AS/A Level GCE

Practical Skills Handbook

GCE Physics A

OCR Advanced Subsidiary GCE in Physics A H158

OCR Advanced GCE in Physics A H558

This Practical Skills Handbook is designed to accompany the OCR Advanced Subsidiary GCE and Advanced GCE specifications in Physics A for teaching from September 2008.

OCR will update this document on a regular basis. Please check the OCR website (www.ocr.org.uk) to ensure that you are using the latest version.

Version 1.3
The changes made since version 1.1 are the correction of the G483 and G486 tables on p. 7, the incorporation of updated screenshots on pp. 9 and 10, the inclusion of an Interchange Help Sheet and the removal of FAQs, these are available as a separate document.

The changes made since version 1.2 include an update to the Healthy and Safety information in Section 8. Also included in the guide on practical skills, p. 48, is the addition of a percentage difference section and advice on use of the term, reliability.

Contents

1 Introduction

New GCE A/AS specifications in Physics have been introduced for teaching from September 2008. The new specifications are set out as units, subdivided into teaching modules. Each teaching unit is assessed by its associated unit of assessment. Guidance notes are provided within specifications to assist teachers in understanding the requirements of each unit.

This Handbook plays a secondary role to the Specification itself. The specification is the document on which assessment is based and this Handbook is intended to elaborate on the content of the specification to clarify how skills are assessed and what practical experience is necessary to support an assessment. The Practical Skills Handbook should therefore be read in conjunction with the Specification.

During their study of Physics, students are expected to acquire experience of planning, carrying-out, interpreting, analysing and evaluating experiments and it is important to recognise that these aspects of practical work require both teaching and continuing practice. Experience has shown that evaluating experiments and suggesting improvements to the procedures employed is a difficult skill for students to master.

Planning skills will **not** be directly examined as part of centre-based assessment but may be tested within the theory papers at both AS and A2 levels. Candidates will need to describe experimental procedures and observations. Other skills will be internally assessed by the centre using the scheme shown on the next page.

2 The assessment model

Summary of the model

Practical and investigative skills developed within contexts encountered during Advanced Subsidiary GCE Physics (for Unit G483) or Advanced GCE Physics (for Unit G486) are assessed by means of three types of task (Qualitative, Quantitative and Evaluative) at each level.

Thus, candidates are required to carry out **three** tasks at AS and **three** tasks at A2:

1. Qualitative task [10 marks]
2. Quantitative task [20 marks]
3. Evaluative task [10 marks]

Tasks will be chosen from a selection provided by OCR *via* the secure Interchange website. Initially, a choice of three Tasks will be offered for each type. All Tasks will be refreshed or replaced each year and additional tasks may be made available. They will be available until 15th May in each year. Tasks for the following year will be available from early June.

The Qualitative and Quantitative tasks will test skills of observation, recording and reaching valid conclusions.

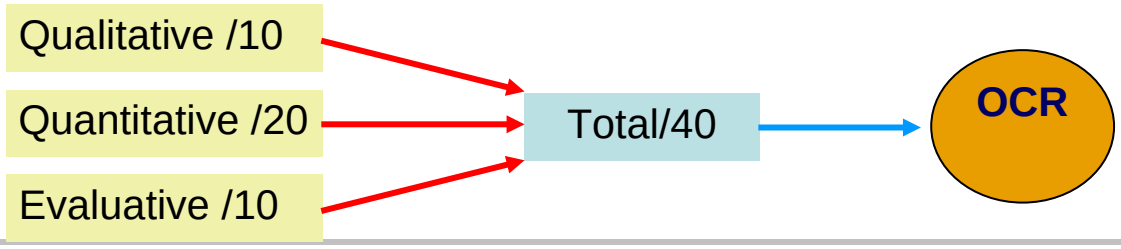
The Evaluative task will test the ability to analyse and evaluate the procedures followed and/or the measurements made. Candidates may also be asked to suggest simple improvements that would increase the reliability or accuracy of an experiment. The Evaluative task will be linked to the Quantitative experiment but no further data collection will be required. Any additional data required will be supplied within the Evaluative task.

Candidates carry out all of their assessed tasks under direct teacher supervision.

Each task is internally assessed using a mark scheme provided by OCR *via* the Interchange website.

Candidates may attempt more than one task from each task type with the best mark from each type being used to make up the overall mark. A candidate is only permitted one attempt at each task.

For each candidate, centres will supply OCR with a single mark out of 40.
Each practical skills unit is teacher assessed and externally moderated by OCR.
Although practical tasks can be used throughout the year, entry for the AS and the A2 practical skills units is available only in the June session of each year.



The mark schemes supplied by OCR will be based on the following criteria:

	Assessable learning outcomes
1. Qualitative Task • Candidates carry out a practical task using instructions supplied by OCR.	Candidates should be able to: (a) demonstrate skilful and safe practical techniques using suitable qualitative methods; (b) make, record and communicate valid observations; organise results suitably.
2. Quantitative Task • Candidates carry out a practical task using instructions supplied by OCR.	Candidates should be able to: (a) demonstrate and describe safe and skilful practical techniques for a quantitative experiment; (b) make, record and communicate reliable measurements with appropriate precision and accuracy; (c) analyse the experimental results; (d) Interpret and explain the experimental results.
3. Evaluative Task • This task may extend a quantitative task. • Candidates will evaluate the quality of the data and procedures. • Evaluative tasks will **not** require additional data collection.	Candidates should be able to: (a) evaluate the results and their impact on the experimental methodology; (b) assess the reliability and accuracy of the experiment by calculating percentage differences and uncertainties; (c) evaluate the methodology with a view to improving experimental precision and accuracy; (d) identify weaknesses in experimental methodology and measurements; (e) understand and suggest improvements to the experimental procedures and measurements.

The assessment of practical skills will include the following qualities which will need to be developed before candidates carry out the practical tasks.

	Quality A1	Quality A2
Strand A	Demonstrate skilful and safe practical techniques using suitable qualitative methods.	Demonstrate skilful and safe practical techniques using suitable quantitative methods.

	Quality B1	Quality B2
Strand B	Make, record and communicate valid observations; organise results suitably.	Make and record accurate measurements to an appropriate precision.

	Quality C1	Quality C2
Strand C	Recognise and interpret data, identify anomalies and reach valid conclusions.	Analyse, interpret and evaluate experimentally derived results quantitatively to reach valid conclusions.
	Quality C3	**Quality C4**
	Assess the reliability and accuracy of an experimental task; Identify significant weaknesses in experimental procedures and measurements.	Understand and select simple improvements to the experimental procedures and measurements.

The qualities assessed by each task type, Qualitative, Quantitative and Evaluative, are shown below.

G483: AS Task Types

Task type	Quality								Assessment outcome			Total
	A1	A2	B1	B2	C1	C2	C3	C4	AO1	AO2	AO3	
Qualitative	✓		✓								10	10
Quantitative		✓		✓	✓	✓			3	2	15	20
Evaluative							✓	✓	2	3	5	10
TOTAL												**40**

G486: A2 Task Types

Task type	Quality								Assessment outcome			Total
	A1	A2	B1	B2	C1	C2	C3	C4	AO1	AO2	AO3	
Qualitative	✓		✓								10	10
Quantitative		✓		✓	✓	✓			2	3	15	20
Evaluative							✓	✓	2	3	5	10
TOTAL												**40**

Downloading Practical Skills tasks

Tasks, Mark Schemes, and Instructions for Teachers and Technicians are provided to centres (as separate PDF files combined into zip files) *via* OCR's secure website, Interchange (*https://interchange.ocr.org.uk*).

Copies of the Practical Skills Handbook and coursework forms are also available via Interchange and OCR's public website (*www.ocr.org.uk*).

(PDF files require the use of adobe acrobat reader. Free copies of acrobat reader are available from http://www.adobe.com/uk/products/acrobat; If you use Windows 95, 98, ME, or NT, a zip program such as WinZip or PKZip can be used to extract the files. Windows XP has a built-in zip extractor.)

How to use OCR Interchange

OCR Interchange is a secure extranet enabling registered users to administer qualifications on-line. Your Examinations Officer is probably using OCR Interchange to administer qualifications already. If this is not the case, then your centre will need to register.

Your Examinations Officer will be able to:

- download the relevant documents for you by adding the role of 'Science Coordinator' to their other roles or
- make you a New User (Science Coordinator role) so that you can access the GCE Physics A pages and download documents when you need them.

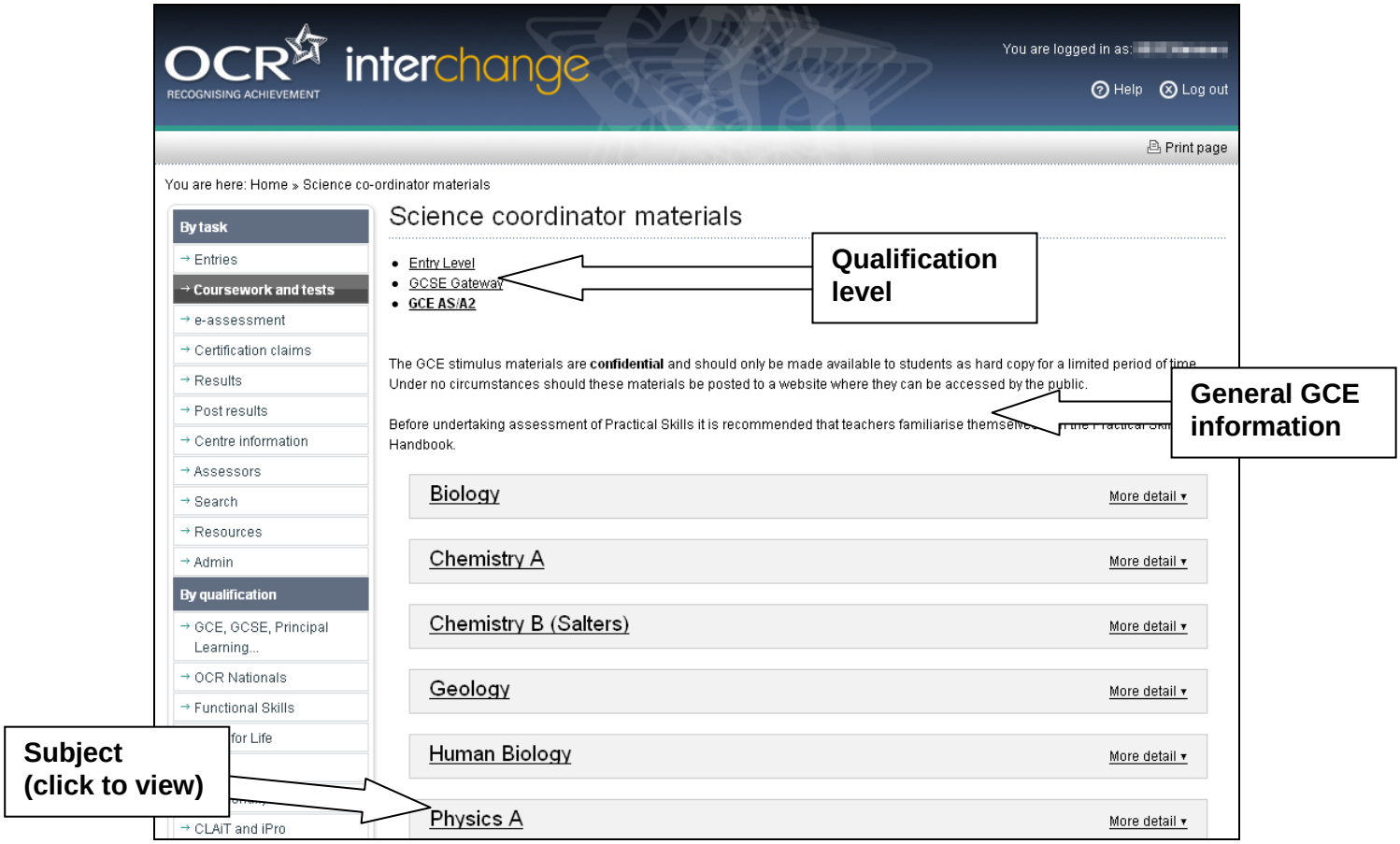
The website address for Interchange is:

https://interchange.ocr.org.uk

The teacher who has downloaded these materials is responsible for ensuring that they are stored securely so that students do not have the opportunity to access them. A record should be kept of the dates on which materials are downloaded.

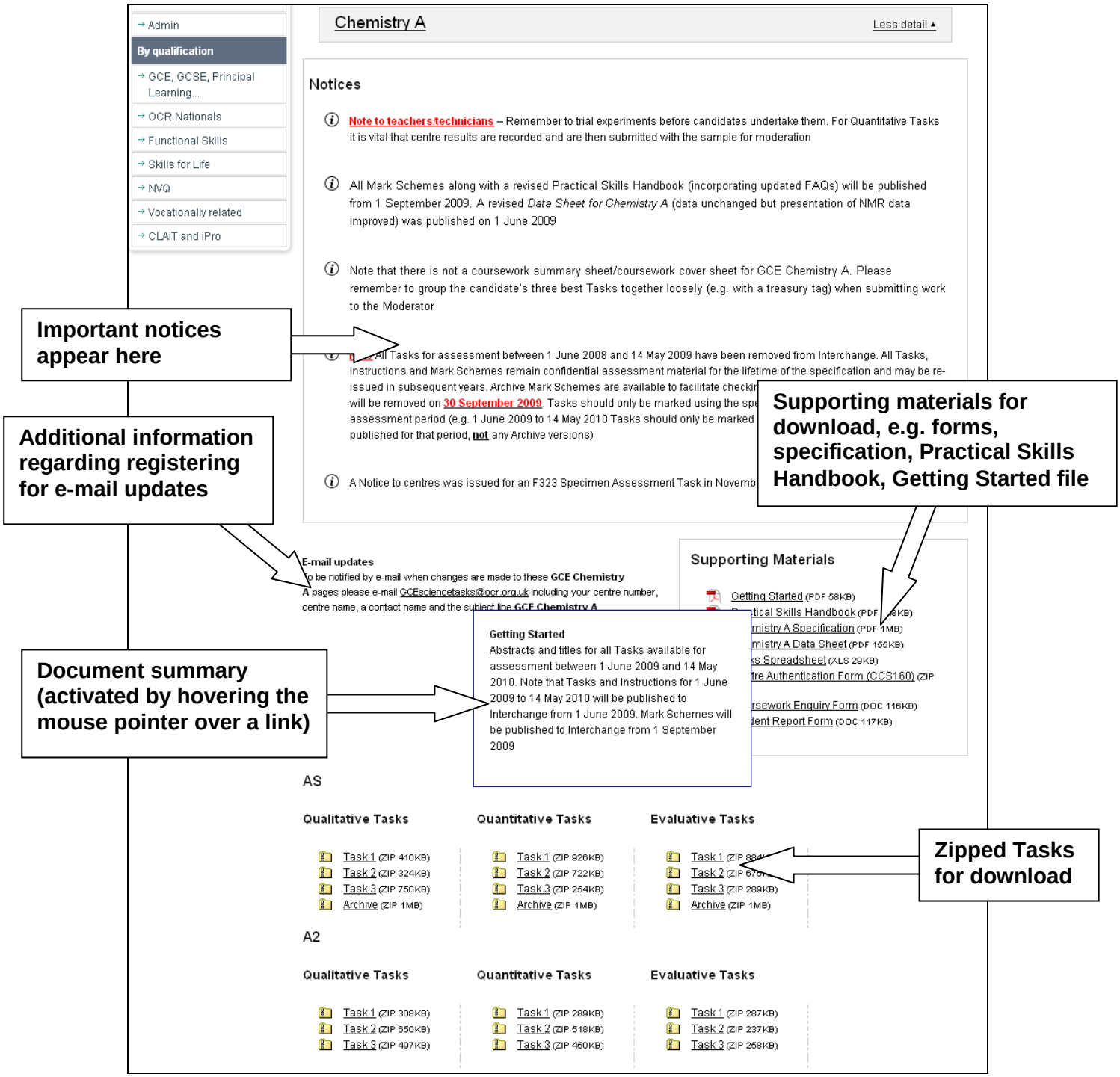
Distribution of the Practical Tasks is limited to those students who are currently undertaking that Task. Task sheets should be photocopied and issued to students at the start of the Task. They must be counted out and in; numbering the documents may help to keep track of them.
All unused Tasks and candidates' scripts must be collected after the assessment and stored securely or destroyed. Candidates must not take Tasks out of the room where assessments are taking place.
Under no circumstances can candidates be allowed to see the mark schemes.

Science Materials pages are arranged according to qualification level and subject (see below).



The user simply clicks on the relevant link to access the relevant subject material. Any important notices are shown at the top of the page along with useful supporting materials (e.g. the specification, the Practical Skills Handbook, forms) and a 'Getting started' file (which includes an abstract and title for each assessment task for the current assessment year). Tasks are arranged according to level and type (Qualitative, Quantitative and Evaluative, see below). Hovering the mouse pointer over a Task or document link generates a summary of the file.

Simply clicking on the Task link allows you to download the zipped material to your desktop. The zip files contain everything you need to complete the task (instructions, task and mark schemes). All files have a unique name so there is no danger of overwriting material on your computer.



E-mail updates

To be notified by e-mail when changes are made to the **GCE Physics A** page on Interchange please e-mail GCEsciencetasks@ocr.org.uk including your centre number, a contact name and the subject line **GCE Physics A**. It is strongly recommended that all centres register for e-mail updates.

Registering for Interchange

If your Examinations Officer is not already a registered user of Interchange then he/she will need to register before the Physics A Tasks can be downloaded.

This is a straightforward process:

- Go to the website – https://interchange.ocr.org.uk;
- The first page has a New User section;
- Click on Sign Up to access the OCR Interchange Agreement Form 1;
- Download this document and fill in your details;
- Return form by post to OCR Customer Contact Centre, Westwood Way, Coventry, CV4 8JQ or fax the form back to 02476 496508;
- OCR will then contact the Head of centre with the details needed for the Examinations Officer to access OCR Interchange.

Administration and regulations

Availability of Tasks

Mark schemes, Tasks and Instructions will be available until **15 May** in each year. Tasks for the following year will be available from early June. The Mark Schemes for all GCE Practical Tasks will not be released until 1st December.

It is intended that Tasks should form part of the normal teaching programme and so may be taken by students at any time during the year. Where possible, a Task should be administered immediately after the knowledge, understanding and skills required for the Task have been taught.

Level	Unit & Task	First Tasks on Interchange by	Coursework submission date
AS	G483 Qualitative x 3 Quantitative x 3 Evaluative x 3	June 2008	15 May each year from 2009
A2	G486 Qualitative x 3 Quantitative x 3 Evaluative x 3	June 2009	15 May each year from 2010

Security

It is the responsibility of the centre to ensure that downloaded Tasks, mark schemes, instructions (including any copies made of these documents), and candidates' scripts are stored securely. Any breach in security should be reported to OCR as soon as possible by submitting a written report (a blank report form is available on Interchange) from the Head of centre to the Subject Officer detailing the circumstances, the students concerned and any action taken.

The instructions for each assessed Task contain information to allow teachers to check the availability of the necessary apparatus and the construction of any specific items of apparatus.

Tasks, mark schemes and instructions can be downloaded at any time as long as they are kept secure. No information must be given either directly or indirectly to students relating to the content of the Tasks or the marking.

Candidates' scripts for all completed Tasks must be stored securely and they should be available for moderation. Centres should retain Tasks securely until such time as they are clear that candidates will not wish to re-submit work to OCR in future sessions. At this point the work should be securely destroyed.

How to use the Tasks

There are at least three Tasks available of each type: Quantitative, Qualitative and Evaluative. These may be used in a variety of ways. For example, students may complete all three of the Quantitative Tasks and the teacher can then submit the best mark. Alternatively, the teacher may use the first Task for formative assessment, the second for submission of marks and keep the third in reserve in case a particular student does not perform well on the second Task.

A candidate is not permitted to have more than one attempt at a single Task, or to re-write or change a Task once it has been submitted to the teacher for marking.

The experiments

The experiments used in the Tasks have been trialled. The Instructions provided should ensure that the students are able to collect appropriate data in the time available. However, it is vital that the teacher trials the Tasks before they are attempted by the students to ensure that:

- appropriate materials and equipment are available;
- the experiment works and generates the expected data.

On some occasions it may be necessary to provide a data set against which students' results can be compared. In such cases this requirement will be stated in the Instructions for Teachers and Technicians.

Teachers may make appropriate changes to the materials and apparatus listed in the Instructions where these make provision easier/cheaper and they have no impact on the outcome, or demand, of the experiment. Other changes can be made to, for example, resistor values for particular meter ranges in order to make the experiment work as intended and to ensure that students are able to make appropriate observations/measurements. **All such changes may be made without OCR's approval**, but details must be retained and made available to the Moderator when work is submitted.

Details of changes made must be notified to OCR by e-mail to **GCEsciencetasks@ocr.org.uk**. Remember to include the centre number on all e-mails.

We will acknowledge all e-mails but will only respond in detail where there are concerns over suggested modifications. OCR may update the materials on the Interchange website where this is appropriate. If there are any issues with any of the experiments **that cannot be satisfactorily resolved by the centre**, details should be provided to OCR using the same e-mail address.

Centres with more than one teaching group

It is recognised that some centres are likely to have more than one group with lessons timetabled at different times. In these circumstances, centres are asked to ensure that a particular Task is carried out by all the groups in as short a period as possible.

Absence at the time of an assessment

If a candidate is absent from a centre when an assessment is carried out, the Task may be set at an alternative time provided that the centre is satisfied that security has been maintained by keeping all materials secure.

Candidates with Access requirements

Candidates who are eligible for access arrangements and need additional time for the Evaluative task may be given up to 25% extra time and their name should be recorded on the Interchange Access Arrangements site. Where other access arrangements are required, applications should be made to OCR at the beginning of the course using the standard forms and procedures in the Joint Council regulations and guidance document. However, it should be remembered that these Tasks are intended to assess practical skills. Credit is given to those skills which the candidate has performed independently. The Disability Discrimination Act lays no duty on awarding bodies to make reasonable adjustments with respect to the application of a competence standard or, in this case, the assessment objective being tested.

Unexpected circumstances

If an unexpected problem (such as a fire alarm or other circumstance beyond the teacher's control) occurs while an assessed practical Task is taking place, the Task may be resumed subsequently provided the teacher ensures that no student is likely to have been advantaged or disadvantaged by doing so.

Support allowed for students

All practical Tasks will be accompanied by appropriate instructions. Teachers may provide additional safety instructions (including written advice) if this is felt to be necessary.

Students will not be permitted to refer to their class notes or to books during the Task except where specifically indicated on the Task cover sheet and Instructions.

If it becomes necessary for a teacher to provide a candidate with assistance during the course of a practical Task, the work may still be marked alongside the work of other candidates but the Task sheet must be annotated to indicate the assistance given. The teacher should use their professional judgement to award marks appropriately.

Supervision

All Tasks must be carried out under the direct supervision of the teacher. However, they are not practical examinations and there is no requirement for 'examination conditions' to be imposed. Students may need to interact as they collect materials or use particular pieces of apparatus, but the teacher should set up the Tasks so that this interaction is kept to a minimum. The teacher must ensure that students do not copy from, or assist, each other so that s/he can with confidence authenticate the work of each student.

Authentication

It is the responsibility of the centre to ensure that the work submitted for assessment is that of the candidate involved.

Group work

Students must work individually to collect their own data. However, where a Task requires the collection of a large data set, instructions may include the pooling of data from a number of students and each student will then work with the same large data set. It will always be expected that each candidate contributes his/her data to the pool. In some cases students may need to share equipment or apparatus and the centre must make arrangements for this to take place without disadvantaging any students.

Time allowed for Tasks

Quantitative and Qualitative Tasks are not time restricted: most have been designed to be conducted in a single practical session lasting about an hour. However, there may be a number of circumstances in which it is not possible to complete the work in the time available; for example, there may be difficulties with the experiment, a fire alarm or shortage of equipments. In such cases, students' work should be collected in and issued to them again at the start of the next lesson. They must **not** take the work away with them or complete it without supervision.

Evaluative Tasks should be completed within 1 hour.

Students with special requirements requiring additional time may be given the time without reference to OCR.

Some Qualitative and Quantitative Tasks may require the use of two practical sessions. Where this is the case, the Task may be divided to allow a convenient point at which the experiment can be set aside for completion in the second session. In such cases the student Task sheets may be provided in two sections.

In these circumstances, teachers must:

- issue **only** the first section of the student Task sheet in the first session;
- collect in all the students' work once the first session is finished;
- keep the candidates' Tasks in a secure place prior to the next session;
- return the Tasks to the candidates at the start of the second session and issue the second section of the Task Sheets.

Submission date for work

Candidates' marks must be despatched to the Moderator and to OCR to arrive by 15 May in the year of the examination.

The following forms (available both from Interchange and *www.ocr.org.uk*) must be included with the submitted marks:

- Centre authentication sheet (CCS160);
- Details of any changes made to the experiments. (Changes can be marked up on a blank copy of the Task or Instruction sheet);
- Specimen sets of results for each qualitative and quantitative task used;
- The Moderator will ask for a sample of work. If there are ten or fewer candidates at the centre, all work submitted should be sent to the Moderator to arrive by 15 May.

Internal standardisation

A centre must set up an internal standardisation procedure to ensure that all teachers at the centre are applying the mark schemes in the same way. This procedure could include double marking of a sample of candidates, or the remarking of work by a senior member of staff.

Coursework consultancy

OCR offers a coursework consultancy service whereby centres can send up to four photocopies of marked work to OCR for commentary by a senior Moderator. If a centre wishes to make use of this service, work should be submitted to OCR no less than 8 weeks before the coursework submission date (15 May). The coursework enquiry forms are available at www.ocr.org.uk and on Interchange.

Repeating Tasks

Candidates can only attempt a Task once. However, if they score poorly on a Task they may take another Task from within that Task-type

Marking advice for teachers

The marking schemes provided to centres have been made as explicit and as easy to apply as possible. Teachers should note that the mark schemes are not hierarchical. A measure of professional judgement may sometimes be necessary.

Once the work has been collected in, it must be marked by the teacher as it stands. **Under no circumstances can a candidate be allowed to change or elaborate on an answer.**

Teachers are reminded that it is possible for a student to be assessed on another occasion using a different Task and that the best mark achieved for each Task type should be submitted. It is appropriate for the teacher to provide feedback to explain how the work could have been improved although details of the mark scheme must not be directly communicated to the student.

Mark Tasks clearly, in red ink, and in accordance with the Task-specific mark scheme. Annotation can help the Moderator and staff in the centre who are checking the marking as part of internal standardisation.

Useful annotations consist of:

- ticks and crosses against responses to show where marks have been earned or not earned;
- specific words or phrases to confirm why a mark has been earned or indicate why a mark has not been earned (e.g. indicate an omission).

Where a student has given an answer not covered by the mark scheme, the teacher should use his/her professional judgement to decide whether the answer is worthy of credit. If it is, then the script should be annotated accordingly and the mark(s) awarded.

3 General requirements for AS and A2 practical work

Suggested practical activities have been included within the specification at the end of each module. Whilst carrying out these practice experiments during the course is not a requirement, their purpose is to ensure that the skills required for assessment will have been covered. Alternative experiments may be chosen but centres should be careful to consider whether sufficient experience will have been provided for students prior to the use of the assessed Tasks.

Skill development

There are generic skills which should be developed during the study of AS and A2 Physics. The sophistication required of students should increase throughout the course, partly as their practical experience grows but also through the extra demands expected by more complex experiments.

General

At both levels, the course aims to provide candidates with the opportunity to:

- develop good laboratory technique;
- make and record accurate measurements and observations;
- interpret the results of experiments to form theories or conclusions;
- establish whether data collected from experiments is valid and reliable;
- evaluate experimental technique and scientific method in light of practical experience;
- gain a knowledge of laboratory safety.

In teaching, teachers should focus on the key areas above whilst developing the candidates' skills through a coherent practical programme.

In carrying out practical Tasks, candidates should acquire the necessary experience to be able to carry out the Qualitative, Quantitative and Evaluative Tasks that will be tested by the assessed Tasks.

Qualitative Tasks

Candidates should be able to:

- identify any safety considerations;
- use appropriate techniques, and apparatus to complete suitable activities;
- manipulate standard laboratory apparatus safely and with confidence to produce accurate data;
- record all suitable observations and data in an appropriate format and to an appropriate degree of accuracy, taking into consideration the apparatus used;
- use and record the correct units for all measurements taken;
- provide simple conclusions based on the observations made.

Quantitative Tasks

Candidates should be able to:

- carry out quantitative experiments with appropriate care and precision;
- make and record measurements reliably and accurately;
- perform calculations, based on their practical work;
- use units accurately;
- use appropriate numbers of significant figures consistent with their least accurate measurement;
- construct and interpret appropriate graphs from data collected or provided;
- reach a valid conclusion based upon the data obtained from experiments.

Evaluative Tasks

Candidates should be able to:

- recognise anomalous results on the basis of measurements taken or provided;
- identify the limitations of accuracy in experimental procedures;
- recognise that some uncertainties may be inherent in the apparatus used;
- calculate percentage uncertainties involved in measurements taken;
- evaluate both the procedural and measurement errors associated with a particular experiment and comment on the most significant errors;
- suggest sensible improvements to experimental procedures and the taking of measurements based on their laboratory experience.

4 Practical work for AS Unit G483

This section provides a summary of the practical experience and skills that will be acquired by the use of the experiments suggested in the modules or by the use of equivalent Tasks devised by the centre.

Unit G481 Mechanics

There are opportunities for candidates to investigate the motion of objects (gliders, trolleys, etc) using ticker timers, light gates, data-loggers and video techniques. There are also opportunities for candidates to develop skills in recording, analysing and evaluating primary data.

- Study vector addition of two coplanar forces using force-meters and masses.
- Determine the average speed of cars and people.
- Use a motion sensor to analyse displacement-time graphs.
- Use a trolley on a ramp and either light-gates or ticker tape to find acceleration or to show displacement α time^2.
- Determine the acceleration of free fall using trapdoor and electromagnet arrangement or video technique.
- Use a ball bearing and a ramp to study projectile motion.
- Determine the initial speed of water from a water hose or jet using the physics of projectiles.
- Use a falling mass to find the acceleration of a trolley or a glider using light-gates, motion sensor or ticker tape.
- Use a video camera or a data-logger to analyse the motion of a falling parachute or a glider with a 'sail' on a linear air track.
- Investigate the motion of a ball bearing falling vertically in oil or water.
- Determine the terminal velocity of parachutes of different size and mass.
- Locate the centre of gravity of various objects.
- Apply the principle of moments for a horizontally loaded 'bridge' (metre rule).
- Use two bathroom scales and a plank to determine the centre of gravity of a person.
- Design an effective crumple zone for a trolley using paper and cardboard.
- Use the principle of conservation of energy to find the speed of a toy car rolling down a plastic track.
- Determine the average power of a person climbing a flight of stairs.
- Determine the power generated by arm muscles when repeatedly lifting known weights through a certain vertical distance.
- Find the relationship between force and extension for a single spring, springs in series and springs in parallel.
- Plot force against extension graphs for a rubber band, polythene strip, etc.
- Determine the Young modulus of metal, eg copper or steel.
- Determine the ultimate tensile strength (UTS) or the breaking stress of a metal such as copper or aluminium.
- Design a safe rollercoaster.

Unit G482 Electrons, Waves and Photons

Students are given practice at developing skills for the qualitative tasks, quantitative tasks and the evaluative tasks.

- verifying Kirchhoff's first law using ammeters.
- observing the conduction of coloured salts.
- Investigate the factors that determine resistance including the effect of temperature.
- Determine the resistivity of a metal.
- Use the resistivity equation to estimate the thickness of a pencil line.
- Investigate the variation of resistance of a thermistor with temperature.
- Investigate energy transferred by components using a joulemeter or data-logger.
- Use a calibrated light-meter to plot the variation of resistance of an LDR against intensity.
- Determine the internal resistance of a chemical cell.
- Use a potential divider circuit to show the validity of the potential divider equation.
- Design a light-sensing circuit based on a potential divider with a light-dependent resistor.
- Design a temperature-sensor based on a potential divider with a thermistor.
- Monitor the output potential difference from either light-sensors or temperature-sensors using a data-logger.
- Determine the wavelength of light from different LEDs using the equation.
- Observe 'diffraction rings' for light passing through a tiny hole.
- Demonstrate the diffraction of electrons by graphite.
- Observe emission line spectra from different discharge tubes.

5 Practical work for A2 Unit G486

This section provides a summary of the practical experience and skills that will be acquired by the use of the experiments suggested in the modules or by the use of equivalent Tasks devised by the centre.
It should be noted that the practical experience acquired at AS may be tested at A2.

Unit G484 The Newtonian World

Students are given practice at developing skills for the qualitative tasks, quantitative tasks and the evaluative tasks.

- There are opportunities for candidates to investigate collisions between objects (gliders, trolleys etc) using ticker timers, light gates and data-logging techniques.
- There are also opportunities for the candidates to develop skills in recording, analysing and evaluating primary data (HSW 5).
- Use a motion sensor to demonstrate Newton's 2nd law.
- Carry out an experiment to show *total initial momentum* = *total final momentum* using trolleys or gliders.
- Find the initial velocity of an air-gun pellet or a dart using a glider and light gates.
- Demonstrate elastic and inelastic collisions using plastic 'super balls' and squash balls.
- Carry out experiments involving collisions of trolleys or gliders.
- Carry out an experiment to show $force \propto speed^2$ for a whirling bung.
- A ball on a rotating turntable and a projector can be used to illustrate simple harmonic motion.
- Barton's pendulums can be used to show resonance.
- Investigate the forced oscillations of a spring-mass system.
- Use an electrical method to find the specific heat capacity of a substance like aluminum, or water.
- Determine the specific heat capacity of water using method of mixtures.
- Determine the specific heat capacity of a metal block by heating the block and immersing it into water.
- Investigate the relationship between pressure exerted by a gas and its volume (Boyle's law).

Unit G485 Fields, Particles and Frontiers of Physics

Students are given practice at developing skills for the qualitative tasks, quantitative tasks and the evaluative tasks.

- Investigate factors affecting the magnetic force on a current-carrying conductor placed in a uniform magnetic field.
- Use a current-balance to determine the magnetic flux density between the poles of a magnet.
- Investigate different ways of inducing an e.m.f. in a coil.
- Make a transformer using insulated copper wire and an iron rod.
- Use a dual-beam oscilloscope to verify the turns-ratio equation for a transformer.
- Use a multimeter set on 'capacitance' to verify the rules for capacitors is series and parallel
- Use an e.h.t. supply, parallel plates and a coulombmeter to show $Q = VC$.
- Plot discharge curves for different values of time constants.
- Determine the capacitance of a capacitor from a discharge curve.
- Investigate the factors that affect the time constant of a C–R circuit.

There are opportunities for students to develop skills in recording, analysing and evaluating primary data.

- Study the absorption of α-particles, β-particles and γ-rays by appropriate materials.
- Deflect beta-particles in magnetic field.
- Deflect beta-particles in an electric field.
- Carry out a simulation of radioactive decay of nuclei using small cubes or dice.
- Determine the half-life of an isotope such as protactinium.
- Use a spreadsheet to simulate exponential-decay.

6 Apparatus list for Units G483 and G486

The specification provides a good indication of typical apparatus requirements for practical work. Some special items may be needed for individual practical tasks.

7 Resources

General resources

There are many resources available to help teachers provide support to students. These include both books and websites.

The OCR website – www.ocr.org.uk – contains marked exemplar material from trials held in a number of centres.

Other useful websites are:

- the Institute of Physics at www.physics.org
- the ASE at www.schoolscience.co.uk

INSET

OCR runs INSET courses every year, primarily in the Autumn term, and these include sessions either wholly or partly to support internally assessed Tasks. More details about INSET provision are available at www.ocr.org.uk

Coursework consultancy

OCR offers a coursework consultancy service whereby centres can send up to four photocopies of marked work to OCR for commentary by a senior Moderator. If a centre wishes to make use of this service, work should be submitted to OCR no less than *8* weeks before the coursework submission date (15 May). The coursework enquiry forms are available at www.ocr.org.uk and on Interchange.

8 Health & Safety

Useful information can be found at www.cleapss.org.uk

In UK law, health and safety is the responsibility of the employer. For most establishments entering candidates for AS and Advanced GCE this is likely to be the education authority or the governing body. Employees, i.e. teachers and lecturers, have a duty to cooperate with their employer on health and safety matters. Various regulations, but especially the COSHH Regulations 1996 and the Management of Health and Safety at Work Regulations 1992, require that before any activity involving a hazardous procedure or harmful micro-organisms is carried out, or hazardous chemicals are used or made, the employer must provide a risk assessment. A useful summary of the requirements for risk assessment in school or college science can be found in Chapter 4 of Safety in Science Education (see below). For members, the CLEAPSS guide, Managing Risk Assessment in Science offers detailed advice. Most education employers have adopted a range of nationally available publications as the basis for their Model Risk Assessments. Those commonly used include:

- Safety in Science Education, DfEE, 1996, HMSO, ISBN 0 11 270915 X;
- Safeguards in the School Laboratory, 10th edition, 1996, ASE ISBN 0 86357 250 2;
- Hazcards, 1995, CLEAPSS School Science Service*;
- Laboratory Handbook, 1988-97, CLEAPSS School Science Service*;
- Topics in Safety, 2nd edition, 1988, ASE ISBN 0 86357 104 2;
- Safety Reprints, 1996 edition, ASE ISBN 0 86357 246 4.
- Hazardous Chemicals, A Manual for Science Education, 1997, SSERC Limited

  ISBN 0 9531776 0 2

Where an employer has adopted these or other publications as the basis of their model risk assessments, an individual school or college then has to review them, to see if there is a need to modify or adapt them in some way to suit the particular conditions of the establishment.

Such adaptations might include a reduced scale of working, deciding that the fume cupboard provision was inadequate or the skills of the candidates were insufficient to attempt particular activities safely. The significant findings of such risk assessment should then be recorded, for example on schemes of work, published teachers guides, work sheets, etc. There is no specific legal requirement that detailed risk assessment forms should be completed, although a few employers require this.

Where project work or individual investigations, sometimes linked to work-related activities, are included in specifications this may well lead to the use of novel procedures, chemicals or micro-organisms, which are not covered by the employer's model risk assessments. The employer should have given guidance on how to proceed in such cases. Often, for members, it will involve contacting CLEAPSS® (or, in Scotland, SSERC).

9 Interchange Help Sheet

Questions and answers

Where can I get the Practical Skills Assessment Tasks?
The live Tasks must be downloaded from Interchange, OCR's secure web portal. Printed copies will not be sent to Centres. Do not confuse the live assessment Tasks on Interchange with the Specimen Assessment Materials (SAMs) on the public OCR website – the SAMs must not be used for live assessment.

What is the web address for Interchange?
https://interchange.ocr.org.uk (Note: do not add 'www.' before the word 'interchange'.)

How do I obtain a username and password to log in to Interchange?
If your Centre is not already registered to use Interchange, your Examinations Officer will need to follow the information about how to register given in the Appendices of the GCE specifications and in the subject specific Practical Skills Handbook. Once registered, your Examinations Officer (or whoever holds the role of 'Centre Administrator') must either set you up as a new user with the role of 'Science Coordinator' to allow you to download the Tasks, or (less preferably) assign the role of 'Science Coordinator' to themselves so that they can download the Tasks and pass them to you.

How does my Examinations Officer set me up as a new user with the role of 'Science Coordinator'?
Your Examinations Officer (or whoever holds the role of 'Centre Administrator') should follow these steps in Interchange:

1. Hover the mouse cursor over 'Admin' in the left-hand menu, and then select 'Manage centre users' from the pop-up menu that appears. A list of all current users at your Centre will be loaded.

2. Click the 'Add New User' link (above the list of current users).

3. Enter user details.

4. Select the 'Roles' tab.

5. Select the role of 'Science Co-ordinator' on the left-hand side of the screen.

6. Click the '>' button. The 'Science Co-ordinator' role moves across to the right-hand side of the screen.

7. Click the 'User' tab.

8. Click 'Add'.

You will receive notification on screen of whether the new user was added successfully or not. Errors are indicated by a red asterisk (*) and are detailed on screen. *Please note that it usually takes approximately 20 minutes for the new user to be able to access Interchange.*

After logging in to Interchange, where can I find the Tasks?
Hover the mouse cursor over ‘Coursework and tests’ in the left-hand menu, and then select ‘Science co-ordinator materials’ from the pop-up menu that appears. Near the top of the new page that opens click the ‘GCE AS/A2’ link. Finally, select the appropriate specification name.

I don't have the ‘Coursework and tests’ and/or 'Science co-ordinator materials' options in the left-hand menu…
You need to be given the role of 'Science Co-ordinator'. Your Examinations Officer (or whoever holds the role of 'Centre Administrator') must assign the role of 'Science Co-ordinator' to you, as follows: step 1 above, click on the relevant username, steps 4 – 7 above, then click ‘Update’).

When I click on the specification name nothing happens / I get an error message / I get a warning about blocked content…
When you click on a subject heading (or click on the 'More detail…' link to the right of the heading), the rest of the page should slide down to reveal the Tasks and other materials available to download for the specification you selected. This works using Javascript, so your browser may alert you to ‘active content’ or ‘blocked content’. Please ensure that you select the appropriate option to allow all content to run. In Internet Explorer, the alert may appear as a pale yellow bar at the top of the page; you will need to click on the pale yellow bar and select ‘Allow blocked content’.

Check also that Javascript is enabled in your browser. In Internet Explorer, go to the 'Tools' menu and select 'Internet Options'; select the 'Advanced' tab on the far right; scroll down the list of check boxes to the coffee cup icon next to the heading 'Java (Sun)'; ensure that the 'Use Java for <applet>' check box (or similar) is ticked; click the 'OK' button; close Internet Explorer and then re-open it and log back in to Interchange. You should only ever have to do this once, unless you move to a different computer.

How do I download the Task ‘zip’ files?
Click on the Task that you want to download. If you are prompted whether to 'Open' or 'Save' the file, select 'Save'. You will be prompted for a location to which to save the file - select an appropriate location on your hard drive or USB stick. It is your responsibility to keep the Tasks strictly confidential after download, so choose a location that only you have access to. Remember that Tasks can only be used for assessment in the period stated on the Task cover (e.g. between 1 June 2009 and 14 May 2010). For future sessions, new Tasks need to be downloaded from Interchange.

What is a ‘zip’ file? / How to I get the Tasks from the ‘zip’ file?
The ‘zip’ file for each Task is a single file that has several PDF documents compressed inside it, namely the candidates’ Task sheet, the Instructions for Teachers and Technicians and the Mark Scheme, together with any additional files pertinent to the Task. You will need to extract the compressed PDF files before you can use them.

In Windows XP and Windows Vista you can look inside the ‘zip’ file by double-clicking it, or by right-clicking it and selecting 'Explore'; once inside the ‘zip’, click on the 'File' menu, and then select 'Extract all'. If you use an older version of Windows (e.g. 95, 98, 2000, ME, or NT) you will need to download and use third-party ‘zip’ extractor software such as WinZip or PKZip to extract the files.

Mac OS X version 10.3 (‘Panther’) and later releases have built-in support for ‘zip’ files. If you are using an older release, or if you experience difficulty extracting the PDF documents from the ‘zip’ file, try downloading and using third-party ‘zip’ extractor software such as StuffIt Expander to extract the files.

I get an error message saying that the ‘zip’ file is corrupt…
OCR has tested the files to ensure that they can all be downloaded successfully. If you are having problems with one of the files you have downloaded, delete the file and download it again or try

downloading it on a different computer. Also check with your IT administrator to ensure that a virus scanner or firewall on your Centre's network is not disrupting the file.

Some of the Tasks / Mark Schemes are missing…
Tasks for all GCE science specifications will be uploaded from **1st June** each year. The previous year's Tasks will have been taken down during May, and must not be used for assessment in the current session. If all of the Tasks are not available the first time you log in, check back in subsequent weeks for the latest additions, or register for e-mail updates to be alerted when new Tasks are uploaded (see below). Mark Schemes for all of the Tasks will be uploaded from **1st December** each year.

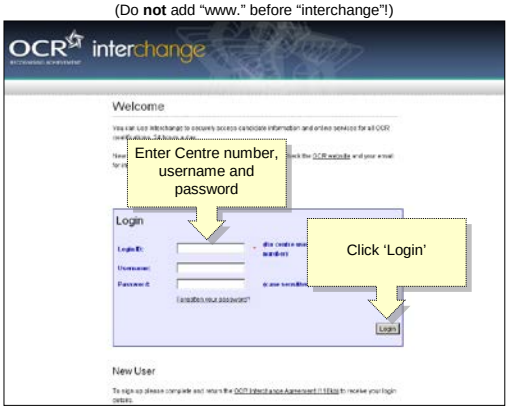
Do I have to keep logging in to Interchange to check for updates?
No. Just above the Tasks for each specification is a notice about 'e-mail updates'. To be notified by e-mail when changes are made to the Task pages, send an e-mail to GCEsciencetasks@ocr.org.uk including your name, Centre number and Centre name, and state the name of the specification(s) for which you wish to receive updates in the subject line.

Is there a way to see titles/summaries the Tasks without downloading them all?
The document called 'Getting Started' in the 'Support Materials' box on each specification page gives titles and summaries for all Tasks that are available for assessment in the current session. Click the 'Getting Started' link to download the document.

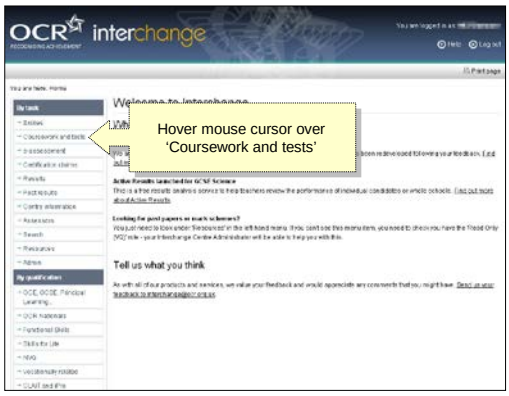
1

https://interchange.ocr.org.uk

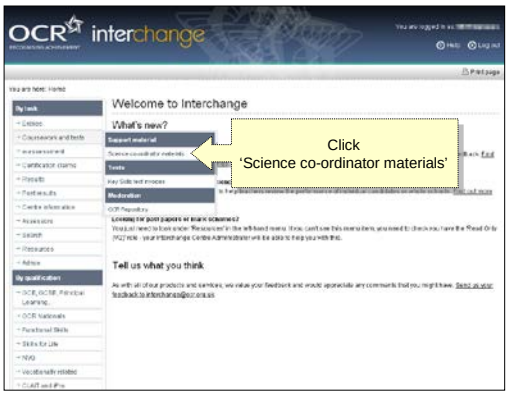
(Do **not** add "www." before "interchange"!)



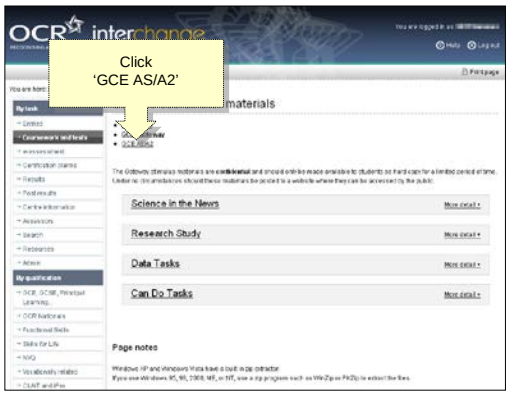
2



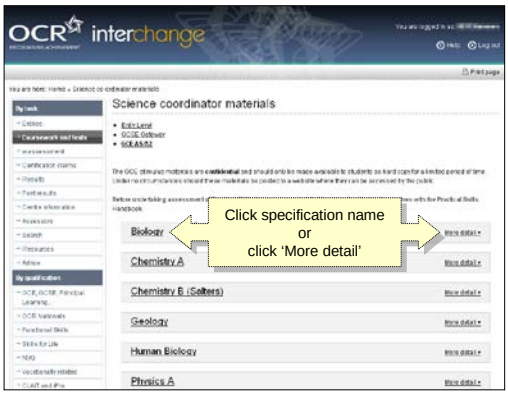
3



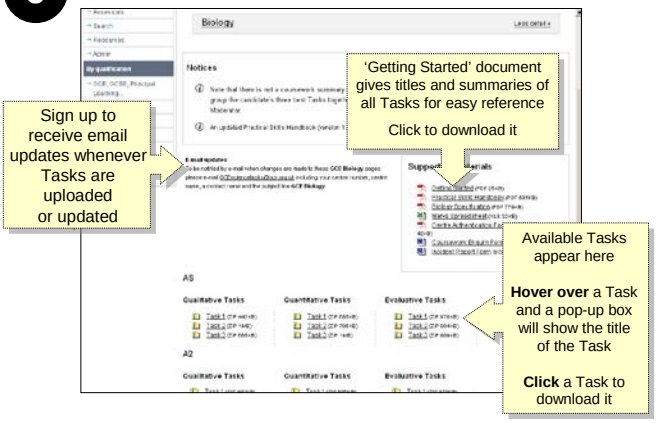
4



5



6



10 Helpful Guide on Practical Skills

This guide is designed to provide helpful tips on the qualitative, quantitative and evaluative tasks for the AS and A2 Practical Skills. It is envisaged that the guide will promote a better understanding of what examiners expect from the candidates. There is particular focus on measurements, presentation of results, graphical work and analysis of results.

Measurements

1. Measurement and observation

The minimum number of observations to be made is usually six for most tasks. This will prevent candidates from spending too much time taking readings and not allowing enough time for the graphical work and the analysis. Six (or more) readings are usually required for a linear trend or nine for a curved trend. Candidates will not be penalised for taking more than the six observations. However, taking fewer than six observations may lead to a penalty. It is expected that **all** observations will be plotted on the graph grid.

The range over which the readings are to be taken may be specified in the task. It is expected that candidates will use sensible intervals between each reading in this range. For example, if a quantity *d* was to be measured, the task may instruct candidates in the following way '... for values of *d* in the range 15 cm < *d* < 75 cm measure the time for ... until you have six sets of readings for *d* and *t* ...', in which case a sensible interval would be 10 cm.

d / cm	*t* / s
20.0	
30.0	
40.0	
50.0	
60.0	
70.0	

Acceptable - the intervals are fine

d / cm	*t* / s
20.0	
22.0	
26.0	
44.0	
68.0	
70.0	

Not acceptable - the first three readings and last two readings are too close together

2. Repeated readings

It is expected that candidates will repeat readings and determine an average. All **raw readings** should be recorded. Many weaker candidates only record a final average value and not the raw values from which it was derived. In consideration of the time limits for the assessments, it is only necessary to repeat readings so that **two** sets of values are obtained. Again, the reason for this is to avoid too much time being spent taking readings from the apparatus.

3. Quality of results

Some marks may be reserved for the candidates who have done the experiment carefully. This is usually judged by the *scatter of points* about a line of best fit.

4. Significant figures

Many candidates use an appropriate number of significant figures in a calculated quantity, but often do not understand why. In their explanation it is expected that the number of significant figures in the final calculated quantity will be related to the number of significant figures in the raw data which has been used in the calculation.

Common errors made by weaker candidates include:

- Vague statements such as 'it increases the accuracy of the experiment'.
- 'I am going to plot a graph, so I will give my answers to 2 sig. figs.'
- Confusion between significant figures and decimal places (e.g. 'I have given x to two decimal places so x^3 should be given to two decimal places').

Many candidates confuse significant figures (sf) and decimal places (dp). It may be helpful to these candidates if increased guidance could be given. Often it is helpful to consider pairs of values such as those shown in the table below:

x	x^3
6.52	277.17
6.53	278.45
6.54	279.73

Too many sf in the values of x^3 (5 sf values from 3 sf data)

Clearly both sets of values for x and x^3 are given to two decimal places. However, values of x^3 are given to five significant figures, which is not justified from the precision of the values of x. Changing the third significant figure in the value for x (2, 3 or 4) changes the third significant figure in the value of x^3 (7, 8 and 9). Hence the values for x^3 should only be quoted to three significant figures (to be consistent with the values of x from which they were derived).

x	x^3
6.52	277
6.53	278
6.54	280

sf in values of x^3 are correct (3 sf values from 3 sf data)

Similar difficulties apply when large numbers are involved. Consider the case of a voltmeter having a resistance of 50 000 Ω. It is unclear as to whether this value is correct to one, two, three, four or five significant figures. In this case candidates would find it helpful to be encouraged to use scientific notation or multiplying prefixes to indicate how many significant figures are intended to be shown.

For example:

. $R = 50\ 000\ \Omega$ (could be 1, 2, 3, 4 or 5 sf)
$R = 5 \times 10^4\ \Omega$ (1 sf)
$R = 5.0 \times 10^4\ \Omega$ (2 sf, 1 dp)
$R = 5.00 \times 10^4\ \Omega$ (3 sf, 2 dp)
$R = 50\ \text{k}\Omega$ (2 sf)
$R = 50.0\ \text{k}\Omega$ (3 sf, 1 dp)

Candidates would benefit from using any of the forms above **except** the first one in order to make it clear how many significant figures they intend to give.

Significant figures in logarithmic quantities are also not well understood by candidates. Often it is not appreciated that the characteristic is a place value and is not 'significant' in relation to the precision of the data. The following set of values could be used to illustrate this. All the values of x have been given to 3 significant figures.

x	lg x
2.53	0.403
25.3	1.403
253	2.403
2.53×10^6	6.403
2.52×10^6	6.401
2.54×10^6	6.405

Clearly the characteristic must be given, but it can be seen that changing the last figure in the value of x will change the third decimal place in the value of lg x. Therefore it would be sensible in this case to quote lg x to three decimal places if the values of x are correct to three significant figures.

Presentation of results

Presentation of results is dealt within three main areas; column headings, consistency of raw readings and significant figures in calculated quantities. Procedures for dealing with these are as follows:

1. Column headings

It is expected that **all** column headings will consist of a quantity **and** a unit.

The quantity may be represented by a symbol or written in words. There must be some kind of distinguishing notation between the quantity and the unit. Candidates should be encouraged to use solidus notation, but a variety of other notations are accepted. For example, a length *L* measured in centimetres may be represented as follows:

$$L \text{ / cm}, L \text{ (cm)}, L \text{ in cm, and } \frac{L}{\text{cm}}$$

are all **acceptable** as column headings.

If the distinguishing notation between a quantity and its unit are not clear then credit will not be given. Examples of this are show below:

$$L \text{ cm}, L_{\text{cm}}, \frac{L}{\text{cm}} \text{ or just 'cm'}$$

are **not** acceptable.

Units relating to quantities where the logarithm has been found should appear in brackets after the 'log'. The logarithm of a quantity has no unit. It is recommended that the logarithm of a length *L* measured in centimetres using a base of ten should be written as lg (*L*/cm).

2. Consistency of presentation of raw data

All the raw readings of a particular quantity should be recorded to the same number of decimal places. These should be consistent with the apparatus used to make the measurement. In the example shown below a rule with a millimetre scale has been used to make a measurement of length. We may expect all the readings of length *L* therefore to be given to the nearest millimetre, even if a value is a whole number of centimetres.

L / cm	*t* / s
2	
3.7	
4.9	
5.9	
6.3	

Not acceptable - the first reading is to the nearest cm and all the others are to the nearest mm.

L / cm	t / s
2.0	
3.7	
4.9	
5.9	
6.3	

Acceptable - all the raw readings have been given to the same degree of precision

Candidates are sometimes tempted to 'increase the accuracy of the experiment' by adding extra zeros to the readings. This makes the readings inconsistent with the apparatus used in measuring that particular quantity. In the case of a thermometer which can measure to a precision of about a degree ($\pm$ 1 ^{0}C) it is unreasonable to give temperatures which indicate that a precision of one hundredth of a degree have been achieved.

θ / ^{O}C	t / s
22.00	
35.50	
47.00	
58.50	
77.00	
89.50	

Not acceptable - too many dp in the values of θ - not achievable with a mercury-in-glass thermometer

Candidates sometimes go the other way and do not record enough decimal places (e.g. length values which are recorded to the nearest centimetre when a rule with a scale in millimetres is used to make the measurement).

3. Significant figures in calculated quantities

Calculated quantities should be given to the same number of significant figures as the measured quantity of least precision. Consider the table of readings below:

V / V	I / A	R / Ω
3.0	1.43	2.1
4.0	1.57	2.5
5.0	1.99	2.5
6.0	2.45	2.4
7.0	3.02	2.3

If values of V and I are measured to two and three significant figures respectively, we would expect R to be given to two significant figures. This is because a value of

V = 3.1 V in the first row of figures would give R = 2.2 Ω (i.e. changing the second significant figure in the value of V will change the second significant figure in the value of R).

Three significant figures would be *acceptable* for R, but **not** one significant figure (e.g: 2 Ω) or four significant figure (2.098 Ω).

The exception to this rule is when candidates use stopwatches reading to 0.01 s. Candidates cannot measure to this accuracy although many will record readings directly from the stopwatch. Therefore in this case it would be acceptable for candidates to round down to the nearest tenth of a second and give values of a calculated quantity (e.g. period T) to three significant figures.

20T / s	T / s
10.49	0.525
14.31	0.716
17.69	0.885
24.88	1.24
29.61	1.48
33.02	1.65

Acceptable. Note that some values of T are to three dp and others are to two dp, but all the values of T are to 3 sf

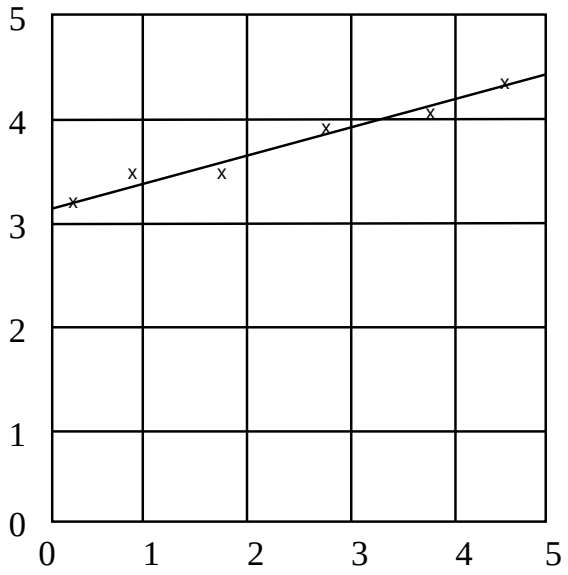
Graphical work

Credit for graphical work usually may often fall into five categories:

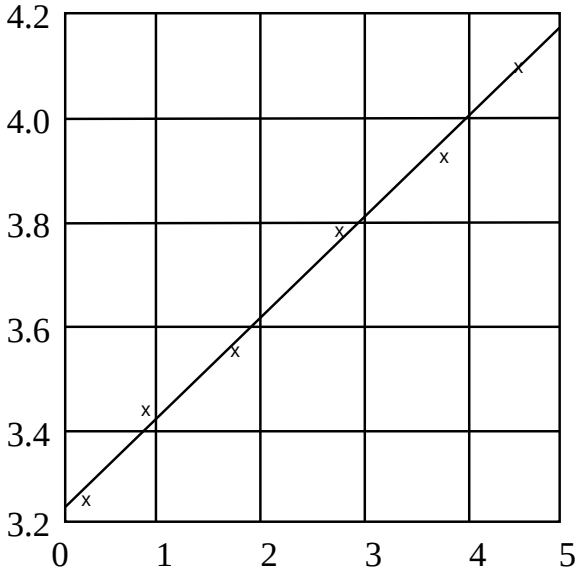
- Choice of scale
- Plotting of points
- Line of best fit
- Calculation of gradient
- Determination of the *y*-intercept

1. Choice of scales

a. Scales should be chosen so that the plotted points occupy at least half the graph grid in both the *x* and *y* directions.



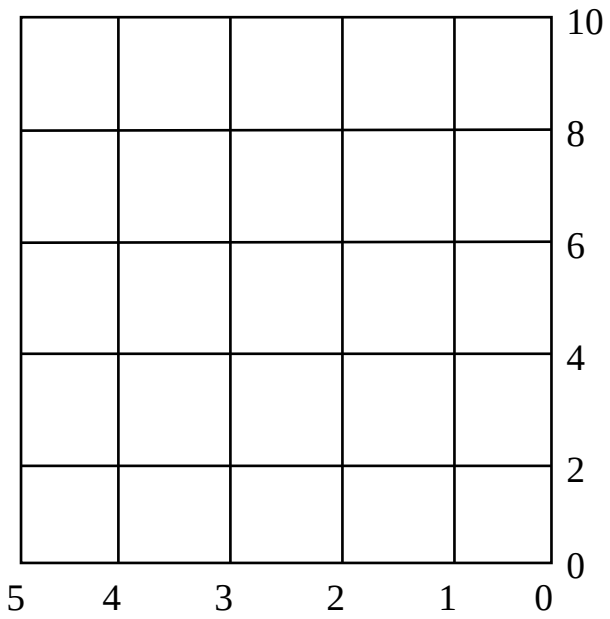
Not acceptable - scale in the *y*-direction is compressed



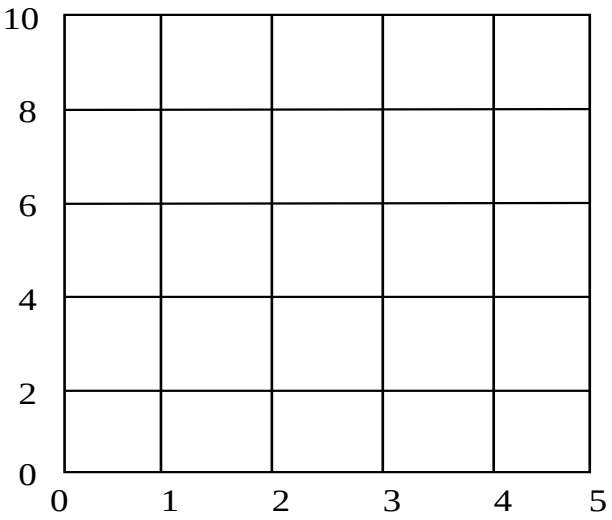
Acceptable - points fill more than half the graph grid in both the *x* and *y* directions

b. It is expected that each axis will be labelled with the quantity which is being plotted.

c. The scale direction must be conventional (i.e. increasing from left to right).



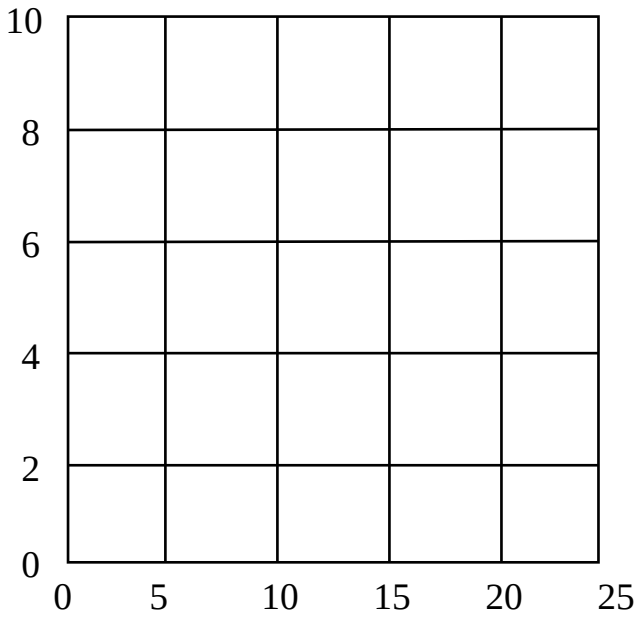
Not acceptable - unconventional scale direction



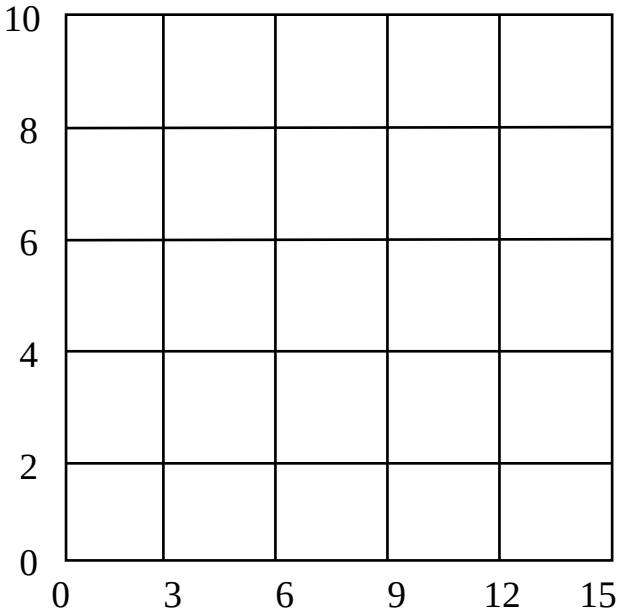
Acceptable - conventional scale direction

This problem often occurs when scales are used with negative numbers.

d. Candidates should be encouraged to choose scales that are easy to work with.



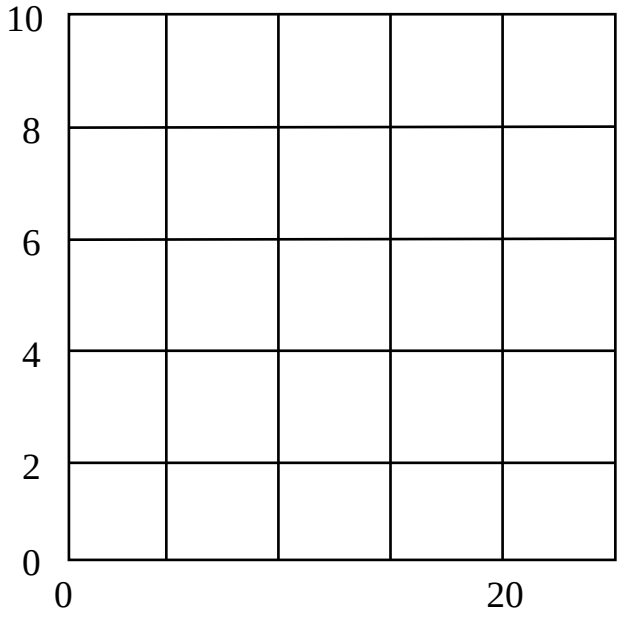
Acceptable scale divisions.



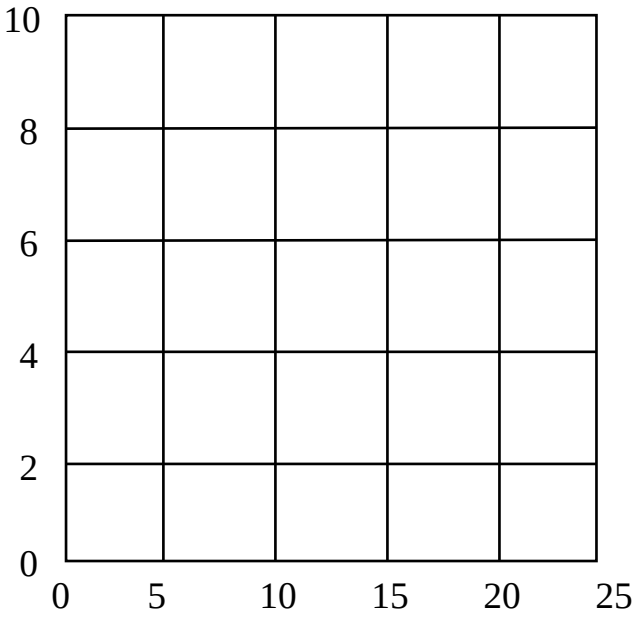
Not acceptable - awkward scale on the *x*-axis.

Candidates who choose awkward scales often lose marks for plotting points (as they cannot read the scales correctly) and calculation of gradient (Δx and Δy often misread - again because of poor choice of scale).

e. Scales should be labelled reasonably frequently (i.e. there should not be more than three large squares between each scale label on either axis).

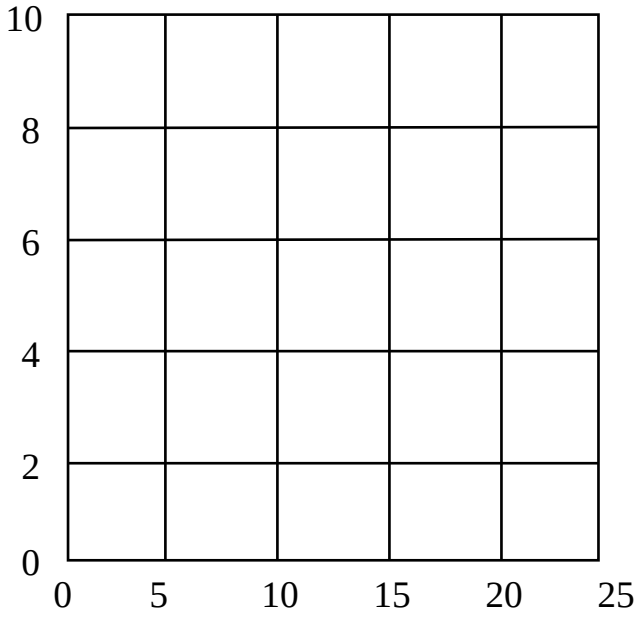


Not acceptable - too many large squares with no label

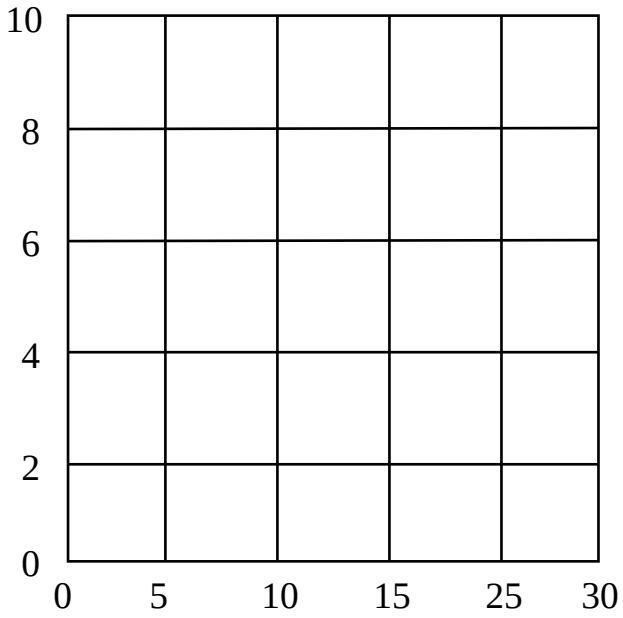


Acceptable - scales have regular labels

f. There should be no 'holes' in the scale.



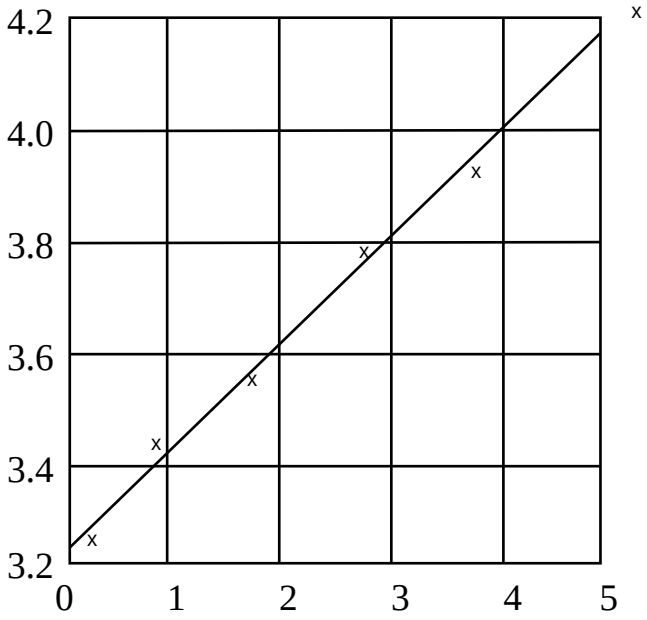
Acceptable - scale labelling is regular



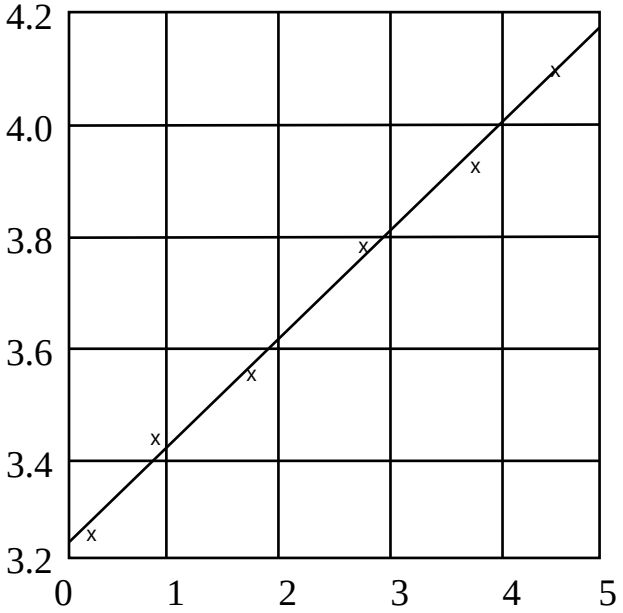
Not acceptable - non-linear scale on the *x*-axis

2. Plotting of points

a. Plots in the margin area are not allowed. Candidates would find it helpful to be told that any plots in the margin area will be ignored. Sometimes weaker candidates (realising that they have made a poor choice of scale) will attempt to draw a series of lines in the margin area so that they can plot the 'extra' point in the margin area. This is considered to be *bad practice* and will not be credited.



Not acceptable - the last point has been plotted in the margin area



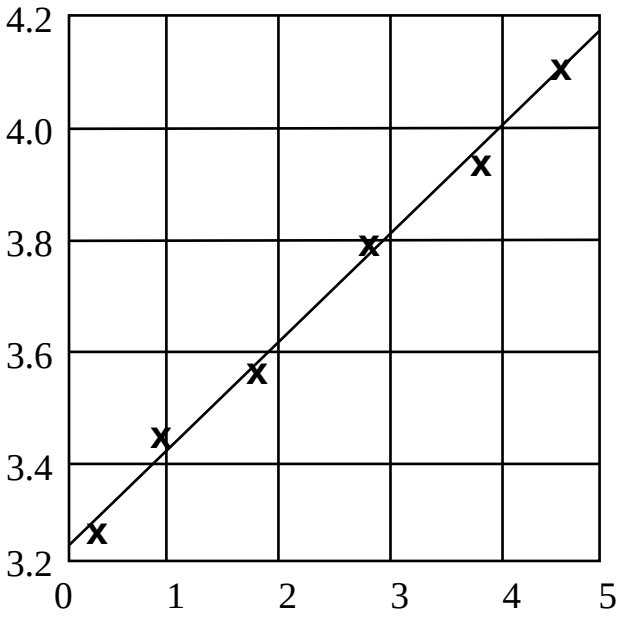
Acceptable - all plotted points are on the graph grid

b. It is expected that all observations will be plotted (e.g. if six observations have been made then it is expected that there will be six plots).

c. Plotted points must be accurate to half a small square.

d. Plots must be clear (and not obscured by the line of best fit or other working).

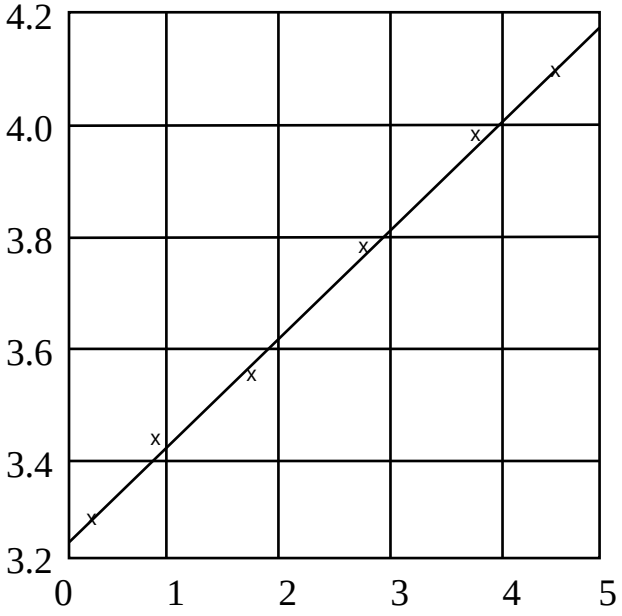
e. Thick plots are not acceptable. If it cannot be judged whether a plot is accurate to half a small square (because the plot is too thick) then the plotting mark will not be awarded.



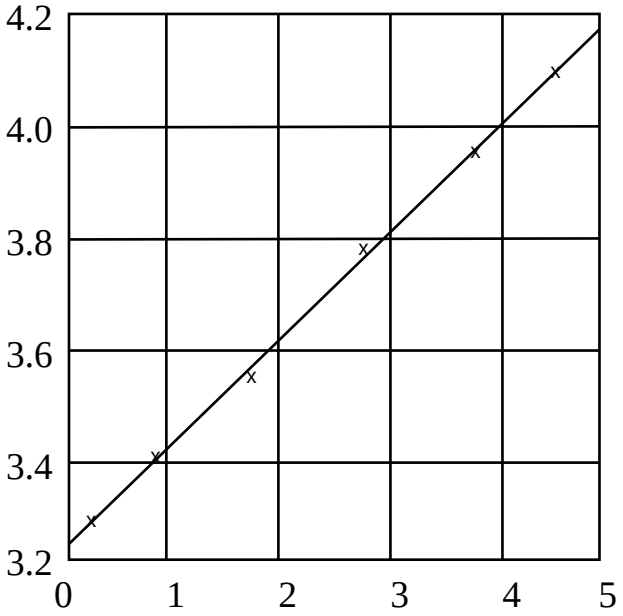
Thick plots not acceptable

3. Line (or curve) of best fit

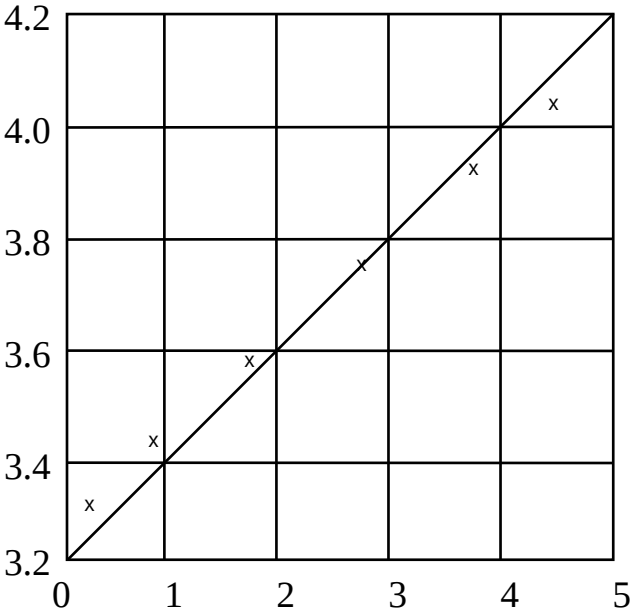
a. There must be a reasonable balance of points about the line. It is often felt that candidates would do better if they were able to use a clear plastic rule so that points can be seen which are on <u>both</u> sides of the line as it is being drawn.



Not acceptable - too many points above the line

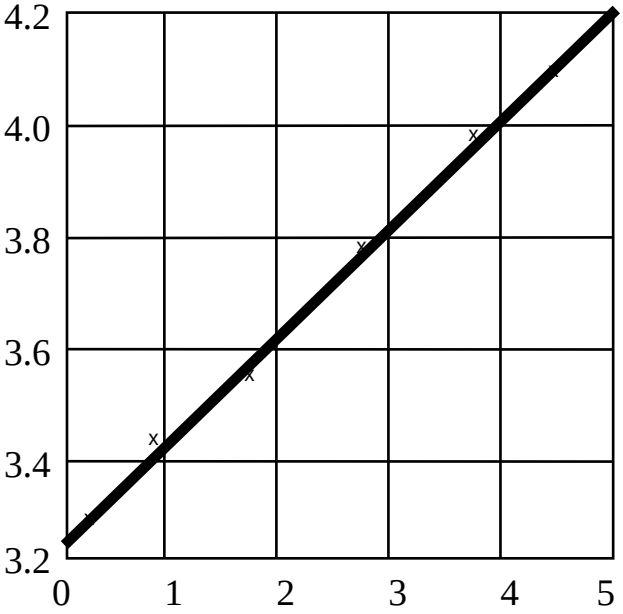


Acceptable balance of points about the line

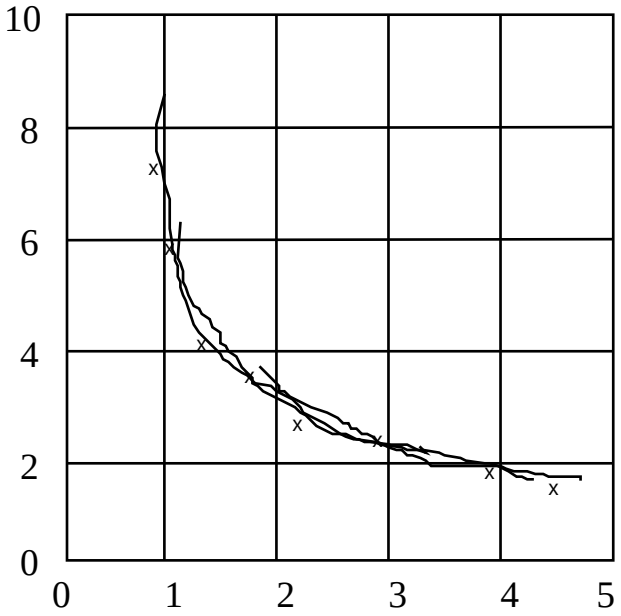


Not acceptable - forced line through the origin

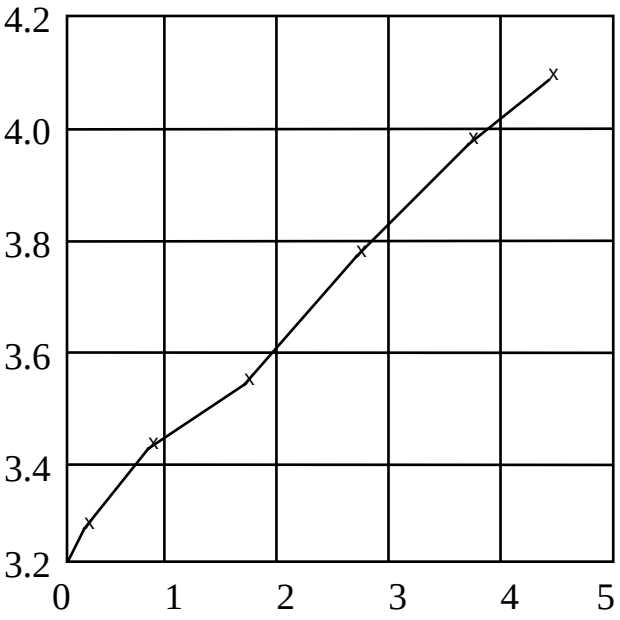
b. The line must be thin and clear. Thick/hairy/point-to-point/kinked lines are not credited.



Not acceptable - thick line



Not acceptable - 'hairy' curve

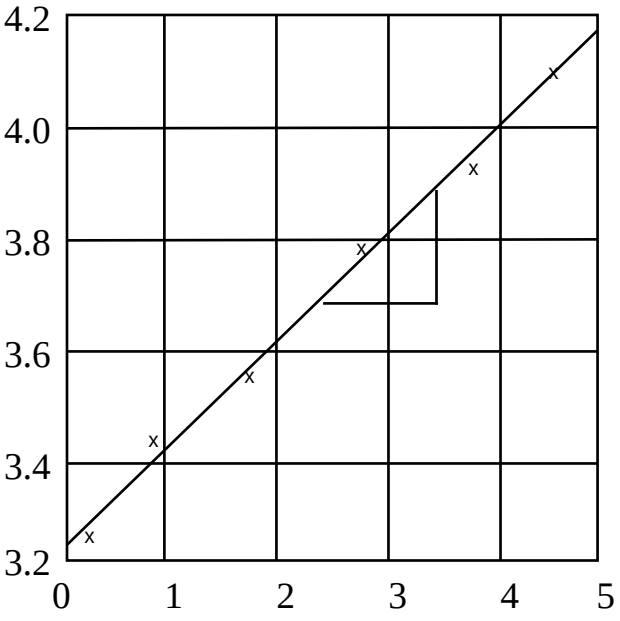


Not acceptable – joining point-to-point

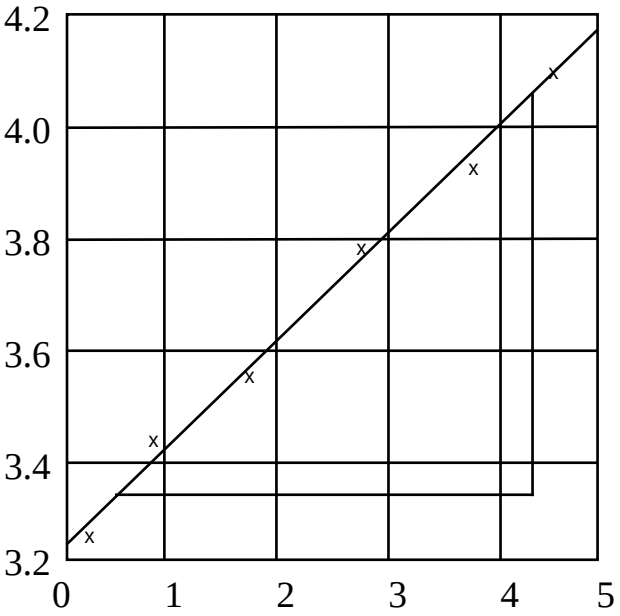
4. Determining gradients

a. All the working must be shown. A 'bald' value for the gradient may not be credited. It is helpful to both candidates and examiners if the triangle used to find the gradient were to be drawn on the graph grid and the co-ordinates of the vertices clearly labelled.

b. The length of the hypotenuse of the triangle should be greater than half the length of the line which has been drawn.



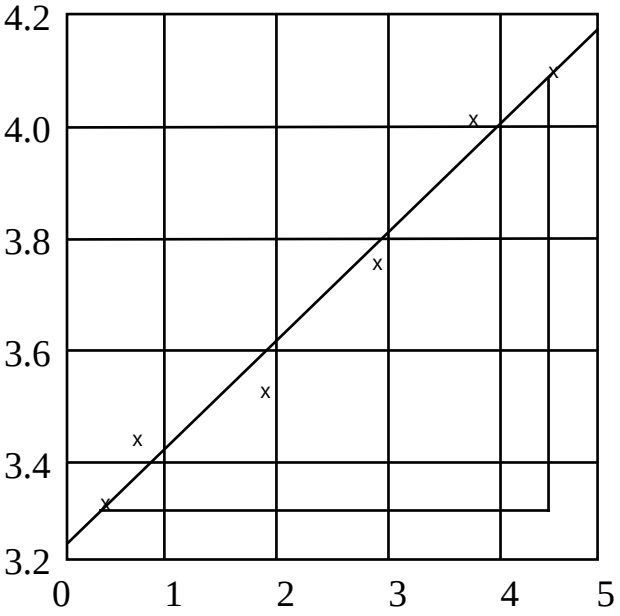
Not acceptable - the ‘triangle’ used is too small



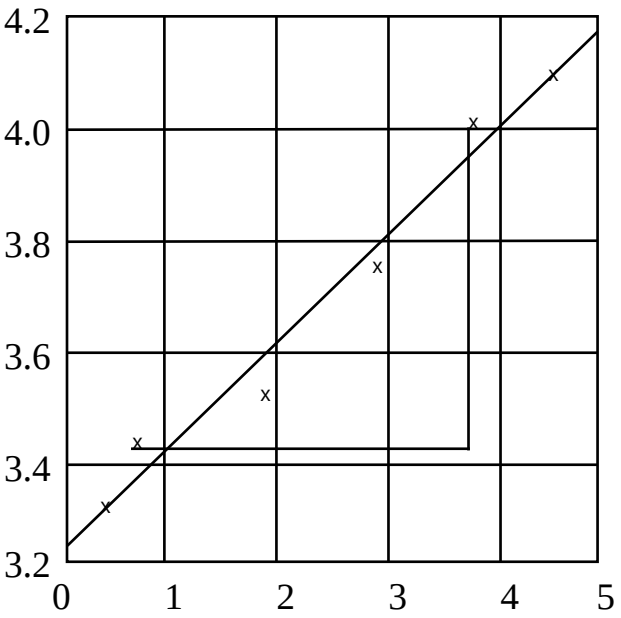
Acceptable – a large 'triangle' used

c. The value of Δx and Δy must be given to an accuracy of at least one small square (i.e. the 'read-off' values must be accurate to half a small square).

d. If plots are used which have been taken from the table of results then they must lie on the line of best fit (to within half a small square).



Acceptable - plots on line

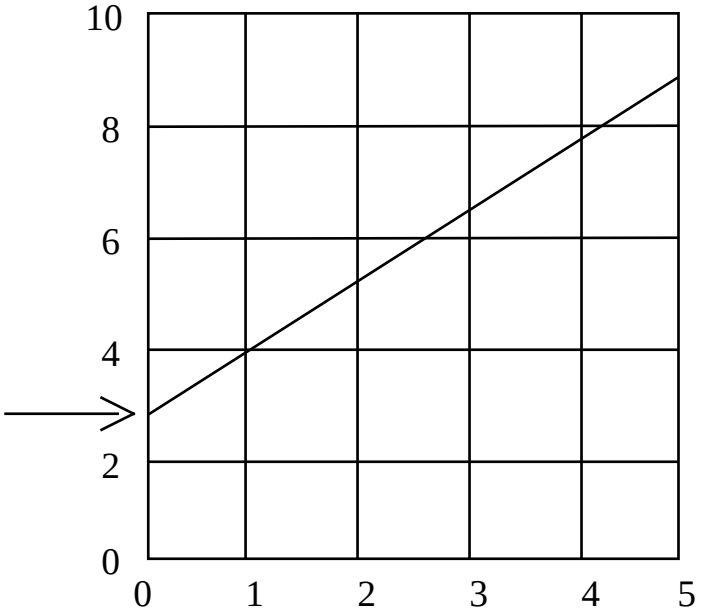


Not acceptable - the data points used which do not lie on the line of best fit

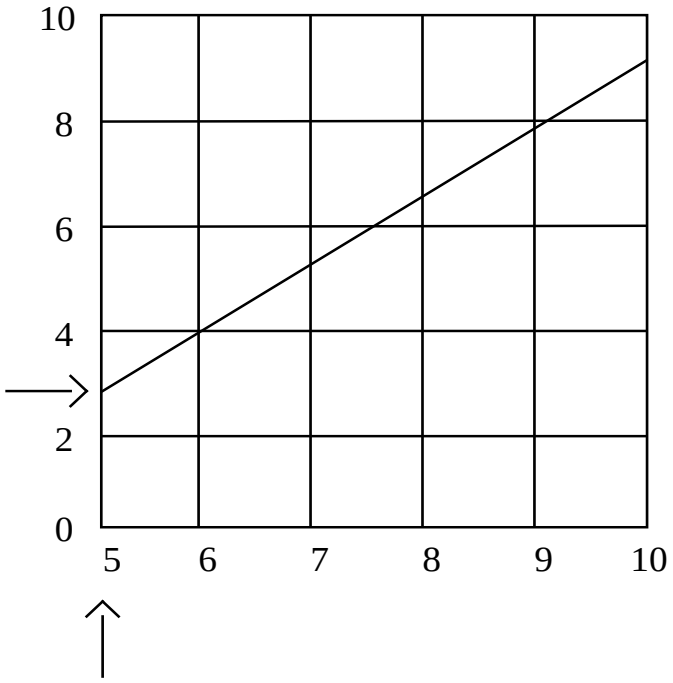
e. A gradient value has no unit since it is a ratio of two numbers from the graph.

5. Intercept

a. The *y*-intercept must be read from an axis where $x = 0$. It is often the case that candidates will choose scales so that the plotted points fill the graph grid (as they should do) but then go on to read the *y*-intercept from a line other than $x = 0$.



Acceptable – the value taken from the line $x = 0$



Not acceptable – the *y*-intercept is found from the line *x* = 5

b. It is expected that candidates will be able to use the equation of a straight line ($y = mx + c$) to determine the *y*-intercept if the choice of scale is such that it is not possible to take a direct reading from the *y*-axis when *x* = 0. In this case it is expected that a pair of *x* and *y* values from the line of best fit (together with a gradient value) will be substituted into the equation *y* = *mx* + *c* to give a value for the *y*-intercept.

Uncertainties

1. Percentage uncertainty

In the evaluative tasks candidates may be asked to calculate a simple percentage uncertainty or state the uncertainty in a measurement. When repeated readings have been done then it is expected that the uncertainty in the measured quantity will be half the range. The expression

$$\text{percentage uncertainty} = \frac{\text{uncertainty}}{\text{average value}} \times 100\%$$

should be used.

If *single* readings have been taken then the uncertainty should be the smallest interval or division on the measuring instrument. Consider the example below.

Example: A metre rule is used to measure the length of a book.

uncertainty in the measuring instrument (the ruler) = $\pm$ 1mm

length = (295 $\pm$ 1) mm

The percentage uncertainty in the length is

$$\% \text{ uncertainty} = \pm \frac{1}{295} \times 100 = \pm 0.34\%$$

Determining the uncertainty in time measurements using a stopwatch raises a few issues. Almost all stopwatches will give times to one hundredth of a second, but candidates clearly cannot operate the watch to this accuracy. Human reaction time will give errors of (typically) 0.1 s to 0.6 s, which are reasonable estimates of the uncertainty.

Similar ideas apply to measurement of length, where parallax errors may make it difficult for candidates to measure a length to the accuracy of the rule used.

2. The rules for determining percentage uncertainties

A key assessment objective of the evaluative tasks is going to be determining the final uncertainty in a quantity. Here are some useful rules:

- If $y = ab$

  Rule: % uncertainty in *y* = % uncertainty in *a* + % uncertainty in *b*

- $y = \frac{a}{b}$ (For example when determining the gradient of a line)

  Rule: % uncertainty in *y* = % uncertainty in *a* + % uncertainty in *b*

- $y = a^2$

  Rule: % uncertainty in *y* = 2 × % uncertainty in *a*

3. Determining the uncertainty in the gradient using maximum and minimum gradients

Candidates may determine the uncertainty in the gradient by drawing lines of maximum and minimum gradients through their scattered data points. What happens when there is little scatter of the data points? This is when candidates may draw *error bars*.

The uncertainty in the gradient can be determined as follows:

a. Error bars may be added to each plotted point if the data points are not too scattered.

b. Draw a best fit line through the scattered points (or through the error bars). The worst acceptable line is then drawn. This will either be the *steepest* or *shallowest* line.

c Determine the gradient of the best fit line and the gradient of the worst acceptable line.

d Uncertainty = |gradient of best fit line – gradient of worst acceptable line|.

e The percentage uncertainty in the gradient can be determined as follows:

$$\text{percentage uncertainty} = \frac{\text{uncertainty}}{\text{gradient of best fit line}} \times 100\%$$

4. Determining the uncertainty in the *y*-intercept using maximum and minimum gradients

Candidates may determine the uncertainty in the *y*-intercept by using lines of maximum and/or minimum gradients through their scattered data points. What happens when there is little scatter of the data points? This is again when candidates may draw *error bars*.

a. Error bars may be added to each plotted point if the data points are not too scattered.

b. Draw a best fit line through the scattered points (or through the error bars). The worst acceptable line is then drawn. This will either be the *steepest* or *shallowest* line.

c Determine the *y*-intercept of the worst acceptable line and the *y*-intercept of the best fit line.

d Uncertainty = |*y*-intercept of best fit line – *y*-intercept of worst acceptable line|.

e The percentage uncertainty in the *y*-intercept can be determined as follows:

$$\text{percentage uncertainty} = \frac{\text{uncertainty}}{y\text{ - intercept}} \times 100\% .$$

5. Percentage difference

Candidates may be asked to determine the percentage difference between experimental values and accepted values. 'Experimental values' are those that are derived from measurement or calculation, whereas 'accepted' or 'theoretical' values are values that are accepted by the scientific community.

The percentage difference between an experimental and accepted value is determined as follows:

$$\text{percentage difference} = \frac{\text{experimental value - accepted value}}{\text{accepted value}} \times 100\%$$

6. Understanding the terms accuracy, precision, and reliability

Candidates generally have a poor comprehension of the terms **accuracy** and **precision**. These are often used to mean the same thing. Candidates are strongly advised to use these two important terms with great care when evaluating their experimental procedures.

An experiment is **accurate** when the measured quantity has a value *very close to the accepted value*. For example an experimental value for the acceleration of free fall of 9.78 m s^{-2} is much more *accurate* than an experimental value of 9.05 m s^{-2}.

The term **precision** is linked to the *spread of the data* or the *percentage uncertainty* in a measurement. A precise experiment has a smaller *spread in the data* or the smaller the *uncertainty*. Hence, an experiment with an acceleration of free fall of

(9.05 $\pm$ 0.05) m s^{-2} is much more *precise* than an experiment with (9.78 $\pm$ 1.20) m s^{-2}; but the latter is much more *accurate*.

If a measurement or test is **reliable**, it gives consistent results each time the activity is repeated.
A **reliable experiment** has consistent results for the same measurement.
Experiments are unreliable if repeated measurements give different results or if the scatter of measurements on a line graph is large (or so great that establishing a line of best fit is difficult).