# Teacher Resource Bank

## GCE Physics A

## ISA/PSA Guidance

## Guidance on Development of Practical Skills for the ISA at AS Level

The information below gives a brief overview of the skills required in the Investigative Skills Assignment (ISA). These are referenced to the *How Science Works* (section 3.7) and/or *Mathematical Requirements* (section 3.9) sections in the specification. This should be read together with the detailed information given in section 3.8 of the specification *Guidance on the Centre Assessed Units*.

Also refer to the document *Glossary of Terms* giving details and definitions of many of the terms used in the ISA.

### ISA Stage 1: Collection and Processing of Data

Candidates will be required to:

- Carry out practical work following instructions given on an AQA task sheet.
- Collect data and tabulate in a suitable format (possibly to include repeat readings and processed data).
- Process data and draw an appropriate graph (*How Science Works* D & E).

Two exemplar ISAs are now available to centres. These give an indication of the type of experiment and questions used in future AS ISAs. These are:

1. Electrical experiment on component characteristics – this is the ISA specimen test paper provided with the new specification.
2. Equilibrium of Forces ISA – this is available in the *Teacher Resource Bank*.

Both of these experiments can be used as practice exercises in preparing students for the actual ISA tests. They are complete with centre instructions, student task sheets and detailed marked schemes. Copies are available on the AQA website http://www.aqa.org.uk/qual/gce/physics_a_trb_new.php.

### Tabulation and Graph Drawing

(See also document entitled *Advice on Marking Practical Skills in GCE Physics ISAs*. This is available in the *Teacher Resource Bank*).

In part 1 of the ISA, the experimental data collected should be clearly presented in a suitable table. The table must include column headings labelled with the appropriate physical quantity and units. This should be in the form in line with the ASE convention, eg current/amps or I/A (credit is awarded for units quoted in other formats as outlined in the *Advice on Marking Practical Skills in GCE Physics ISAs* document and ISA mark schemes). Significant figures for raw data recorded should be compatible with the precision of the instrument used.

Where appropriate, tables should also include columns for repeat readings and processed data together with column headings and units.

Graphs should be plotted on A4 graph paper with either 1 mm or 2 mm squares. Graph scales should have sensible divisions on which points can be easily plotted and read (ie **not** generally in multiples of 3, 4, 6, 7, 9 etc). Axes should be labelled with the plotted quantity and unit. This should be in the same form as column headings in line with the ASE convention, ie quantity/unit. The scale should be chosen so that the plotted points occupy as large an area of the paper as possible. As a general guide, a scale would be deemed too small if the plotted points do not occupy at least half the length of each axis. Such a scale could easily have been doubled. In some cases this will require starting either or both axes at a suitable non-zero value.

It is good practice to ensure that all graphs have an appropriate title.

The plotted points should be represented as a small horizontal cross '+' or a small diagonal cross '×'. Error bars will not be required at AS level (other acceptable methods of representing the plotted points are outlined in the *Advice on Marking Practical Skills in GCE Physics ISAs* document). Generally, a plotted point would be deemed as correctly plotted if it is a distance of 1 mm or less from the correct position.

Where the plotted points suggest a straight line, the line should be drawn with approximately equal numbers of points on either side of the line. Points which are obviously anomalous should not unduly influence the line (candidates should indicate that an anomalous point has been ignored when drawing the line of best fit). If the plotted points suggest a curve, a smooth curve should be drawn.

Where a gradient is to be calculated, a suitably large triangle should be used. Candidates should be encouraged to draw as large a triangle as possible to ensure accuracy of the calculated value. As a general guide, candidates should be instructed that the **minimum size of triangle is where both the x-step and y-step are at least 8 cm** (this is approximately half the size of the smallest axis). However, on occasions, in the mark schemes for some ISAs, we may suggest that a slightly smaller triangle is allowed, dependent on the data collected.

Where a gradient is taken from two points on the graph, the points must be sufficiently far apart to be equivalent to a 'large' triangle as defined above. The gradient should not be taken from plotted points which **do not** lie on the line of best fit.

Where the line of best fit is a smooth curve, the gradient at a point may be found by drawing a tangent to the curve at that point. The same criteria for the size of the gradient triangle will apply (ie minimum size 8 cm × 8 cm).

Where an intercept is required this can either be read directly from the axis or, in the case of axes not starting from zero, a suitable calculation may be required.

## ISA Stage 2: The Written Test

The table which follows gives an indication of the range of questions/tasks which may be required in the ISA written test. This does not necessarily represent an exhaustive list of every possible type of question which may be used in future ISAs.

| Skill | Type of question/example | Specification reference |
|---|---|---|
| planning – selection of appropriate apparatus and factors in determining suitable range of measurements | • explain reasons for choice of range of readings<br>• explain why a particular instrument/method was used | How Science Works C |
| identify dependent, independent and control variables | • identify the dependent, independent or control variable (variable to be kept constant) in a particular experiment | How Science Works C |
| instrument precision | • state the precision of instruments used<br>• use this in calculation of uncertainty | How Science Works C |
| identify and minimise significant sources of error | • identify possible sources of error<br>• explain how these might be reduced | How Science Works D |
| risk assessment | • explain potential risks and safety procedures in an experiment | How Science Works D |
| tabulate and process measurement data | • complete data processing for data provided in tabular form | How Science Works E |
| plot graph and establish or verify relationship between variables | • plot graph from data provided – in the ISA test, this will usually involve plotting additional points onto a partly plotted graph and drawing the line of best fit<br>• identify relationship between variables plotted, e.g. direct proportionality for straight line graph through origin | How Science Works E |
| relate gradients and intercepts to appropriate linear equations<br>use of $y = mx + c$ | • rearrange equation into suitable format to compare with $y = mx + c$<br>• state what physical quantity gradient of graph represents<br>• state what physical quantity the intercept of graph represents | How Science Works E<br><br>Mathematical Requirements |
| random and systematic errors | • identify possible source of random errors in an experiment<br>• identify possible systematic errors in an experiment | How Science Works F |

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<tr>
<td>make reliable estimates of errors/uncertainty:<br>• for single measurements based on instrument precision<br>• for repeated readings: uncertainty = ± 0.5 × spread<br>(nb a full statistical treatment, including calculation of standard deviation, is not required at this level<br>the above simple calculation gives a realistic estimate of the uncertainty based on the spread of repeated readings, this is adequate at this level)</td>
<td>• calculate the percentage uncertainty in the smallest current reading<br>eg if the instrument precision is 0.01 A and the smallest current reading 0.30 A<br>uncertainty in current = ± 0.01 A<br>% uncertainty = (0.01/0.30) × 100 = ± 3.3 %<br>• estimate the uncertainty from repeat readings, eg repeated time readings of 2.22 s, 2.25 s, 2.34 s<br>mean = 2.27 s<br>0.5 × spread = 0.5 × 0.12 = 0.06<br>quoted mean with uncertainty is:<br>2.27 ± 0.06 s<br>% uncertainty in timing measurement<br>= (0.06/2.27) × 100 = ± 2.6 %</td>
<td>How Science Works<br>F<br><br>Mathematical Requirements</td>
</tr>
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<td>combination of errors<br>at AS this will involve only simple cases of products and quotients involving two quantities<br>the combined % uncertainty is found by adding together the % uncertainty in each quantity</td>
<td>• calculate the % uncertainty in the area of a metal wire given that diameter is 0.16 ± 0.01 mm<br>% uncertainty in diameter =<br>(0.01/0.16) × 100 = ± 6.3 %<br>area is proportional to diameter squared<br>% uncertainty in area<br>= 6.3 + 6.3 = ± 12.6 %<br>• calculate % uncertainty in the speed measurement given the following uncertainties in distance and time measurements<br>% uncertainty in distance = ± 0.5 %<br>% uncertainty in time = ± 2.5 %<br><br>% uncertainty in speed = 0.5 + 2.5<br>= ± 3.0 %</td>
<td>How Science Works<br>F</td>
</tr>
<tr>
<td>most significant error estimate<br>judgement of reliability</td>
<td>• based on estimates of uncertainty, candidates may be asked to identify the most significant errors in an experiment, eg in the above example of measurement of speed, the uncertainty in the measurement of time would be identified as the ‘most significant error’<br>• use error estimates to make judgements of reliability and suggest improvements</td>
<td>How Science Works<br>F</td>
</tr>
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| | | |
|---|---|---|
| use data, graphs and other evidence to draw a conclusion | • use evidence from gradient or intercepts to calculate a physical quantity<br>• use evidence from graph to suggest relationship between quantities, eg direct proportionality for straight line graphs through origin | How Science Works F |
| plan or modify a procedure and test a hypothesis | • modify an experiment to investigate a relationship over a different range or improve reliability<br>• plan a procedure, closely related to the ISA experiment, to test a hypothesis<br>candidates should be able to describe a brief outline plan giving details:<br>• diagram/details of set up<br>• list measurements to be made<br>• state suitable instruments to use<br>• give a brief step by step procedure<br>• identify potential errors and suggest improvements<br>• suggest how results might be used/processed to test hypothesis | How Science Works B & C |
| determination of gradient/slope and intercept | same criteria apply as outlined in Stage 1 of ISA above, ie drawing line of best fit, large triangle for gradient etc | Mathematical Requirements |
| use of trig functions – sine, cosine tangent | possibly used in experiments relating to resolution of forces, refraction etc | Mathematical Requirements |

## Guidance on Development of Practical Skills for the PSA at AS Level

This information should be read in conjunction with information given in section 3.8 of the specification, *Guidance on the Centre Assessed Units*.

Assessment of the practical skills involved in the PSA is judged by the teacher, based on direct observations of the candidate in carrying out practical work. There are no tasks specified by AQA for this part of the assessment. Assessment can be based on a wide range of practical work which centres would normally include in their schemes of work for this specification.

Centres do not have to keep the work of any individual students. In the unlikely event of any further supporting evidence being required, this would only be in the form of a log or tick sheet indicating the experiment(s) on which the assessment of a particular skill was based.

It is up to individual centres to decide on what records to keep in order to track the performance of their candidates on the PSA. In centres with larger groups and several teachers involved in the assessment process, some kind of log or tick sheet would probably be required. Two examples of log sheets are attached but there is no requirement that these should be used and it is likely that most centres would prefer to design their own system.

## Guidance for Awarding Marks on the PSA

Detailed skill descriptors for both AS and A2 are given in the specification, section 3.8.3.

Three strands are included at both AS and A2

- Following instructions and group work.
- Selecting and using equipment.
- Organisation and safety.

Each strand has a descriptor with a three point scale at both AS and A2. The descriptors are hierarchical and candidates can score 0, 1, 2 or 3 marks on each strand, giving a possible total of 9 marks on all three strands at both AS and A2.

The descriptors are different at AS and A2 reflecting the different demands of the units at each level.

The teacher should record when a candidate has achieved a particular skill descriptor in each strand. Achieving a skill descriptor higher up the hierarchy automatically subsumes any levels below it in the same strand, eg a candidate who achieves skill 2A is automatically credited with skill 1A, giving a total of 2 marks for that strand. The highest level a candidate achieves in each strand would be the final level awarded in that strand. The assessment can continue throughout the course allowing candidates many opportunities to demonstrate competence and reach the highest possible level within each strand. The highest level achieved in each strand can be considered a reflection of their overall performance in the AS or A2 course.

## Re-submitting PSA Marks

If a candidate is re-sitting an ISA, it is not necessary to provide a new assessment for the PSA skills. A separate PSA mark is still required and should be entered as a mark out of nine on the *Candidate Record Form*. The PSA mark from the previous series can be re-submitted but this must be written again as a separate mark together with the new ISA mark on the *Candidate Record Form*. The total mark should then be entered on the *Centre Mark Form*.

## Interpretation of Skill Descriptors at AS Level

| **Following Instructions and Group Work** | |
|---|---|
| **skill descriptor** | **example of how student might achieve skill** |
| **1A** follows instructions in standard procedures but sometimes needs guidance | • student follows instructions in carrying out a standard experiment (eg simple electrical experiment to plot I-V characteristic), but needs guidance from the teacher or other students at some point in the procedure |
| **2A** follows instructions for standard procedures without guidance<br>works with others making some contribution | • student can carry out a standard experiment following instructions, and can successfully complete the task without any additional guidance<br>• observed to make some positive contribution when working with other students in practical activities |
| **3A** follows instructions on complex tasks without guidance<br>works with others making some contribution | • student can carry out a more complex experiment (involving several different measurements eg measurement of resistivity of metal wire) by following instructions, and can complete the task without any additional guidance<br>• working with other students in practical activities |
| | **maximum 3 marks** |

| **Selecting and Using Equipment** | |
|---|---|
| **skill descriptor** | **example of how student might achieve skill** |
| **1B** uses standard laboratory equipment with some guidance as to the appropriate instrument/range | • uses standard laboratory equipment (eg voltmeters and ammeters in electrical experiments)<br>• at some stage in experiment needs help or guidance in either reading instrument scale or selecting appropriate scale in multi-range instruments |
| **2B** uses standard laboratory equipment selecting appropriate range | • uses standard laboratory equipment (eg voltmeters and ammeters in electrical experiments)<br>• needs no further guidance on use of instrument and confidently selects appropriate instrument range or scale on multi-range instruments where a choice exists |
| **3B** selects and uses standard laboratory equipment with appropriate precision and recognises when it is appropriate to repeat measurements | • makes appropriate instrument selection (eg metre rule, callipers or micrometer screwgauge for distance measurements)<br>• reads instrument with appropriate precision without guidance (eg metre rule to nearest mm)<br>• takes repeat readings where appropriate |
| | **maximum 3 marks** |

| **Organisation and Safety** | |
|---|---|
| **skill descriptor** | **example of how student might achieve skill** |
| **1C** works in a safe and organised manner following guidance provided but needs reminders | • candidate shows **some** evidence of working in a safe and organised manner but would need reminders/advice at some stage in the practical session, eg equipment cables causing potential trip hazard, apparatus precariously balanced on edge of bench |
| **2C** works in an organised manner with due regard to safety with only occasional guidance or reminders | • candidate works in an organised manner showing awareness of safety issues, but needs the occasional reminder re: potential hazards |
| **3C** works safely without supervision and guidance (will have effectively carried out own risk assessment) | • candidate always works in safe manner without supervision or guidance<br>• in experiments with specific safety issues the candidate might have demonstrated that they have researched documented safety advice or specifically requested safety information from the teacher/supervisor |
| | **maximum 3 marks** |

## Examples of Possible Tracking Grids for PSA marks

Enter PSA criteria reference when achieved by each candidate (example shown for one candidate).

| | candidate 1 | candidate 2 | candidate 3 | candidate 4 | candidate 5 | candidate 6 | candidate 7 | candidate 8 | candidate 9 | candidate 10 |
|---|---|---|---|---|---|---|---|---|---|---|
| experiment 1 | 1A, 1C | | | | | | | | | |
| experiment 2 | | | | | | | | | | |
| experiment 3 | 1B, 2A | | | | | | | | | |
| experiment 4 | 2B | | | | | | | | | |
| experiment 5 | | | | | | | | | | |
| experiment 6 | 2C, 3A | | | | | | | | | |
| experiment 7 | | | | | | | | | | |
| experiment 8 | 3C | | | | | | | | | |
| experiment 9 | 3B | | | | | | | | | |
| experiment 10 | | | | | | | | | | |

An individual grid for each student for AS Level PSA.

| candidate name<br>________________<br>candidate number | following instructions and group work | following instructions and group work | following instructions and group work | Selecting and using equipment | Selecting and using equipment | Selecting and using equipment | Organisation and safety | Organisation and safety | Organisation and safety |
|---|---|---|---|---|---|---|---|---|---|
| | **4A** | **5A** | **6A** | **4B** | **5B** | **6B** | **4C** | **5C** | **6C** |
| experiment 1 | ✓ | | | 1 | | | | | |
| experiment 2 | | | | ✓ 2 | | | ✓ | | |
| experiment 3 | | ✓ | | | 3 | | | | |
| experiment 4 | | | | | | | | | |
| experiment 5 | | | | | | | | | |
| experiment 6 | | | | | ✓ 4 | | | | |
| experiment 7 | | | | | | 5 | | ✓ | |
| experiment 8 | | | ✓ | | | | | | |
| experiment 9 | | | | | | | | ✓ | |
| experiment 10 | | | | | | ✓ 6 | | | ✓ |

Numbers in columns for skills 4B, 5B and 6B might be a possible way of tracking number of complex instruments or techniques covered for these skills.

## Guidance for the ISA at A2 Level

### A2 PSA

### Selecting and Using Equipment - Strand B

Assessment of this strand in PSA at A2 requires that candidates demonstrate the correct use of a range of complex instruments and techniques.

Equipment varies considerably from centre to centre, so we have not specified particular instruments to be used by all candidates.

It should also be noted that, although the assessment is for A2, there are some topics covered in the AS specification which provide more complex practical experiments and which can still be used for assessment of some aspects of the A2 PSA. Indeed, provided the practical task is of sufficient complexity, there is nothing to prevent centres assessing some aspects of the PSA in the first year of the full Advanced Level course.

### Complex instruments

We refer to a 'complex instrument' as being any instrument which has a more complex scale, is more demanding to set up and operate or requires special safety considerations.

Examples:

- Cathode Ray Oscilloscope (AS or A2 experiments)
- Spectrometer (AS specification or A2 Astrophysics)
- Any instrument with vernier scale (eg vernier callipers)
- Micrometer screwgauge (old mechanical type or modern digital type if zeroing required)
- Light gates and data logger (AS Mechanics/A2 Momentum)
- Temperature sensor with data logger/computer (eg Kinetic Theory experiments)
- Position sensor with data logger/computer (eg SHM experiments)
- Voltage sensor and data logger (eg Capacitor Discharge experiments)
- Ratemeter or scaler with GM tube
- Vacuum tubes with EHT supply (eg Electron Deflection experiments)
- Hall effect probe/search coil (to measure magnetic field)
- Laser as monochromatic source (eg AS Interference and Diffraction/A2 Astrophysics)
- Travelling microscope (for accurate measurement of small distances)
- Multimeters (eg old style AVO requiring selection of appropriate scale)
- Use of scale analogue meter which requires zero setting and scale selection
- Light beam galvanometer, centre-zero galvanometer

The above examples are not intended to be a definitive list.

**Complex techniques**

A complex technique would count instead of a complex instrument as part of the six required for the A2 PSA.

Examples:

- Timing techniques - multiple oscillations, use of fiducial marker (eg A2 SHM)
- Avoiding parallax errors in distance measurement or instrument scales
- Setting up any sensor with data logger/computer
- Simultaneous reading of two simple instruments at the same time (eg voltmeter and stopclock in Capacitor Discharge experiments)

**It should be noted that it is the responsibility of individual centres to make appropriate risk assessments for any experimental work carried out in their own centre.**

**A2 ISA**

**Key Differences between AS and A2**

1 The A2 ISAs will involve experimental work based on A2 specifications, eg Simple Harmonic Motion, Capacitor Discharge experiments etc. Questions and data in the ISA paper may refer to topic areas where class experiments might not be possible, eg questions and data on radioactivity might follow from a Capacitor Discharge experiment in Stage 1 of the ISA.

2 The A2 ISA will have a greater mathematical demand (refer to section 3.9 of the specification *Mathematical Requirements*), eg use of exponential functions, manipulation of logs and exponential functions in equations.

- A typical question might involve a log–log graph, where the gradient represents the power relationship between the plotted quantities. In a simple pendulum experiment plotting logs of time period, *T*, and length, *l*, would produce a graph with gradient 2 (or 0.5), allowing the relationship between *T* and *l* to be deduced.

- An exponential function might be ‘rearranged’ as a natural log, allowing a straight line graph to be plotted. In radioactive decay a graph of ln(*N*) against time would give a straight line graph, allowing the decay constant to be calculated from the gradient.

3 The A2 ISA will involve recognition of systematic errors from graph intercepts, eg in a simple pendulum experiment with a graph of $T^2$ against length:

- An intercept on the horizontal axis might indicate a systematic error in length measurement

- Length might have been measured to some other point rather than the centre of mass of the pendulum bob.

4 The A2 ISA will involve a combination of errors (uncertainties) in individual measurements and calculation of final ± value, eg in a simple pendulum experiment:

- Uncertainty in time period = ± 2.3%. Uncertainty in length = 0.6%
- Uncertainty in *g* = 2.3 + 2.3 + 0.5 = 5.1% (nb *T* is squared)
- If data from the experiment had achieved a value of $9.71\,N\,kg^{-1}$
- 5.1% (or just 5% is adequate for this 'estimate') of 9.71 represents an overall uncertainty of $\pm\,0.5\,N\,kg^{-1}$
- Final value should be quoted as $9.7 \pm 0.5\,N\,kg^{-1}$

5 Instructions on the A2 task sheet will be more open ended in some cases, requiring greater knowledge of experimental techniques, eg candidates might be instructed to take appropriate measurements to accurately determine the time period of an oscillation, with an expectation that they would time multiple oscillations, repeat readings and use an appropriate fiducial marker.

6 In the A2 ISA fewer marks will be allocated to lower level skills such as tabulation and graph plotting. Stage 1 will typically be worth eight marks rather than ten marks as in Stage 1 of the AS ISA.

7 The A2 ISA will contain open ended evaluative questions, eg from data presented, evaluation of experimental techniques using either hand operated stop clocks or electronic timing devices using light gates.

Two A2 sample ISAs are available for practice on the website.