand that mark schemes do not provide model answers to the questions. Mark schemes are written for examiners and so sometimes refer to what examiners expect to see rather than giving a complete answer.

Candidates should also be encouraged to consider the number of marks available for a question, and to use this to determine the length of response required. The space allowed for responses is usually sufficient but sometimes candidates started their response by repeating the question, so they wasted valuable space and time. If candidates need more space or want to replace an answer with a different one, they should indicate clearly where the response they wish to be marked by examiners can be found. The responses to be marked must also be clearly labelled with the question and part number so that examiners know what they are awarding marks for.

There is still evidence that candidates are not paying sufficient attention to the command words used in the question. In several cases, questions requiring an explanation were answered with a description and vice versa by some candidates. Some command words are used to indicate that a judgement needs to be formed from the information in the question. These were evident in some questions, but candidates either did not form a conclusion or make a clear comparison between values.

In general, calculation, deduce and 'show that' questions gave candidates an opportunity to demonstrate their problem-solving skills. Some very good responses were seen for such questions, with solutions that were accurate and clearly laid out making it easy to follow the logic. The processes related to analysing data and quantifying uncertainties in practical work were generally sound, with success displayed by many candidates in combining uncertainties. However, in some questions the final mark was not awarded due to a missing or inappropriate unit or giving the value to an inappropriate number of significant figures.

There was a mixed response to the two linkage questions in this paper. Q06 tended to generate better responses than Q11(b). In general, the responses to both questions were commensurate with the responses to linkage questions seen in previous series. Candidates' knowledge of experimental methods was also varied. In both types of question, there were instances where candidates disadvantaged themselves by not using suitably precise language.

Question 1(a)

Q01 was based on an investigation into the *I-V* characteristics of a filament bulb and assessed indirect practical skills. In general, candidates found this quite challenging, possibly owing to the command words rather than the context.

Part (a) involved commenting on the suitability of the circuit for this investigation. The command word "Comment" requires the synthesis of two or more pieces of information to form a judgement. Candidates should have stated whether the circuit was suitable for this investigation and given reasons to support their judgement. Overall, many candidates did not conclude whether it was suitable or not. Some did make some attempt at a judgement, but these were based on one piece of information; candidates that argued that the circuit was only partially suitable based on two factors were rare. Other common errors included suggesting that the ammeter was incorrectly positioned and not considering the full range of potential differences.

Comment on the suitability of the student's circuit.

(3)

The circuit does allow for the student to take a range of values for current and potential difference. However, the minimum p.d. that the student can measure from this circuit is greater than 0 V as p.d. is shared amongst both the bulb and variable resistor, and the maximum p.d. that they can measure for the bulb will depend on the ~~x~~ variable resistor. Therefore, the full range of p.d. values (0 - 9 V) cannot be measured using this circuit so it is not as suitable to measure the range of p.d. and current as a potentiometer would be (which would allow full range of values for p.d to be measured.)

ResultsPlus
Examiner Comments

This response displays a sound line of reasoning based on two pieces of information. Here they note that the circuit will allow for the current and p.d. to be varied but a full range of p.d. cannot be obtained. The comment on the suitability was deemed just enough to score the mark.

ResultsPlus
Examiner Tip

"Comment" questions need a judgement to be formed using at least two pieces of information.

Question 1(b)

Part (b) involved assessing the validity of the student's conclusion which used the terms precision and accuracy.

As with part (a), the command word "Assess" requires candidates to form a judgement, ie whether the use of these terms was valid.

Most candidates gave good definitions of these terms but did not apply them to the information in the question.

Some candidates decided that the value was precise even though the term precision had been defined well.

Some candidates argued that the student meant to use the term resolution.

Although the term accuracy was defined well more often, candidates did not refer to a true value, but some did refer to a systematic error which could be credited.

(b) When the p.d. across the bulb was 3.0 V, the student recorded a value of 1.29 A for the current.

In his conclusion he stated

This will give an accurate value for the working resistance, as the value of current is precise.

Assess the validity of the student's statement. You do not need to carry out a calculation.

(4)

Accuracy is a measure of location (how close to true value)
precision is a measure of spread (how close points are to each other).
As no repeats have been taken and there is only one measurement found, it is impossible to comment on precision of results.
Even if results were precise this does not mean it is accurate
A systematic or zero error could lead to points that are precise but all out by a certain fixed amount

ResultsPlus
Examiner Comments

This response includes good definitions on the first two lines. Lines 3-5 contain sound reasoning as to why the term precision cannot be used. The whole of the final three lines was good enough for MP4. Line 6 or lines 7-8 individually would not have scored the mark.

ResultsPlus
Examiner Tip

Ensure you understand the meaning of precise and accurate, and how they apply to data.

Question 2

Q02 assessed the candidate's knowledge of the formation of standing waves. This was generally answered well. Most candidates described the wave being reflected and superposition taking place. Many candidates referred to constructive and destructive interference but did not relate this to phase, phase difference or path difference. Occasionally, candidates gave phase difference in terms of wavelength which was credited. Most candidates used the wave equation, but some did nothing further with the value. Those that calculated the wavelength and compared to the distance between nodes were more successful than those that calculated the speed of the wave. Some candidates did not understand the significance of obtaining a wavelength close to the speed of light when using a wavelength of 0.30 cm. Some used 0.15 cm and did not seem perturbed with a value half the speed of light.

Explain these observations. Your answer should include a calculation.

The emitted waves from the transmitter travel towards the metal plate and the wave is reflected. The reflected wave travels in the opposite direction to the initial wave, so they overlap, superpose and interfere, forming a standing wave. At points where the waves are in phase and the path difference is $n\lambda$, constructive interference occurs and an antinodes of maximum amplitude ~~is~~ are formed, so R detects the maximum intensity at antinodes. At points where the waves are in antiphase and the path difference is $(n+\frac{1}{2})\lambda$, destructive interference occurs and nodes of minimum amplitude are formed, so R detects minimum intensity at nodes. The intensity varies from minimum to maximum as R moves from a node to an antinode. $V=f\lambda$, ~~so~~ and $\lambda = 2 \times 1.5 = 3$ cm and the nodes are 1.5cm apart. Wavespeed of the microwave $= 10.7 \times 10^9 \times 0.03 = 3.21 \times 10^8$ m s^{-1} $\approx 3 \times 10^8$ ms^{-1} which is consistent with the speed of EM waves in a vacuum.

ResultsPlus
Examiner Comments

This is a well-crafted response to this question. The candidate refers to path difference when discussing the places of maximum and minimum intensity, which is sensible as this then relates directly to the observation. This candidate calculated the speed of the microwaves and clearly related this to the speed of light.

ResultsPlus
Examiner Tip

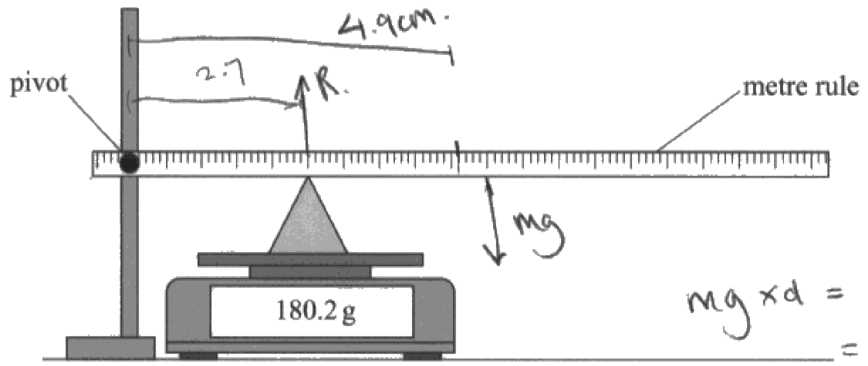
When explaining interference effects, refer to the phase difference in degrees or pi, or path difference in terms of wavelength.

Question 3(a)i

Q03 assessed the candidate's knowledge of moments in a practical context. In general, candidates find this area of physics more challenging, so few candidates scored well.

Part (a)(i) was rarely articulated well, as candidates did not understand the set-up or that it related to moments. Some candidates managed to state that the pivot and centre of mass were at different distances from the pivot but went no further. Most candidates did not understand that the mass reading related to the force acting at that point, and many thought the prism acted as the pivot. Another common error was to assume there was a force acting at the pivot, preventing the force on the balance matching the weight of the rule.

A uniform metre rule is pivoted at its 5.0 cm mark. The metre rule is then supported horizontally at the 30.0 cm mark by the prism, as shown below.



$mg \times d = R \times \frac{1}{2}d$
$= R$

(a) (i) The metre rule is in equilibrium.

Explain why the increase in mass recorded by the balance is not equal to the mass of the metre rule.

(2)

Because the mass of the ruler will act from middle (which is to the left of the prism) so according to conservation moment : clockwise force x perpendicular distance from pivot is ~~b~~ equal to anticlockwise force x perpendicular distance from pivot , hence it in equilibrium and since prism is closer to pivot , the upward reaction force between ruler and prism must be greater than the weight of ruler, hence the mass reading is going to be larger than the weight of ruler.

ResultsPlus
Examiner Comments

An unusual response that scored full marks. The candidate has clearly labelled the diagram with the forces, which has helped to formulate the response. Although the response does not follow the mark scheme exactly, there is the idea that the forces are at different distances from the pivot, and therefore the forces need to be different to allow for the moments to balance. It was even rarer for candidates to state that the force at the prism was the reaction force.

ResultsPlus
Examiner Tip

Recognise examples involving moments by looking for a fixed point about which an object can rotate.

Question 3(a)ii

The calculation in part (a)(ii) was rarely answered well. Common errors included not subtracting the masses and not using the value of g. There was also confusion with the distances. There were cases where the centre of mass was at the end of the rule, not the centre, and some were clearly using the prism as the pivot. Some candidates tried to include the overhang. This does lead to the same answer if done correctly, but many candidates either did not use half the distance from the pivot or did not use the correct ratio of masses.

(ii) Calculate the weight of the metre rule. You should take moments about the pivot.

(4)

$\Sigma ACM = \Sigma CM$

Moment = F x perp distance

Clockwise moment   Anticlockwise moment

$= \cancel{mg \times 20 \times 10^{-2}}$ =

$mg \times (50-5) \times 10^{-2} = (180.2 - 25.5) \times 10^{-3} \times g \times (30-5) \times 10^{-2}$

$$m = \frac{(180.2-25.5)\times 10^{-3} \times (30-5)\times 10^{-2}}{(50-5)\times 10^{-2}}$$

$m = 0.086$ kg $\times 9.81 = 0.84$ Weight of metre rule = 0.84 N

ResultsPlus
Examiner Comments

The calculation in this response is easy to follow. The candidate starts with stating the relevant formula and the principle of moments, which helps the candidate structure the answer. In this case, the candidate cancels out the factor of g but realises at the end to multiply the mass by g to calculate the force. The candidate could have calculated all the relevant masses and distances before rearranging the formula.

ResultsPlus
Examiner Tip

Set out calculations clearly and include the relevant formula.

Question 3(b)

Part (b) was another question requiring a judgement. Most candidates only focused on the effect of changing one variable, i.e. the distance from the pivot. Relatively few realised the mass would increase.

Candidates were reluctant to suggest that the effect would be unknown, as one increases as the other decreases, and preferred to try and present an argument that would result in a definitive change.

(b) The student wants to reduce the percentage uncertainty in the value obtained for the weight of the metre rule.

The student repeated her determination of the weight of the metre rule. She moved the prism towards the centre of gravity of the metre rule before taking moments about the pivot.

Deduce whether the percentage uncertainty in the value obtained for the weight of the metre rule is reduced by the student moving the prism. No calculations are required.

(3)

Moving the prism towards the centre of mass increases the distance between the pivot and prism so perent uncertainty in length is reduced. However mass recorded ~~on~~ on the balance will be smaller so percent uncertainty for ~~anticlockwise moment will be increase~~ this will be increased. Therefore difficult to determine.

ResultsPlus
Examiner Comments

A very unusual response that scored full marks.

ResultsPlus
Examiner Tip

Do not be afraid to give a judgement that contradicts the question, or state that a judgement can't be reached, if that's what the evidence suggests.

Question 4(a)i

Q04 assessed indirect practical skills linked to measuring radioactivity.

Part (a)(i) was similar to questions in previous series and was answered well by most candidates. The majority opted for set-up A with reasoning based on the larger surface area, although some candidates referred to the amount of radiation hitting the surface, rather than an increase in the measured value or count rate. Those that chose set-up B appeared to be basing it on the assumption that the gamma radiation would not be able to penetrate the sides of the G-M tube. Occasionally, candidates thought that more background radiation would be able to enter the G-M tube when pointing upwards.

Deduce which set-up will lead to a smaller percentage uncertainty in the count rate.

(3)

Student A, as there is a larger surface area on the GM tube available for the gamma rays to be incident on, as gamma travels in all direction and can penetrate through the tube plastic cover. The count recorded will be greater for Student A, so will have a smaller percentage uncertainty.

ResultsPlus
Examiner Comments

A typical 3-mark response. This candidate is specific as to the effect on the count rate for this situation.

ResultsPlus
Examiner Tip

Remember that gamma radiation can penetrate all sides of a G-M tube.

Question 4(a)ii

In part (a)(ii) many candidates fell into the trap of describing rather than explaining, as often candidates stated that a background count was needed and to increase the time for recording the counts. Very few candidates could justify the reasons for doing these, usually discussing a more accurate reading. Repeating and calculating a mean was seen quite often, but this is equivalent to taking readings over a longer period of time, so those candidates that stated both could only access one mark. Usually, the justification for this was given as reducing the effect of random errors rather than stating that the decay is random. Occasionally, candidates forgot to state that the background count would need to be subtracted from the count.

(ii) Explain two modifications to the experimental method which would improve the accuracy of the data.

(4)

Remove ~~radioacte~~ radioactive source and record count for 10 minutes to get a background count. This can be ~~corrected into a count~~ subtracted from the final count so only the count from the source is measured.

Record with source for longer period e.g. 10 minutes to get a larger count to decrease percentage uncertainty.

ResultsPlus
Examiner Comments

A very clear answer that scores full marks.

(ii) Explain two modifications to the experimental method which would improve the accuracy of the data.

(4)

- did not record background radiation ~~and~~ count
- and remove from measured count
- record count for more than 2 minutes
- ~~and~~ record multiple times, take average of count
- ~~as radiation~~ as decay is random.
- shorten distance d of GM tube and source as radiation ~~...~~ spreads out from source
- these decrease percentage uncertainty

ResultsPlus
Examiner Comments

This candidate clearly did not take notice of the command, as they describe more than two modifications. There is no explanation as to why a background count should be removed.

ResultsPlus
Examiner Tip

Remember to explain how different techniques can improve data collection.

Question 4(b)

Part (b) introduced a different radioactive source that also emitted alpha and beta radiation.

Whilst many candidates suggested placing a material between the source and detector, often these were unsuitable to absorb both alpha and beta, such as paper and cardboard.

Aluminium foil was also unacceptable, as this suggested a very thin sheet which would not absorb beta radiation adequately enough.

Some candidates went to the other extreme and suggested very thick sheets of lead, e.g. 20 cm.

Some candidates suggested changing the distance, which was the whole purpose of the practical.

(b) Student A suggests that the investigation into the inverse square law for a gamma radiation source could be carried out successfully using a radium-226 source.

Radium-226 emits alpha and beta radiation as well as gamma radiation.

Explain **one** modification that would be necessary if a radium-226 source were to be used.

(2)

You need to ~~use a piece~~ place a piece of aluminium foil between the source and the GM tube as α and β can't penetrate through (they are blocked) so you only measure gamma radiation

ResultsPlus
Examiner Comments

This candidate stated foil, which was not accepted. However, the explanation of why a suitable absorber was needed was accurate.

ResultsPlus
Examiner Tip

Use your knowledge of physics to explain modifications to experiments.

Question 5(a)

Q05 was based on the resistance of fuse wire.

Part (a) assessed indirect practical skills related to measuring the diameter of the wire. Measuring small distances with a micrometer should be familiar to candidates, as this is part of three core practicals. It was clear that some candidates had experience of this, as they suggested using a ratchet. Most candidates suggested using a micrometer as the most suitable measuring instrument and had the idea of taking multiple measurements in different places along the wire, or at different orientations. Very few candidates suggested checking and correcting for zero error. Some candidates forgot to mention how to use the diameter to calculate the cross-sectional area, suggesting that they had not read the question properly.

(a) Describe how the student could determine an accurate value for the cross-sectional area of a wire.

(4)

measure diameter d of wire with a micrometer

close micrometer jaws around wire by turning ratchet so it is not closed

too tightly and wire is not deformed.

measure diameter at different positions along the wire and ~~[illegible]~~

different orientations and ~~[illegible]~~ find the mean.

check for zero error on micrometer before measuring d

subtract zero error from mean d value.

cross-sectional area = $\pi r^2 = \pi(\frac{d}{2})^2 = \frac{\pi}{4}d^2$.

ResultsPlus
Examiner Comments

A detailed response that scores full marks. It is clear that this candidate has had plenty of practice using a micrometer.

(a) Describe how the student could determine an accurate value for the cross-sectional area of a wire.

(4)

The student should measure the diameter of the wire using a micrometer at multiple different

~~ort.~~ orientations such as 10 and then find a mean diameter to reduce random errors.

The student should then divide this by 2 to get the radius. He should then use the formula πr^2

where r is the radius to get the cross-sectional area.

ResultsPlus
Examiner Comments

A good answer that addresses the question. This candidate only included the "repeating" technique but not an additional one, such as correcting for zero error or using the ratchet. This candidate also described how to determine the radius, which related to the formula for the cross-sectional area stated. This response also included an explanation (to reduce random error) which was not needed as this is a describe, not explain, question.

ResultsPlus
Examiner Tip

Ensure you revise techniques used in core practicals.

Question 5(b)i

Part (b)(i) assessed the candidate's knowledge of how a current causes resistance in a metal wire. This was not answered well and often the wording was poor, which was surprising since this is AS content. Candidates often scored the first mark. Common errors included the use of the word particles instead of ions, not including the amplitude for increasing vibrations, not including the rate or frequency of collisions, or not stating what was colliding with what.

(b) (i) Explain why a current in a wire causes the resistance of the wire to change.

(3)

When current moves through a wire the moving electrons collide with ions in the lattice structure, transferring kinetic energy to them. This causes their amplitude of oscillations within the lattice to increase, meaning more frequent collisions occur. More frequent collisions means more energy transferred by charge carrier and ∴ greater resistance.

ResultsPlus
Examiner Comments

A good response to this question that focuses on collisions. As collisions between the electrons and lattice ions had already been mentioned, it was clear which collisions were being referred to at the end of the response.

(b) (i) Explain why a current in a wire causes the resistance of the wire to change.

(3)

As current flows through the wire ~~[illegible]~~, charge carriers (electrons) collide with metal lattice ions transferring energy to them and causing greater vibrations in the metal lattice structure due to higher kinetic energy. As a result the rate of collisions of charge carriers ~~[illegible]~~ with the metal ions increases ~~[illegible]~~, reducing the flow of current and hence increasing resistance.

ResultsPlus
Examiner Comments

Another clear answer, but unfortunately the candidate does not refer to the amplitude of the vibrations increasing.

ResultsPlus
Examiner Tip

Ensure that you use correct scientific terminology in your descriptions and explanations.

Question 5(b)ii

Part (b)(ii) was a synoptic question based on black body radiation. This was aimed at the highest grades, but it was very rare to see two marks being awarded. Most candidates went down the path of using resistivity, drift velocity or Wein's law. Some candidates stated the Stefan-Boltzmann law but then defined *A* as the cross-sectional area, or stated that length was not a factor. Some included the formula for the surface area of a sphere, so had not realised that the wire was cylindrical, not spherical. Very few candidates stated that the energy emitted per second would relate to the surface area. Of those that did, even fewer realised that the length would change the surface area.

X (ii) The length of a wire does not affect the value of current at which the wire melts.

Explain why. Assume the wire behaves as a black body.

(2)

$L = \sigma A T^4 \rightarrow L = \sigma 4\pi r^2 T^4$. Luminosity is ~~power~~ power, which is energy transferred per second. Length is not involved (only radius of wire and temperature of wire are involved), so length will not affect the power hence energy transferred to wire per second, so it won't affect value of current at which the wire melts.

(Total for Question 5 = 9 marks)

ResultsPlus
Examiner Comments

This candidate starts well by referring to the Stefan-Boltzmann law but made the common mistake of not realising that *A* is the surface area, despite including the correct formula for a sphere.

ResultsPlus
Examiner Tip

Ensure you understand what each variable in a formula means.

Question 6

Q06 was a linkage question and assessed the candidate's knowledge of kinetic theory applied to the effect of decreasing temperature on pressure. Most candidates scored marks, with the comments relating to the effect on velocity, force and pressure commonly being scored. Candidates were able to state that the rate of collisions decreased, rather than just the number of collisions, but sometimes this was related to collisions with other molecules. Some candidates also missed the final mark by not referring to the formula. Other errors included not referring to the average kinetic energy, or using particles instead of molecules. Although some candidates referred to the formula relating force with the rate of change of momentum, this was rarely used adequately and most just omitted the idea of rate of change of momentum.

***6** Air at room temperature was sealed in a closed container. The container was placed in an ice bath and the temperature of the air decreased. The volume of the container remained constant.

temp ↓

Explain what happened to the pressure exerted by the air. In your response you should refer to the momentum of the air molecules.

- As temperature decreases, average kinetic energy of air molecules decreases
- so air molecules make less frequent collisions with walls of container
- air molecules travel with less momentum
- ~~air mol~~ rate of change of momentum of air molecules when colliding with container walls decreases as change of momentum of particles decreases
- since $F = \frac{\Delta p}{\Delta t}$, and Δp of air molecules decreases, force exerted by air molecules on container walls decreases
- ~~F~~ $p = \frac{F}{A}$ and A is constant so as force exerted on walls ~~increases~~ decreases, pressure exerted on ~~c~~ container walls decreases.

(Total for Question 6 = 6 marks)

ResultsPlus Examiner Comments

All IC points are there in a logical sequence to give full marks.

ResultsPlus Examiner Tip

Start with the condition that changed to avoid confusion, but do not repeat too much of the question as this wastes space and time.

*6 Air at room temperature was sealed in a closed container. The container was placed in an ice bath and the temperature of the air decreased. The volume of the container remained constant.

Explain what happened to the pressure exerted by the air. In your response you should refer to the momentum of the air molecules.

-The pressure exerted by the air decreased due to the decrease in temperature caused by the ice bath. As the temp. decreased, the ~~particl~~ air particles energy decreases and they are less excited ∴ moving at a lower velocity than in room temp. Due to this, they collide less with eachother and bounce off the walls less often, ∴ decreasing the pressure exerted. due to V being constant, N and k being constant, the ideal gas equation: $pV = NkT$ shows that ~~P~~ if T decreases and V ~~P~~ constant, p must decrease.

ResultsPlus
Examiner Comments

An answer that could have scored more marks if the language was more precise. The candidate refers to the energy, not average kinetic energy, and also to particles, not molecules, so no IC1. IC2 is on line 3. The candidate mentions collisions with other particles, which is irrelevant here, but was given IC3 for colliding with the walls less often. There is no mention of rate of change of momentum (or momentum at all) or force, so no IC4 or IC5. There is no formula that relates pressure and force, so no IC6. The candidate has included some comments relating to universal gas laws but this was not credited.

Question 7(a)

Q07 assessed indirect practical skills related to determining the density of a material.

Part (a) involved describing improvements to the student's method. Some candidates tried to describe the measurement of thickness and diameter at the same time, rather than separately, which limited the marks available. Many suggested using another piece of equipment, which is not improving the method so could not be awarded a mark. Stacking the discs was suggested by most, although the descriptions were often brief. Few candidates suggested lining up the discs. Some candidates suggested that using the vernier calipers for the diameter would be an improvement, although most described the measurements for one disc, e.g. taking readings in different places, rather than using many discs.

(a) Describe improvements to the student's method that would give more accurate values for *d* and *t* of the discs.

(4)

To measure the thickness of the discs, stack the 10 ~~..~~ discs on top of eachother. Use ~~the~~ a micrometer to measure the thickness. Divide the measurement by 10 to find thickness of one disc. Repeat and average to reduce effect of random error. Measuring a larger thickness reduces percentage uncertainty. ~~Measure the~~ Put the discs side by side ~~to~~ along ~~the~~ a metre rule. Make sure there is no zero error. Measure the length of all 10, divide by 10 to find diameter of one. Repeat and average.

ResultsPlus
Examiner Comments

This response scores full marks. This candidate took the sensible approach of describing each measurement separately, using the same apparatus as the original method. On lines 4 and 5, the candidate has included explanations that are not needed.

ResultsPlus
Examiner Tip

To describe improvements to an existing method, use the apparatus given in the question and think about improving how they are used.

Question 7(b)

Part (b) assessed the candidate's ability to combine uncertainties. This was answered very well by most candidates. Common errors in the density calculation included not calculating the volume correctly, e.g. not halving the diameter or cubing the radius, or conversion errors. Unit errors were relatively rare. Apart from the occasional candidate that halved or doubled the absolute uncertainties when calculating the percentage uncertainty, most combined the percentage uncertainties well. Common errors included not doubling the percentage uncertainty in the diameter or doubling one of the other two, not including the percentage uncertainty in mass, or using too many significant figures in the final percentage uncertainty.

(b) The student determined the average mass of a disc to be 42.5 g ± 0.5 g.

Calculate the density of the material the discs are made from and the percentage uncertainty in this value.

average diameter of disc = 5.2 cm ± 0.1 cm
average thickness of disc = 1.9 mm ± 0.1 mm

$$\rho = \frac{m}{V} = \frac{(42.5 \times 10^{-3})}{(4.0351 \times 10^{-6})}$$

$$V = (1.9 \times 10^{-3})\,\pi\left(\frac{5.2 \times 10^{-2}}{2}\right)^2$$

(6)

$$V = 4.0351 \times 10^{-6}$$

$$= 10532.68\ \text{kgm}^{-3}$$

$$\%U \text{ in } V = 2\left(\frac{0.1}{5.2} \times 100\right) + \left(\frac{0.1}{1.9} \times 100\right)$$

$$= 3.846\% + 5.263\%$$

$$= 9.109\%$$

$$\%U \text{ in } \rho = \left(\frac{0.5}{42.5} \times 100\right) + (9.109)$$

$$= 10.2857\%$$

$$= 10.3\%$$

Density = 1.05×10^{4} kgm^{-3}

Percentage uncertainty = 10.3 %

ResultsPlus
Examiner Comments

Very clear working leading to correct answers. The value for density was given to an appropriate number of significant figures, but there was no penalty for this value. Generally, derived quantities should be given to the fewest number of significant figures used in the data, but no more than the largest number of significant figures. On this occasion, three significant figures on the percentage uncertainty was accepted, as this meant giving the answer to a tenth of a percent. Generally, final percentage uncertainties should be given to one or two significant figures.

ResultsPlus
Examiner Tip

Understand what is meant by "appropriate" significant figures for derived quantities and percentage uncertainties.

(b) The student determined the average mass of a disc to be 42.5 g ± 0.5 g.

Calculate the density of the material the discs are made from and the percentage uncertainty in this value.

average diameter of disc = 5.2 cm ± 0.1 cm 1.92%
average thickness of disc = 1.9 mm ± 0.1 mm 5.26%

(6)

$\frac{0.5}{42.5} \times 100$ 1.18%

2.6 $\times$ 2 / 2

$\pi \times (0.026)^2 = 2.12 \times 10^{-3}$

ans $\times 1.9 \times 10^{-3} = 4.035 \times 10^{-6}$ = vol

$\frac{0.0425}{4.035 \times 10^{-6}}$ = 10532.84

w

1.92 + 5.26 = 7.18%

~~uncertainty~~ % in vol

3.84% + 5.26% = 9.1%

9.1% + 1.18% = 10.28%

Density = 10532.84 kg/m³

Percentage uncertainty = 10.28%

ResultsPlus
Examiner Comments

The working in this response is quite haphazard and the candidate is fortunate that the values for the percentage uncertainties were correct. There appear to be three lines of working for combining the percentage uncertainties. The first line (7.18%) does not include doubling the percentage uncertainty in the diameter but the second line does. It appears that these were attempts at calculating the percentage uncertainty in volume. As the second one was used in the final calculation, this was the one credited. The final percentage uncertainty is given to too many significant figures.

ResultsPlus
Examiner Tip

Label calculations with the quantity being calculated.

Question 8(a)

Q08 was based on the viscosity of chocolate.

Part (a) concerned calculating the speed of an air bubble and was answered very well. The most common errors were forgetting to use *g*, conversion errors and using an incorrect formula for volume.

Calculate the constant speed at which the air bubble moves upwards in the liquid chocolate.

radius of air bubble = 6.8×10^{-3} m
density of liquid chocolate = 925 kg m^{-3}
viscosity of liquid chocolate = 52.6 Pa s

(5)

Upthrust = weight of fluid displaced = $\rho V g$

$= \frac{4}{3}\pi r^3 \rho_c g = \frac{4}{3}\pi (6.8\times10^{-3})^3 \times 925 \times 9.81$

$= 0.0119516 0104$ N

Upthrust = drag

$0.0119516 0104 = 6\pi\eta r v$

$0.01195... = 6\pi \times 52.6 \times (6.8\times10^{-3}) v$

$v = 1.77\times10^{-3}$ ms^{-1}

Speed air bubble moves upwards = 1.77×10^{-3} ms^{-1}

ResultsPlus
Examiner Comments

A good example of a response scoring full marks. Although this is not a "show that" question, it is important to lay out each step of the calculation clearly so that intermediate marks can be awarded if the final answer is incorrect.

ResultsPlus
Examiner Tip

Show your working and lay it out clearly.

Question 8(b)

Part (b) assessed indirect practical skills.

Part (b)(i) required an explanation of why a graph of log η against log T would produce a straight line. This is a standard question that is repeated in each series. Most candidates produced a correct log expansion. There are only two forms this can take, either a power law or an exponential. The second mark requires an explicit comparison to the equation of a straight line and an explicit statement about the gradient. For some questions, the y intercept needs to be stated, but not in this case. For the comparison to be explicit, the order of the log expansion should match the order of $y=mx+c$. Common errors here included mixing the order or not including the = and +. For the statement to be explicit, candidates must state the "gradient is B". Common errors included relying on loops or arrows or just stating "$m = B$".

(b) The viscosity of a gas increases with temperature.

(i) It is suggested that the relationship between viscosity η and temperature T is of the form

$$\eta = AT^B$$

where A and B are constants.

Explain why a graph of log η against log T would give a straight line.

(2)

$\log \eta = \log AT^B = \log A + \log T^B$

$y = \log \eta \quad \log T = x$

$= \log A + B \log T = \log \eta \quad B = m \quad \log A = C$

$C + Mx = y$

So straight line ~~formula~~ equation

ResultsPlus
Examiner Comments

This candidate has a correct log expansion and has put y=mx+c in an order to match the expansion. Unfortunately, the candidate has relied on arrows and not stated how the gradient relates to the line.

ResultsPlus
Examiner Tip

Ensure the order of y=mx+c matches the order of the log expansion and state what m and c mean in words.

Part (b)(ii) is the graph question and candidates that scored well are usually those that have had plenty of practice in graph drawing.

Most candidates scored marks and it was quite rare to see candidates draw a graph of the raw data.

The processed values were often correct and given to an appropriate number of decimal places, however occasionally candidates truncated rather than rounded, or used too many decimal places.

Centres should note that it is not necessary to convert units, or to use logs to other bases, other than 10 or natural logs.

Most candidates placed the axes the correct way around, i.e. log η as y and log T as x, however a common error was not labelling the axes with the correct format, i.e. log (quantity/unit), as the values need to be dimensionless.

Scales were often large enough so that the plots cover at least half the page in both directions and sensible, i.e. in 1, 2, 5, and their multiples of 10.

Awkward scales, including based on 4, were quite rare.

Plotting was generally accurate, and the best-fit lines were often reasonable enough to be awarded the mark.

equation

(ii) The table shows data for the viscosity of hydrogen gas over a range of temperatures.

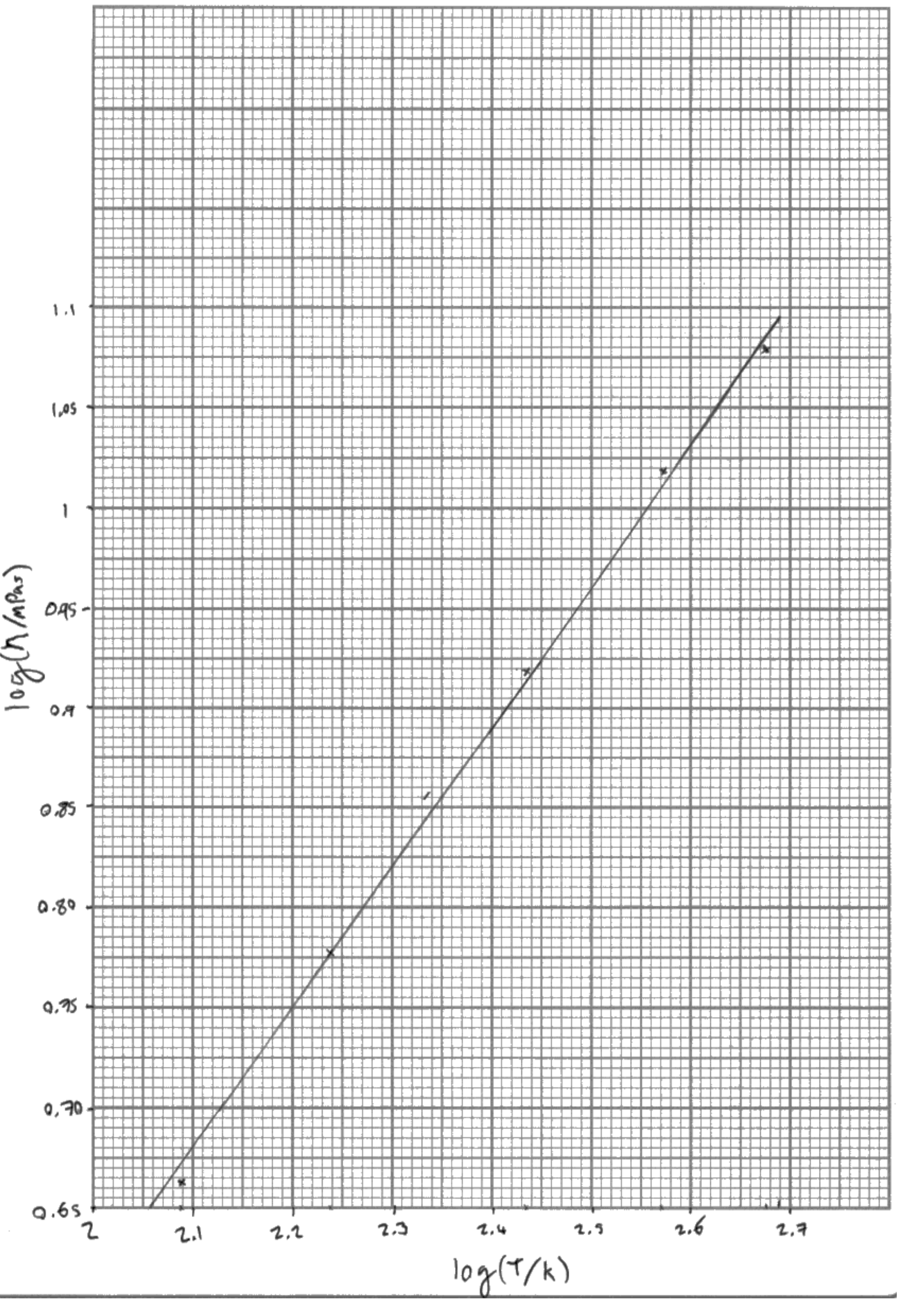
T/K	η/mPa s	$\log(\eta/\text{mPas})$	$\log(T/\text{K})$
123	4.60	0.663	2.090
173	6.00	0.778	2.238
273	8.30	0.919	2.436
373	10.4	1.017	2.572
473	12.0	1.079	2.675

Plot a graph of log η against log T. You should use the columns provided to show any processed data.

(5)

ResultsPlus Examiner Comments

This candidate uses a consistent number of decimal places in the log values. Using 3 will often be enough to produce an accurate graph.


1.1
1.05
1
0.95
0.9
0.85
0.80
0.75
0.70
0.65
2
2.1
2.2
2.3
2.4
2.5
2.6
2.7
log(η/mPas)
log(T/K)

ResultsPlus
Examiner Comments

The candidate went on to draw an appropriate graph to score full marks. The axes are the correct way around and the titles are in the correct format. The scales are sensible and allow all points to be plotted over half a page in both directions. The best-fit line is reasonable for this data.

ResultsPlus
Examiner Tip

Practice drawing graphs using sensible scales.

Part (b)(iii) was the calculation of the constants *A* and *B*. Candidates should be using their graph for this type of question. Most candidates calculated the gradient using points over half the page apart, and those that drew the triangle on the graph were often more successful. Occasionally, candidates chose points too close together or used their *y* intercept but forgot there was a false origin, so the denominator was too large. Most calculated a value in the range and gave the value to 2 or 3 significant figures but then insisted on giving a unit which is not appropriate, as powers are dimensionless. As log *A* was the value of the *y* intercept, those candidates that used a false origin often just used this value, so did not score the final mark. Those candidates who had used a scale starting at zero often scored this, as they were able to read off the value of log *A* directly rather than calculate it.

(iii) Determine values for *A* and *B*. You are not required to state the units of *A*.

(4)

~~2.69 − 2 = 0.69~~

$2.69 - 2.06 = 0.63$

$\frac{0.445}{0.63} = 0.706 = 0.71$

$1.095 - 0.65 = 0.445$

$\log \eta = B \log T + \log A$

$0.65 = 0.71(2.06) + \log A$

$\log A = -0.813$

$A = 10^{-0.813} = 0.154$

A = 0.15

B = 0.71

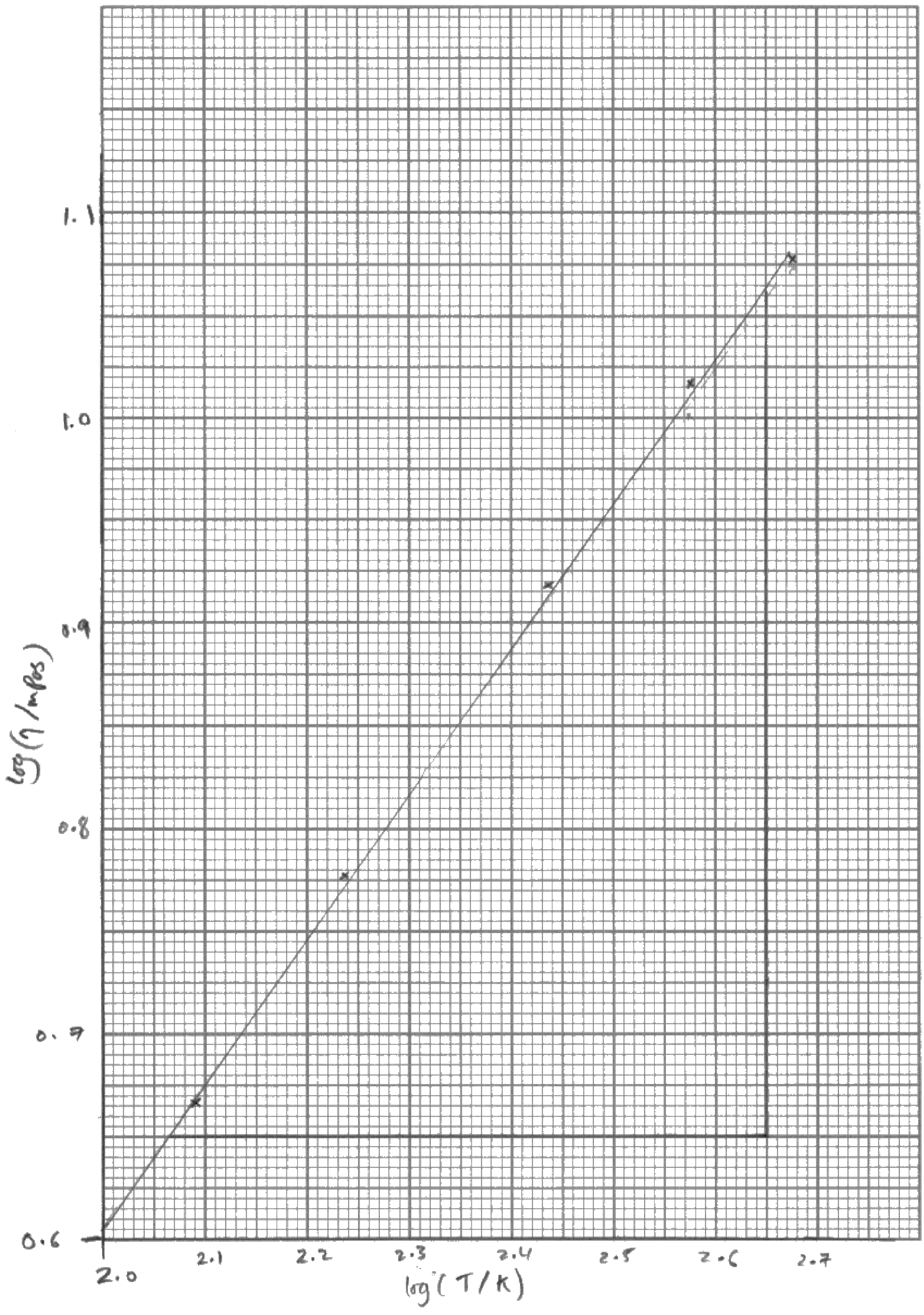
(Total for Question 8 = 16 marks)

ResultsPlus
Examiner Comments

This candidate realised that there was no y intercept on their graph as a false origin had been used, so calculated it using their gradient and a point from the best-fit line. Both values are given to an appropriate number of significant figures with no units. The triangle used for calculating the gradient clearly covered at least half the page in one direction.

ResultsPlus
Examiner Tip

Practice calculating a y intercept using the gradient and a point from the best-fit line.



1.1
1.0
0.9
0.8
0.7
0.6
log(η/mPas)
2.0
2.1
2.2
2.3
2.4
2.5
2.6
2.7
log(T/K)

ResultsPlus
Examiner Comments

This is a graph similar to the previous example that scored full marks. Notice here that the candidate has extended the line to the y axis and drawn a large triangle on the graph for use in part (iii).

ResultsPlus
Examiner Tip

Use a 30 cm ruler for the best-fit line and extend it to cover as much of the page as possible. Draw a triangle that is as large as possible.

(iii) Determine values for A and B. You are not required to state the units of A.

(4)

$\log A$ = y intercept = 0.605

$A = 10^{0.605} = 4.027 = 4.03$ (3sf)

B = gradient $= \dfrac{(1.065 - 0.65) \times 10^{-3}}{2.65 - 2.065} = 7.094 \times 10^{-4}$

A = 4.03

units - B = 7.09×10^{-4} Pa/K

(Total for Question 8 = 16 marks)

Pa / K

ResultsPlus
Examiner Comments

This candidate drew the graph above. Note that this candidate has made two common errors. There is a unit on the value of *B,* which is the gradient. This is not appropriate as powers are dimensionless. The best-fit line was extended to the y axis, so the candidate used that value as log *A*, forgetting about the false origin. This scored both process marks only.

ResultsPlus
Examiner Tip

Remember to check false origins and do not put units on constants that are powers.

Question 9(a)i

Q09 was based on investigating the oscillations of a cantilever constructed from a rule.

Part (a) assessed indirect practical skills related to timing oscillations. Although this was answered well in general, some candidates gave the answer to (i) as (ii) and vice versa. This suggested that they did not understand the difference between improving accuracy and reducing percentage uncertainty when timing oscillations.

Part (a)(i) involved explaining a modification that would improve the accuracy of the data obtained by the student. Most candidates referred to using a fiducial marker at the equilibrium position, but some just referred to equilibrium or centre. Some candidates referred to using a marker to see where the oscillation starts and ends. Very few candidates could explain why the marker is placed at the equilibrium position.

~~(a)~~ The student measured the time for 5 oscillations with an electronic stopwatch. This was repeated twice.

(i) Explain **one** modification to the apparatus which would improve the accuracy of the data the student obtained.

(3)

Place a ruler or a fudicial marker ~~x~~ behind the oscillating ruler, this will help to determine whether or not an oscillation has occured. this removes a chance of missing or counting extra oscilations, leading to less random errors.

ResultsPlus
Examiner Comments

This response made the common error of not stating where the fiducial marker was placed. The candidate also thinks that the purpose of the fiducial marker is to count oscillations, which is not correct.

(a) The student measured the time for 5 oscillations with an electronic stopwatch. This was repeated twice.

(i) Explain **one** modification to the apparatus which would improve the accuracy of the data the student obtained.

(3)

A rule could be clamped alongside it with the equilibrium position marked with ~~boa~~ a fiducial marker, this can then be used as the start and stop point of timing as this is where the cantilever is moving fastest so lowest percentage uncertainty.

ResultsPlus
Examiner Comments

A good answer that explains the purpose of a fiducial marker in terms of the uncertainty in displacement.

ResultsPlus
Examiner Tip

Be clear about where a fiducial marker should be placed and how this improves accuracy.

Question 9(a)ii

Part (a)(ii) involved explaining a modification to the method that would reduce the percentage uncertainty. As with other questions relating to the method, some candidates insisted on using a light gate and data logger. Another common error was referring to an increase in *T*, or the time period, rather than the time.

(ii) Explain **one** modification to the student's method which would reduce the percentage uncertainty in her measurement of *T*.

(2)

~~decrease the mass~~ [illegible]

- Increase the time for oscillation to 10 oscillations, as The value of T is larger, so % uncertainty will be smaller.

ResultsPlus
Examiner Comments

This response scored MP1 only. This candidate made the mistake of referring to *T* being larger rather than the time.

(ii) Explain **one** modification to the student's method which would reduce the percentage uncertainty in her measurement of T.

(2)

Time how long for ~~to~~ many more oscillations to occur and measure multiple times and take an average.

ResultsPlus
Examiner Comments

This candidate did not explain the modification, just described it.

ResultsPlus
Examiner Tip

Be able to explain how to reduce percentage uncertainty.

Question 9(b)

Part (b) was a deduce question which resulted in a variety of methods being used. Most candidates scored marks for calculating a mean time or time period and substituting values into the given formula. Some candidates got this far and then compared values to values in the table, which was insufficient to score more marks. Answers tended to diverge after this point, and the more successful candidates were those that laid out their calculations in a sensible order so the logic could be followed easily. Some candidates did not show their working adequately enough for marks to be awarded. Those that used the ratio method were often the more successful, although some candidates did not score the final mark as there was no comparison of values. Some candidates seemed uncomfortable with using ratios and included additional unnecessary steps to reach a conclusion, such as calculating a mass or constant.

Deduce the type of wood each rule is made from.

(6)

time 1: $\frac{14.69 + 14.64 + 14.76}{3} = 14.7$

time 2: $\frac{5.33 + 5.4 + 5.24}{3} = 5.32$

$T_1^2 = \frac{kML_1^3}{E_1}$ $\quad T_2^2 = \frac{\cancel{3}kML_2^3}{E_2}$

$\Rightarrow \frac{T_1^2 E_1}{L_1^3} = \frac{\cancel{3}T_2^2 E_2}{L_2^3}$

$\therefore E_1 \frac{(14.7)^2}{0.95^3} = E_2 \frac{(\cancel{3}(5.32)^2)}{(0.45)^3}$

$E_1 \cdot 252 = E_2 \cdot \cancel{62}\ 310$

$\frac{E_1}{E_2} = 1.23$ $\quad \frac{9.6}{7.7} = 1.25$ $\quad \Rightarrow E_1 = \text{Spruce}, E_2 = \text{Cedar}.$

ResultsPlus
Examiner Comments

This candidate used the standard method of using a ratio. As this was a ratio, using the mean time, rather than the mean time period, was acceptable. The calculation is laid out clearly so the logic is easy to follow. The only reason this did not score full marks was that the comparison was not explicit.

ResultsPlus
Examiner Tip

Include a comparison of values in conclusions.

Question 10(a)-(b)

Q10 was based on alternating current.

Part (a) was almost always done correctly. Very few candidates did not show their working or used too few significant figures.

(a) Show that the rate of power dissipation in the resistor is about 48 W.

(2)

$P = \frac{V^2}{R}$

$= \frac{(8.5)^2}{1.5} = 48.2\,W$

$\approx 48\,W$

ResultsPlus
Examiner Comments

Show clear working, with an answer given to more significant figures than the "show that" value.

Part (b) was done well by most candidates. Common errors included converting the temperature increase into kelvin, not converting g into kg, and incorrect manipulation of the power formula.

(b) A lab technician used the resistor to heat $1.25 \times 10^{-4} m^3$ of milk in a beaker.

Calculate the time taken for the milk to increase in temperature by 12 °C.

specific heat capacity of milk = $3930 J kg^{-1} K^{-1}$
density of milk = $1050 kg m^{-3}$

(4)

$\rho = \frac{m}{V}$ $\quad$ $E = mc\Delta\theta$ $\quad$ $12°C \rightarrow 285 K$

$\frac{1050}{\cancel{3930}} = \frac{m}{1.25\times10^{-4}}$ $\quad$ $E = \cancel{0.491}\ 0.131 \times 3930 \times \cancel{12}\ 285$

$E = 0.131 \times 3930 \times 285$

$\cancel{0.491kg}\ 0.131 = m$ $\quad$ $E = 146726.55 J$

$P = \frac{E}{t}$

$48.2 = \frac{\cancel{146726.55}}{t}$

$t = 3044 s$

Time = 3044 s

ResultsPlus
Examiner Comments

This candidate made the mistake of converting the temperature increase into kelvin.

(b) A lab technician used the resistor to heat $1.25 \times 10^{-4}\,m^3$ of milk in a beaker.

Calculate the time taken for the milk to increase in temperature by 12 °C.

specific heat capacity of milk = $3930\,J\,kg^{-1}\,K^{-1}$
density of milk = $1050\,kg\,m^{-3}$

(4)

$E = mc\Delta\theta = (1.75 \times 10^{-4} \times 1050) \times 3930 \times 12$

$= 6190J$

$\cancel{= \frac{6190J}{48.2} =}$

$\frac{6190}{48.2} = \underline{\underline{128s}}$

Time = 128 s

ResultsPlus
Examiner Comments

An example that scored full marks.

ResultsPlus
Examiner Tip

It is useful to include the formula being used in your working.

Question 10(c)

Part (c) assessed indirect practical skills. This involved writing a method to determine the frequency and the r.m.s. potential difference of the power supply, using an oscilloscope.

It was clear from the answers which candidates had used an oscilloscope to take measurements and those that had not.

In general, candidates only scored marks for the use of the formulae.

Some candidates tried to describe how to measure the "wavelength" but were unclear as to where the measurements were being taken from, i.e. corresponding points on the trace. Some candidates did mention using the time base but often didn't mention how it would be used. Most candidates did not mention the time base at all.

Similarly, measuring the peak potential difference was not described at all. Most candidates just stated "measure the peak p.d." without stating how, and even fewer candidates mentioned the voltage sensitivity.

(c) The lab technician used an oscilloscope to determine the supply frequency and check the r.m.s. output p.d. displayed by the voltmeter.

Describe the methods the technician should use.

(6)

make sure oscilloscope is calibrated correctly.
find Time period of one oscillation by finding ~~the~~ no: time division for one wavelength.
find ~~wavel~~ T multiple times and find a mean Time period. use $T = \frac{1}{f}$ to find f. $V_{rms} = \frac{V_0}{\sqrt{2}}$ = find peak voltage

from osillo sope, find multiple peaks and average. and sub into equation to find V_{rms}.

ResultsPlus
Examiner Comments

This is a fairly standard answer that scored the marks for the two formulae. The descriptions are too vague. "No: time division for one wavelength" is not enough for MP2 as it does not say where to measure from and to, and "find peak voltage" was not enough for MP5. The time base and voltage sensitivity were not mentioned at all.

ResultsPlus
Examiner Tip

Practice measuring time period and potential difference from an oscilloscope screen.

Question 11(a)i

Q11 was based on particle accelerators.

Part (a)(i) was generally done well. Some candidates got as far as using centripetal force but then either missed a step and stated that the magnetic flux density should increase, which was given in the question, or went no further. Some candidates tried to relate this to the formula for kinetic energy only or used *F=BIl*.

11 Particle accelerators produce beams of high speed charged particles which are used to investigate particle collisions. New particles are created during the collisions.

(a) In the Large Hadron Collider (LHC), protons are maintained in a circular path by the force exerted on the protons due to a magnetic field.

(i) The magnetic flux density required to maintain the protons in a circular path increases as the kinetic energy of the protons increases.

Explain why.

(2)

A greater kinetic energy results in greater linear velocity $E_k = \frac{1}{2}mv^2$. Force to keep it in a circle is $F=\frac{mv^2}{r}$ so as V is increased the force required to keep it in a circular path increases.

ResultsPlus
Examiner Comments

This is a fairly standard answer that stops at centripetal force.

11 Particle accelerators produce beams of high speed charged particles which are used to investigate particle collisions. New particles are created during the collisions.

(a) In the Large Hadron Collider (LHC), protons are maintained in a circular path by the force exerted on the protons due to a magnetic field.

(i) The magnetic flux density required to maintain the protons in a circular path increases as the kinetic energy of the protons increases.

Explain why.

(2)

-This is because $F = \frac{mv^2}{r}$, as velocity increases due to an increase in kinetic energy, the force required to maintain circular path (centripetal force) increases.
-Therefore magnetic flux density must increase due to $F = Bqv$.

ResultsPlus
Examiner Comments

This is a good answer that relates the centripetal force to the magnetic force.

ResultsPlus
Examiner Tip

Use formulae to aid your explanations.

Question 11(a)ii

Part (a)(ii) was the calculation of the magnetic density and was done well by most candidates. The most common error was to use the circumference or half the circumference instead of the radius, or not converting to m. Occasionally, candidates used the mass of an electron or the atomic mass unit value. Most candidates correctly rearranged the formula and used the correct unit, although there were some that gave Wb or W.

for the same r.

(ii) Calculate the magnetic flux density required to maintain the protons in the LHC when the protons are travelling at a speed of $3.0 \times 10^7\,\mathrm{m\,s^{-1}}$.

circumference of LHC = 27 km

(4)

$r = \frac{27}{\pi \times 2} = 4.297\,\mathrm{km}$

$r = \frac{p}{BQ}$ $\qquad 3.0\times10^{7} \times 1.67\times10^{-27} = 5.01\times10^{-20}\,\mathrm{kg\,m\,s^{-1}}$

$p = mv$

$4.297 = \frac{5.01\times10^{-20}}{B \times 1.60\times10^{-19}}$

$B = 0.07287\,\mathrm{T}$

$\approx 0.073\,\mathrm{T}$

Magnetic flux density = $0.073\,\mathrm{T}$

ResultsPlus
Examiner Comments

A clearly laid out answer, however the candidate has not converted the circumference from km to m, leading to a power of ten error in the final answer. All the processing marks were given.

ResultsPlus
Examiner Tip

Remember that showing all your working allows intermediate marks to be awarded.

(ii) Calculate the magnetic flux density required to maintain the protons in the LHC when the protons are travelling at a speed of $3.0 \times 10^{7}\,m\,s^{-1}$.

circumference of LHC = 27 km

(4)

$27km = 27000m$ $\quad \pi d = 27000m \quad d = 8594.37$

$r = \frac{8594.3...}{2} = 4297.18$

$F = \frac{mv^2}{r} = \frac{(1.67 \times 10^{-27})(3 \times 10^7)^2}{4297.18...}$

$= \cancel{3.4}\ \underline{\underline{3.50 \times 10^{-6}}}$

Magnetic flux density = 3.50×10^{-6} F

ResultsPlus
Examiner Comments

This candidate got halfway through the calculation so only scored the first two marks.

Question 11(a)iii

Part (a)(iii) was a calculation of mass from energy and was mostly answered correctly. Common errors included not converting to Joules or not using the correct power of ten, often 106. Most candidates used $E=mc^2$ but some used the formula for kinetic energy with the velocity from the previous part.

(iii) A maximum of 13 600 GeV of energy is available to create a new particle.

Calculate the theoretical maximum mass, in kg, of the new particle.

(3)

$E = mc^2$

$\frac{13600 \times 10^9}{(3 \times 10^8)^2} = 1.51 \times 10^{-4}$

Maximum mass = 1.51×10^{-4} kg

ResultsPlus
Examiner Comments

No conversion to Joules so MP2 only.

(iii) A maximum of 13 600 GeV of energy is available to create a new particle.

Calculate the theoretical maximum mass, in kg, of the new particle.

(3)

$\Delta E = c^2 \Delta m$ $\quad 13\,600 \times 10^9\ eV = 13600 \times 10^9 \times 1.60 \times 10^{-19}\ J = 2.176 \times 10^{-15}\ J$

$\Delta m = \frac{\Delta E}{c^2}$

$= \frac{2.176 \times 10^{-15}}{(3.00 \times 10^8)^2} = 2.42 \times 10^{-32}\ kg$

Maximum mass = 2.42×10^{-32} kg

ResultsPlus
Examiner Comments

This candidate has written the correct powers of ten in the conversion to Joules but has made a calculation error. MP1 could be awarded here along with MP2.

ResultsPlus
Examiner Tip

Learn powers of ten for common unit prefixes.

Question 11(b)

Part (b) was a linkage question based on comparing colliding beams with a fixed target.

It was clear that candidates had missed the part of the stem that stated that the total energy is the same for both collisions, as many stated that the colliding beams have twice the kinetic energy than the fixed target.

Most candidates that started with this premise and conservation of energy rarely scored many marks. Some candidates also wasted time and space by stating the laws of conservation of momentum and energy without reference to any particular type of collision.

Those candidates that started by using the conservation of momentum often scored some marks and there were some high scores seen.

Some candidates were not clear enough in their descriptions to score marks, or used imprecise language.

Some candidates did not explicitly state that there would be momentum either before and after the collision in the fixed target, or that momentum would be zero before and after the collision in the colliding beams.

Occasionally, candidates referred to momentum being “close to zero”, which was not credited.

Some candidates referred to “most” kinetic energy being converted into mass rather than “all”, and some candidates did not refer to kinetic energy.

*(b) Fifty years ago, fixed-target collision experiments were carried out at the Stanford Linear Accelerator Centre (SLAC). In these experiments, high speed particles were made to collide with a stationary target.

Currently, colliding beam experiments are carried out at SLAC. In these experiments, high speed particles travelling in opposite directions are made to collide head-on.

For a given total energy in the collision, colliding beam experiments allow particles to be created with a larger mass than could be created in a fixed-target experiment.

Explain why colliding beam experiments allow a new particle with the larger mass to be created. You should consider how the conservation of energy and the conservation of momentum apply to each type of collision.

(6)

~~$p + p = x$~~

Total momentum before and after = 0 as the same particles are travelling in opposite directions at the same speed. Kinetic energy not conserved as collision is inelastic, but total mass-energy must be conserved, which must be higher than fixed-target experiments as multiple particles travelling at very high speeds implies high KE, but as total momentum = 0, ~~Most~~ of this KE is converted to mass as $E = mc^2$, and hence a large mass is created.

ResultsPlus
Examiner Comments

This candidate did not make it clear that they were discussing colliding beams, but since they stated "must be higher than fixed targets", it was assumed that the first three lines related to colliding beams. They have started with momentum conservation and IC4 and IC5 were awarded on line 1. They then get a little muddled and start discussing higher kinetic energy, but then focus on momentum again. Unfortunately, they say "most" rather than "all" kinetic energy is converted into mass.

ResultsPlus
Examiner Tip

Where there are two separate conditions, state which condition is being discussed.

Question 12(a)i-ii

Q12 was based on measurements on a falling object, so this would be similar to one of the core practicals.

Part (a) assessed indirect practical skills related to repeated measurements of time.

Part (a)(i) was an explanation of whether a measurement should be discarded from the data in calculating the mean. Most candidates thought that this was the correct thing to do, as a difference of 0.05 ms was clearly too large. Some did realise that this value was not "anomalous" but gave a weak reason for including it, such as "you should include all the data". The best answers included sound reasoning, such as giving a percentage difference between the values or suggesting that there is not enough data to judge whether the value was indeed anomalous.

(a) A student recorded the following data.

t_1/ms	t_2/ms	t_3/ms	t_4/ms
7.85	7.81	7.79	7.80

(i) The student omitted t_1 when calculating the mean time. He justified this by stating that t_1 is an anomalous result.

Another student stated that the correct mean time should use all the data in the table.

Explain who is correct.

(2)

- Other student is most likely correct because there are only 4 pieces of data collected so hard to draw a firm conclusion that 7.85 is anomolase.

(ii) Calculate the percentage uncertainty in the mean time t_{mean}.

(3)

mean = $\frac{7.85 + 7.81 + 7.79 + 7.80}{4}$

= 7.8125 s

~~mean~~ abs U = $\frac{\text{range}}{2}$

abs U = $\frac{7.85 - 7.79}{2}$

= 0.03 s

$\frac{0.03}{7.8125} \times 100 = 0.384\%$

Percentage uncertainty in t_{mean} = 0.38%

ResultsPlus Examiner Comments

"Other student" was enough to refer to the correct student in this context. They have the idea that there is not enough data to judge whether t_1 is anomalous.

ResultsPlus Examiner Tip

Understand what is meant by "anomalous" and how data should be judged.

Part (a)(ii) was a calculation of the percentage uncertainty in the set of readings. Most candidates knew that the half range should be used, but some gave a value with too many significant figures. Most candidates were consistent in removing what they thought was the anomalous value but some still did the calculation with the value included.

(ii) Calculate the percentage uncertainty in the mean time t_{mean}.

(3)

$$\text{mean} = \frac{7.85 + 7.81 + 7.79 + 7.80}{4} \qquad \cancel{\text{mean}}\ \text{abs } U = \frac{\text{range}}{2}$$

$$\text{abs } U = \frac{7.85 - 7.79}{2}$$

$$= 7.8125\ \text{s} \qquad = 0.03\ \text{s}$$

$$\frac{0.03}{7.8125} \times 100 = 0.384\%$$

Percentage uncertainty in t_{mean} = 0.38%

ResultsPlus
Examiner Comments

The calculation is clear here and is consistent with their answer to part (i). Appropriate significant figures are used in this case.

ResultsPlus
Examiner Tip

Usually, it is best to use one or two significant figures for a final percentage uncertainty.

Question 12(a)iii

Part (a)(iii) was surprisingly poorly answered. Common errors included the length of the glass tube or the length of the light gate itself.

Question 12(b)i-ii

Part (b)(i) was a calculation for the velocity of the cylinder as it reached the light gate. Many candidates just did not take into account that the cylinder is in free fall. About half of the candidates used $v = s / t$ with their average time, rather than an appropriate equation of motion. This often led to a very high velocity, but there was little evidence of candidates reworking their calculation.

(b) The metal cylinder fell through a distance 0.75 m before reaching the light gate.

(i) Calculate the velocity of the metal cylinder as it reached the light gate.

(2)

$t \quad s \quad u \qquad s = \frac{(u+v)t}{2} \qquad \cancel{v^2 = u^2 + 2as}$

$\cancel{v^2 = u^2 + 2as} \qquad \cancel{\sqrt{0 + 2 \times 9.81 \times 0.75} = 3.84\ \text{ms}^{-1}}$

$\frac{2s}{t} = 0 + V \qquad \frac{2 \times 0.75}{7.813 \times 10^{-3}} = V = 192\ \text{ms}^{-1}$

$192\ \text{ms}^{-1}$

Velocity = $\cancel{3.84\ \text{ms}^{-1}}$

ResultsPlus
Examiner Comments

Unfortunately, this candidate had crossed out the correct calculation and replaced it with the incorrect calculation.

Part (b)(ii) assessed indirect practical skills relating to the use of light gates and data loggers to record short times. This generated a spread of marks with references to reaction time being very common. Some candidates think that "human error" is an acceptable phrase to use, when it is not. Although the question directed candidates to refer to their answer in the previous part, many did not. Some candidates did, but just stated the value rather than comment about it.

Only a few candidates mentioned time in their answer and some that did were not precise enough in stating which time they were referring to.

In some cases, it was evident that candidates were referring to the time they used in the previous part or were a bit vague in suggesting the "time for the cylinder to fall".

(ii) Explain why a light gate and data logger were used in this experiment rather than a stopwatch. You should refer to your answer to (b)(i).

(3)

The cylinder is moving very fast at $19.2 m s^{-1}$ and so the time for ~~the~~ it to pass the light gate is small. This means the percentage uncertainty induced from reaction time and human error would be huge from using a stopwatch & data logger can take more readings in a smaller time

(Total for Question 12 = 11 marks)

ResultsPlus
Examiner Comments

This candidate commented on both the calculated velocity (but didn't seem bothered that the cylinder was falling at 192 ms^{-1}) and stated which time they were referring to. The comment regarding the uncertainty in the measurement was enough for MP3.

ResultsPlus
Examiner Tip

Understand the pros and cons of using light gates and data loggers and relate these to the investigation in the question.

Paper Summary

Based on their performance on this paper, candidates should:

- Ensure they have a thorough knowledge of the physics content of the whole specification.
- Be ready to apply their knowledge of core practicals and general techniques to questions testing their indirect practical skills.
- Read each question carefully and answer what is asked.
- Show all workings in calculations.
- Make a note of the marks available and include that number of different physics points in their response.
- Try to base their answer around a specific equation or principle.
- Formulate a response that is consistent with the command word used in the question.

Grade boundaries

Grade boundaries for this, and all other papers, can be found on the website on this link: https://qualifications.pearson.com/en/support/support-topics/results-certification/grade-boundaries.html

Pearson Education Limited. Registered company number 872828
with its registered office at 80 Strand, London WC2R 0RL.