8225
Paper 3

GENERAL COMMENTS

The overall standard of the NSSCAS 8225 Physics Paper 3 appeared to be more challenging to the average learner compared to the NSSCH Paper 3 Practical Test. This difference in standard is expected because the NSSCAS Paper 3 focuses on Advanced Practical Skills compared to the NSSCH Paper 3 Practical Test. In particular, the Mathematical requirements to be applied in NSSCAS Physics are more in terms of both depth and volume, as specified in the NSSCAS Physics syllabus that learners are required to apply arithmetic, algebra, geometry and trigonometry, vectors and graphs throughout the NSSCAS Physics course (NSSCAS Physics syllabus, page 5).

It should be emphasised that in order for learners to be well prepared for the 8225 Physics paper 3, there is a need to focus on **ANNEXE A**: Assessment criteria for Paper 3 (Advanced Practical Skills) on page 31 to page 39 of the 8225 Physics syllabus. This annexe stipulates clearly the marking scheme for Paper 3 (page 32) in terms of the three main skills which are assessed (manipulation, measurement and observations; presentation of data and observation; analysis, conclusion and evaluation) as well as the breakdown of marks per skill.

The Supervisor's Reports from many centres included useful detail about difficulties encountered in the experiments and any help given to candidates. This information is useful to the Examiners who can take it into account when marking candidates' work. When this information is provided, candidates who have recorded readings that are outside of the expected range can still be given credit where appropriate.

For some centres, there were many excellent scripts; the candidates' work was of a good standard, and with data and graphs presented clearly. Working was usually clear and legible. Candidates did not seem to be short of time and both questions were attempted by most candidates. They demonstrated good skills in the generation and handling of data but could improve by giving more thought to the analysis and evaluation of experiments.

Candidates should be encouraged to draw tables carefully using ruled lines and, where possible, record data systematically. For graph work, candidates should be encouraged to use a 30 cm ruler to draw lines of best fit and to provide legible scale markings on axes. Supervisors are reminded that help should not be given with the recording of results, graphical work or analysis.

Key messages

- Candidates need to remember to state their recorded measurements to the precision of their measuring instruments e.g. ruler used for measuring the length *L* in **1(a)** and distance *d* in **2(a)(ii)** and **2(c)** to the nearest 1mm (0.1cm; 0.001 m).
- Candidates should then be encouraged to undertake repeated readings (at least two) especially if a time is asked for, e.g. time *t* in **2(b)(i)**. Each raw reading should have the same degree of precision (number of decimal places).
- In answering **Question 2**, candidates should be reminded that limitations and suggestions for improvement must be focused on the experiment. General points such as 'avoid parallax error' or 'use more precise measuring instruments' or 'use better apparatus' will not gain credit without further detail. As candidates take measurements, they should ask themselves 'why is this measurement difficult to take?' and then 'is there a better method I could use to take this measurement accurately?'

COMMENTS ON SPECIFIC QUESTIONS

1 (a) Many candidates recorded the value of *L* that was in the expected range. Answers were generally provided to the nearest cm e.g. 60 (cm). Candidates need to remember to state their recorded measurements to the precision of their measuring instruments, in this case it is expected that 60 cm be recorded as 60.0 cm (to the nearest mm).

Many candidates recorded the value of I to the nearest mA and in the expected range.

(b) Table of results

A reasonable number of candidates were awarded credit for the column headings, stating the quantity and correct unit. A few candidates omitted either the unit or the separating mark for one or more of the columns. The heading and the unit should be separated by a solidus or by using brackets around the unit.

One common error was the omission of a suitable separating mark between the quantity and unit, for example writing $\frac{1}{I}$ mA^{-1} instead of $\frac{1}{I}$ / mA^{-1} $\frac{1}{I}$ or $\frac{1}{I}$ (mA^{-1}). Some candidates gave the unit of $\frac{1}{I}$ as mA instead of mA^{-1} and lost marks as a result.

Successful collection of data and observations

Most candidates were able to collect six sets of values of L and I without assistance from the Supervisor. A minority of candidates collected more results. A few candidates collected five or fewer. In a few cases the trend was wrong, possibly caused by a reversed metre rule scale.

Range of readings

Some candidates extended their range of length L of wire to below 30 cm and/or above 100 cm. Other candidates fell just short of this range (30 cm to 100 cm). Candidates are encouraged to use the full limit possible with the apparatus provided, in this case the range was specified in the question as 30.0 cm to 100.0 cm.

Consistency in presentation of raw readings

Many candidates correctly recorded their raw values for L to the nearest 0.1 cm. Some candidates recorded L to the nearest cm (e.g. 10 cm) without considering that they can make the measurement to the nearest mm using the ruler provided.

Some candidates added a trailing zero to the end of their number if it was less than 10.0 cm and/or omitted a trailing zero at the end of their number if it was equal to or greater than 100.0 so that the number of significant figures was the same down the column (e.g. 15.0, 9.00, 5.00, 100 cm). This was penalised as the number of decimal places in the raw readings of L must reflect the precision of the ruler used (i.e.15.0, 9.0, 5.0, 100.0 cm). As the ruler measuring L can be read to the nearest mm, the number of decimal places in L must be consistent down all raw data columns and not the number of significant figures.

Many candidates recorded all values of I to the same number of decimal places as expected.

Significant figures

Many candidates recorded their calculated values for $\frac{1}{I}$ to the correct number of significant figures, i.e. to the same number of significant figures as (or one more than) the number of significant figures in the raw values of I. Some candidates either stated too many or too few significant figures, or aimed to be consistent in their use of decimal places at the expense of significant figures. This often increased the amount of scatter in the results plotted on the grid.

Calculations

A satisfactory number of candidates calculated $\frac{1}{I}$ correctly. A few candidates rounded their final answers incorrectly, including rounding to only one significant figure. A significant number of candidates made mistakes by ignoring the exponents in their calculations, for example $\frac{1}{300}$ recorded as 3.33 instead of 3.33×10^{-3}.

(c) (i) Layout (axes)

The best graphs had scales chosen to give simple intervals (using ratios of 1, 2 or 5 to a 2 cm square) as well as making good use of the available grid area, and each axis was labelled with the plotted quantity.

Candidates were required to plot a graph of $\frac{1}{I}$ on the y-axis against L on the x-axis. A significant number of candidates plotted points carefully using a sharp pencil. Candidates could improve by ensuring scales (in either the x or y direction) are chosen to spread out plotted points to occupy the whole of the graph grid, rather than points being squashed into a small part of the grid. Compressed scales (where the plotted points occupy less than four large squares in the x or less than five large squares in the y direction) were often seen and also did not gain credit. This may have arisen because of the candidate's perceived need to start the graph at the true origin. Candidates are encouraged to use the false origin where appropriate.

A few weaker candidates set the minimum and maximum reading in the table to be the minimum and maximum of the graph grid, leading to time-consuming work plotting and using the scales. Awkward scales cannot be awarded credit and it was very common for candidates using such scales to make further mistakes with subsequent read-offs. Some candidates used irregular (i.e. non-linear) scales. Irregular scales could not be given credit, and often the data could not be awarded credit for quality either because the error was often in the region of the plotted points. Candidates should be encouraged to set up their graphs to make them easy to work with in later parts of the question i.e. gradients and y-intercepts.

Plotting of points

Small crosses generally produce the clearest plotted points as long as the pencil is sharp. The use of large dots (with diameter greater than 1 mm) is not awarded credit because the accuracy of their position cannot be judged.

Candidates need to draw points with a diameter equal to or less than half a small square (1 mm). They can improve by carefully checking that points are plotted in the correct position. If a point seems anomalous, candidates should be encouraged to check the plotting and to repeat the measurement if necessary. If such a point is ignored in assessing the line of best fit, the anomalous point should be labelled clearly, e.g. by circling the point. There is no credit specifically for identifying an anomalous point, so candidates should be reminded that they do not need to identify an anomalous point if they do not think they have one. Any data recorded in the table must be plotted on the graph.

Quality

The quality of the candidates' data was judged by the scatter of points about a straight-line trend. In the some cases this was good and so credit was awarded. Some candidates lost marks because of a negative trend. A mark was awarded for a positive trend of points.

(ii) Good candidates drew suitable lines of best fit which had a balanced distribution of points either side along the entire length. In some cases, a stray point was apparently ignored without explanation. If such a point is to be ignored in assessing the line of best fit, the anomalous point should be labelled clearly (e.g. by circling the point). Candidates should not ignore more than one point in this way. Some candidates were not awarded credit for their line because of using a short ruler and having to extend their line to cover the range of their plotted points. Kinks, hairy, feathery, breaks and joins in the line are often apparent in such cases and are penalised.

Some candidates joined the first and last points on the graph or any three points on a straight line regardless of the distribution of the other points. Others joined the plotted points from point to point with a ruler, forming zig-zag patterns. There should always be a balanced distribution of points either side of the line along the entire length. Candidates should be encouraged to draw the line according to the positions of the plotted points, and not to force the line through the origin.

(iii) Some candidates used a suitably large triangle to calculate the gradient, gaining credit for correct read-offs, and substituted into $\frac{\Delta y}{\Delta x}$. Candidates need to check that the triangle for calculating the gradient is large enough (the hypotenuse should be greater than half the length of the line drawn). Other candidates needed to check that the read-offs used were within half a small square (1mm) of the line of best fit and show clearly the substitution into $\frac{\Delta y}{\Delta x}$ (not $\frac{\Delta x}{\Delta y}$). The equation, if used, m(x – x1) = (y – y1) should be shown with substitution of read-offs. There were many instances of incorrect read-offs, and many candidates would benefit from double-checking their read-offs. Instead of read-offs, some candidates used table points that were not on their line and this was not credited. Many candidates were able to correctly read off the y-intercept at x = 0 directly from the graph, but a large number of candidates incorrectly read off the y-intercept when there was a false origin. Some candidates correctly substituted a read-off into y = mx + c to determine the y-intercept. Others needed to check that the point chosen (if it was from the table) was on the line of best fit drawn.

(d) This question was very well answered. The majority of candidates were able to record a value of e.m.f within the expected range.

(e) The majority of candidates only scored 1 out of 3 at this part. Many candidates recognised that K = gradient. However, most candidates mistakenly took Z as equal to the y-intercept instead of relating y = mx + c to $\frac{1}{I}$ = KL + $\frac{Z}{E}$ to deduce that c = $\frac{Z}{E}$ therefore Z = C × E. Many candidates therefore failed to score this mark. As a result, most of the candidates were able to deduce the unit for the gradient correctly, but were unable to deduce the unit for constant Z because of the fact that they did not recognise how constant z was to be determined as Z = C × E. Some candidates omitted the units altogether. Candidates should remember that they should be able to determine the units for these constants.

Answers to Question 1

Question	Answer	Marks
(a)	Value of L in the range 58.0 cm to 62.0 cm and value I in the range 100 mA to 400 mA.	1
(b)	Table of results: Column headings for L, I and $\frac{1}{I}$. Each column heading must contain a quantity and a unit where appropriate. The unit must conform to accepted scientific convention e.g. $1/I$ / A^{-1} or $1/I$ (A^{-1}) $1/I$ / mA^{-1} or $1/I$ (mA^{-1}) Accept separating mark as a solidus, brackets.	1 (M1)

	Successful collection of data and observations Six sets of readings with correct trend as L increases, I decreases scores three marks, five sets two marks and four sets 1 mark.	3 (M2)
	Range of readings at least one value of L less than or equal to 40.0 cm and one value of L greater than or equal to 90.0 cm	3 (M2)
	Consistency of presentation of raw readings: All values of L given to the nearest millimetre All values of I given to the same number of decimal places.	1 (M4) 1
	Significant figures in $\frac{1}{I}$ must be given to the same sf (or one more) than the sf in I	1 (M5)
	Calculations for $\frac{1}{I}$.	1 (M6)
(c) (i)	Layout (axes): Scales must be chosen so that the plotted points occupy at least half the graph grid in both x and y directions. Axes labelled with the quantity (and unit) being plotted, e.g. x-axis: L / cm and y-axis: $\frac{1}{I}$ / mA^{-1} Sensible scales must be used. Do not accept awkward scales (e.g. 3:10) or fractions. Place regularly-spaced numerical labels along each axis at least every 4 cm	1
	Plotting of points: All observations in the table must be plotted on the grid. Diameters of plotted points must be ≤ 1mm. (no blobs) Points must be plotted to an accuracy of ≤ 1mm in both x and y directions.	1
	Quality: Trend of points must be positive. All points in the table must be plotted (at least 5) on the grid for this mark to be awarded.	1
(c) (ii)	Trend line (line of best fit): Judge by balance of all points on the grid about the candidate's line (at least 5 points). There must be an even distribution of points either side of the line along the full length. Allow one anomalous point (indicated i.e. circled or labelled by the candidate). There must be at least five points left after the anomalous point is disregarded. Lines must not be kinked or thicker than half a small square	1
(c) (iii)	Gradient: The hypotenuse of the triangle used should be greater than half the length of the drawn line. Both read-offs from the line must be accurate to ≤ 1 mm in both x and y directions. The method of calculation must be correct. Do not allow $\Delta x/\Delta y$.	1
	y-intercept: Correct read-off from a point on the line and substituted correctly into y = mx + c or an equivalent expression. Read-off accurate to ≤ 1 mm in both x and y directions. or Intercept read directly from the graph, with read-off at L = 0, accurate ≤ 1 mm in y direction	1
(d)	Value of E in the range 2.2 V – 3.4 V	1
(e)	K = candidate's gradient value	1
	Z = E × candidate's y-intercept value	1
	Units K: A^{-1} m^{-1} or mA^{-1} cm^{-1} Z: V A^{-1} or V mA^{-1}	1
		[20]

2 **(a)** **(i)** This question was the most accessible in the whole question paper.

Most candidates correctly recorded the mass of the block to the appropriate degree of precision.

(ii) Just like in question **1(a)** with regards to the value of length L, many candidates recorded the value of d that was in the expected range. Answers were generally provided to the nearest cm e.g. 60 (cm) while the answer line specifies for the length to be recorded in metres. Candidates need to remember to state their recorded measurements to the precision of their measuring instruments, in this case it is expected that 60 cm be recorded as 0.600 m (to the nearest mm).

The majority of candidates recorded the mass m of the mass hanger in the expected range and to the appropriate degree of precision.

(iii) Stronger candidates, on the one hand, realised that the measurement of d was difficult to measure to the nearest mm and so the absolute uncertainty in their value was greater than the precision of the ruler scale. On the other hand, stronger candidates who repeated the measurement for d were also able to recognise that they needed to express the uncertainty as half the range of the repeated readings.

(b) **(i)** Some candidates carried out this part competently. They were able to recognise that the measurements of time should be repeated and recorded consistent raw data. Other weaker candidates appeared to have little experience of the process and several types of error were seen. In most cases, there was no evidence of repeated measurements with averaging.

(ii) Most candidates were able to correctly carry out this calculation by using their values from **(a)(ii)** and **(b)(i)**. Most candidates scored at least 1 out of 2 marks at this part. They mostly lost the 1 mark because there was no evidence of repeated readings. Others lost the 1 mark by not rounding of their answer to the appropriate number of significant figures.

(iii) This question proved to be one of the least accessible in the whole question paper. Candidates found it difficult to justify the number of significant figures they had given for the value of a with reference to the number of significant figures used in their time *t* and distance *d* (since both *d* and *t* had the same number of significant figures). Many candidates stated either 'raw readings' or 'least number of significant figures used in the calculation' without making reference to what the raw quantity actually was, or incorrectly involved *m* in their justification while m is not part of the quantities used to calculate a.

(c) Stronger candidates were able to record *d*, *m*, *t* and a in the expected range and to the appropriate degree of precision. Some candidates lost marks for example because they had a greater value of *t* compared to *t* in **(b)(i)** when it was expected to be a lesser value as per the experimental procedure. Other candidates lost marks because the degree of precision of *t* was inconsistent with the degree of precision of *t* recorded in **(b)(i)**.

(d) Many candidates were able to calculate *g* for the two sets of data, showing their working clearly. A significant number of candidates incorrectly rearranged the equation or inadvertently substituted the wrong values. Others simply wrote down the memorised value of g = 9.81 from data booklets by recall, without recognising that they needed to make use of their own data to calculate this value.

(e) Only a handful of candidates scored this mark. The majority of candidates ignored or overlooked the **5%** value which is given in the question and they went ahead and tested the relationship against their own specified numerical percentage uncertainty as a criterion, commonly using 10%, 20%. This deviation from the given 5% was penalised. Some candidates omitted the criterion altogether and just gave general statements such as 'this is valid because the values are close to each other' or 'strongly supported' without any working, which could not be accepted. Occasionally candidates gave a contradictory statement such as 'my results do not support this relationship as my % difference is less than 5%' or vice versa, in which case they were supposed to deduce that if their % difference less than the given 5% then their results support the relationship, and vice versa.

(f) For both the limitations and improvements, candidates are advised, where appropriate, to state both the quantity being measured, example time t, distance d, and the reason for any uncertainty. Many candidates gave partial statements in one or more of their responses and so were unable to gain credit for these.

A good answer, for example, would be 'there is an uncertainty in *t* because it is difficult to start the stop watch and release the mass at the same time': a difficulty is identified and the candidate specifies which measurement is affected.

For the limitations, the majority of candidates recognised that calculating two values of g is insufficient to draw a valid conclusion. Some candidates incorrectly linked the lack of *g* values to accuracy whereas others gave insufficient statements such as 'two *g* values are not enough'. Careful use of language was needed here as some candidates stated two readings were not enough to 'conclude the experiment' (which means in effect, to end the experiment) instead of meaning to reach a conclusion or candidates referred to taking results rather than drawing a conclusion.

A significant number of candidates recognised that it was difficult to measure d and hold the wooden block at the same time. There were many good answers referring to the difficulties in measuring the distance *d*. Very few candidates gave an acceptable reason for uncertainty in *d* due to the zero error of the metre rule on the floor. Many candidates gave general statements such as 'the ruler does not start at zero'.

For improvements, many candidates correctly suggested taking more readings and plotting a graph. Other good answers include using a video which was well explained in terms of measuring time e.g. a stopwatch in view of the camera and film played back or count frames.

Credit is not given for suggested improvements that could be carried out in the original experiment, such as 'repeat measurements', 'do more readings to get an average value', 'zero the stop watch before you take the next reading of t'. Unrealistic solutions were also not given credit, e.g. 'robotic arm' or 'mechanical hand' to hold and release the wooden block/ mass hanger. Limitations that were irrelevant or that could have been removed if the candidate had taken greater care were not given credit e.g. parallax error. Vague or generic answers did not gain credit such as 'too few readings' (without stating a consequence).

The key to this section is for candidates to identify **genuine** problems associated with setting up this experiment to obtain **specific readings**. Candidates are then encouraged to suggest practical solutions that either improve technique or give more reliable or accurate data. Clarity of thought and expression separated stronger candidates from those less prepared to deal with practical situations. Candidates should be encouraged to write four different limitations (relating to the different measurements undertaken or approaching them chronologically) stating how these difficulties impact on the experiment. Candidates should then try to think of associated solutions that address each of these limitations.

Answers to Question 2

Question	Answer	Marks
(a) (i)	Value of mass in the range 20 g to 300 g	1
(a) (ii)	Value of d in the range 0.580 m to 0.620 m and *d* measured to the nearest millimetre and value of mass recorded as 100 g	1
(a) (iii)	Absolute uncertainty in the range 0.002 m to 0.010 m and correct method to determine percentage uncertainty, e.g. $\frac{\text{value of uncertainty}}{\text{their actual value}} \times 100$ If several readings have been taken, then the absolute uncertainty can be half the range, but not zero if values are equal.	1
(b) (i)	Two or more measurements of time t	1
(b) (ii)	Average t determined correctly (evidence of repeats) Correct calculation of a using candidate's d value and candidate's t value in the formula $a = \frac{2d}{t^2}$ given to a minimum of two significant figures.	1 1
(b) (iii)	Justification based on the significant figures in the values of d and t.	1
(c)	value of d between 0.580 m to 0.620 m, value of m is 200 g, and t and a for the second experiment raw t is recorded to the same no of decimal places t is smaller	1 1 1
(d)	Value of *g* calculated for the first experiment and value of *g* calculated for the second experiment. $g = \frac{a(m + B)}{m}$	 1

(e)	percentage difference between the two values calculated and compared with 5%.	1
(f) (i)	Suggesting improvements • Take many readings and plot a graph (of a against $\frac{m}{m+B}$) • Use a heavier wooden block to slow it down. • Check position of hook in the centre of the block or alignment of pulley • Reduce friction on the surfaces by putting wheels on the block or polishing the table surface. • Use adhesive putty to hold block while d is measured / clamp rule in a retort stand vertically next to mass • Mark distance d on bench (so that block / mass hanger starts from same position). • Measure zero error and subtract form rule reading. • Detailed use of electronic method to determine time.	4
Total		**20**

POSITIVE SUGGESTIONS TO TEACHERS

In order the prepare learners well for the 8225 Physics Advanced Practical Skills Paper 3, it is important to bring to the attention of the learners that ANNEXE A: Assessment criteria for Paper 3 (Advance Practical Skills) which is outlined in the NSSCAS 8225 Physics syllabus from page 31 to page 39 plays a pivotal role in this regard. This is the annexe in which the assessment skills are specified as to which skills the paper advanced practical skills focus on (i.e. manipulation, measurement and observation; presentation of data and observations; analysis, conclusion and evaluation). This is the case in the NSSCAS Physics course as well as the two other cognate NSSCAS subjects (i.e. Chemistry and Biology). It is exciting to know and to bring to the attention of the learners that the mark scheme for Paper 3 is already included in the syllabus (see page 32).

It is also important to expose the learners to the basic practical skills using for example the NSSCAS Physics specimen question paper and materials as specified in ANNEXE A4 (page 37). Once the learners have this expose, they will be at ease to apply the skills to any advanced practical skill they are faced with and they will have the confidence to tackle the practical. This in turn will also prepare learners to be able to finish the two questions comfortably in the two hours without struggling to use some of the basic apparatus such as stopwatches.