Astronomy guide

First examinations 2008

Notes

- This document should be read in conjunction with section B.11 of the Handbook of Procedures for the Diploma programme
- As a school-based syllabus (SBS), Astronomy may be offered only by schools authorized by the IB to do so prior to the commencement of teaching the subject
- An SBS may not be combined within the same Diploma with a pilot programme or another SBS.
- Any queries arising from this documentation should be directed to the subject manager via IB Answers.

Diploma Programme
Astronomy—guide

This school-based syllabus guide was produced in 2006 by Oakham School in conjunction with the IBO

2nd edition November 2012

International Baccalaureate Organization
Peterson House, Malthouse Avenue, Cardiff Gate
Cardiff, Wales GB CF23 8GL
United Kingdom
Phone: +44 29 2054 7777
Fax: +44 29 2054 7778
Web site: http://www.ibo.org

IBO mission statement

The International Baccalaureate Organization aims to develop inquiring, knowledgeable and caring young people who help to create a better and more peaceful world through intercultural understanding and respect.

To this end the IBO works with schools, governments and international organizations to develop challenging programmes of international education and rigorous assessment.

These programmes encourage students across the world to become active, compassionate and lifelong learners who understand that other people, with their differences, can also be right.

IB learner profile

The aim of all IB programmes is to develop internationally minded people who, recognizing their common humanity and shared guardianship of the planet, help to create a better and more peaceful world.

IB learners strive to be:

Inquirers They develop their natural curiosity. They acquire the skills necessary to conduct inquiry and research and show independence in learning. They actively enjoy learning and this love of learning will be sustained throughout their lives.

Knowledgeable They explore concepts, ideas and issues that have local and global significance. In so doing, they acquire in-depth knowledge and develop understanding across a broad and balanced range of disciplines.

Thinkers They exercise initiative in applying thinking skills critically and creatively to recognize and approach complex problems, and make reasoned, ethical decisions.

Communicators They understand and express ideas and information confidently and creatively in more than one language and in a variety of modes of communication. They work effectively and willingly in collaboration with others.

Principled They act with integrity and honesty, with a strong sense of fairness, justice and respect for the dignity of the individual, groups and communities. They take responsibility for their own actions and the consequences that accompany them.

Open-minded They understand and appreciate their own cultures and personal histories, and are open to the perspectives, values and traditions of other individuals and communities. They are accustomed to seeking and evaluating a range of points of view, and are willing to grow from the experience.

Caring They show empathy, compassion and respect towards the needs and feelings of others. They have a personal commitment to service, and act to make a positive difference to the lives of others and to the environment.

Risk-takers They approach unfamiliar situations and uncertainty with courage and forethought, and have the independence of spirit to explore new roles, ideas and strategies. They are brave and articulate in defending their beliefs.

Balanced They understand the importance of intellectual, physical and emotional balance to achieve personal well-being for themselves and others.

Reflective They give thoughtful consideration to their own learning and experience. They are able to assess and understand their strengths and limitations in order to support their learning and personal development.

Contents

Purpose of this document

This publication is intended to guide the planning, teaching and assessment of the subject in schools. Subject teachers are the primary audience, although it is expected that teachers will use the guide to inform students and parents about the subject.

This school-based syllabus guide is not a published sales item—copies are made freely available by the IB (contact IB Answers). This guide will eventually be made available on a page dedicated to the school-based syllabuses (SBSs) on the online curriculum centre (OCC) at http://occ.ibo.org, a password-protected IB website designed to support IB teachers.

Additional resources

Additional resources such as specimen and past examination papers, markschemes, and grade descriptors will also eventually be made available on the OCC. In the meantime, please contact IB Answers to enquire about these.

Teachers are encouraged to share resources with other teachers, for example: websites, books, videos, journals or teaching ideas. This is particularly important in SBS subjects, where the IB expects schools to support each other in the advancement of their subject. The "host" school for an SBS is usually able to provide information and contact details of other schools offering the subject. Schools are given contact details of the host school for their SBS in their letter of authorization.

Acknowledgment

The IB wishes to thank the educators and associated schools for generously contributing time and resources to the production of this guide, and, in particular, Oakham School, and their teachers, Dr John Chilton and Dr Andrew Davies.

First examinations 2008

The Diploma Programme

The Diploma Programme is a rigorous pre-university course of study designed for students in the 16 to 19 age range. It is a broad-based two-year course that aims to encourage students to be knowledgeable and inquiring, but also caring and compassionate. There is a strong emphasis on encouraging students to develop intercultural understanding, open-mindedness, and the attitudes necessary for them to respect and evaluate a range of points of view.

The Diploma Programme hexagon

The course is presented as six academic areas enclosing a central core (see figure 1). It encourages the concurrent study of a broad range of academic areas. Students study: two modern languages (or a modern language and a classical language); a humanities or social science subject; an experimental science; mathematics; one of the creative arts. It is this comprehensive range of subjects that makes the Diploma Programme a demanding course of study designed to prepare students effectively for university entrance. In each of the academic areas students have flexibility in making their choices, which means they can choose subjects that particularly interest them and that they may wish to study further at university.

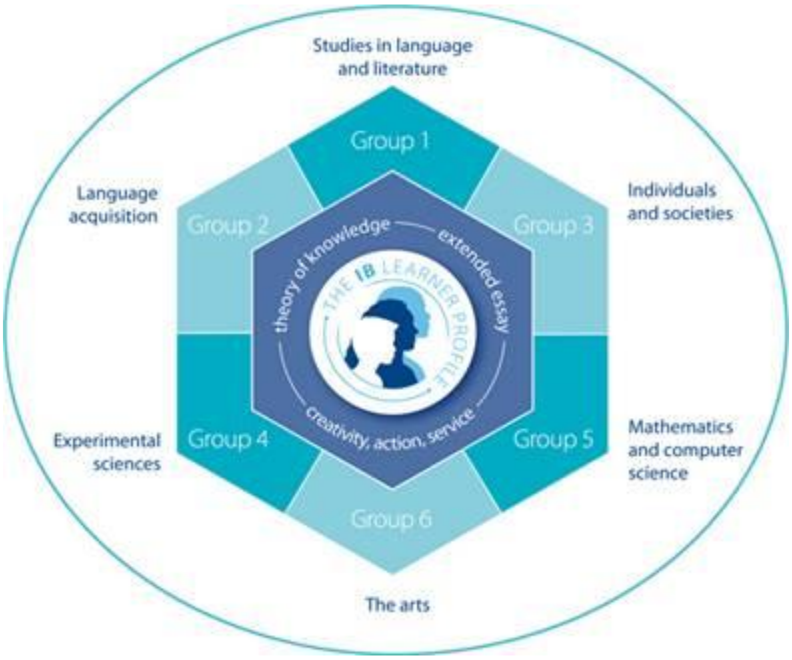


Figure 1

Diploma Programme model

Choosing the right combination

Students are required to choose one subject from each of the six academic areas, although they can choose a second subject from groups 1 to 5 instead of a group 6 subject. Normally, three subjects (and not more than four) are taken at higher level (HL), and the others are taken at standard level (SL). The IB recommends 240 teaching hours for HL subjects and 150 hours for SL. Subjects at HL are studied in greater depth and breadth than at SL.

At both levels, many skills are developed, especially those of critical thinking and analysis. At the end of the course, students' abilities are measured by means of external assessment. Many subjects contain some element of coursework assessed by teachers. The courses are available for examinations in English, French and Spanish.

The core of the hexagon

All Diploma Programme students participate in the three course requirements that make up the core of the hexagon. Reflection on all these activities is a principle that lies at the heart of the thinking behind the Diploma Programme.

The theory of knowledge course encourages students to think about the nature of knowledge, to reflect on the process of learning in all the subjects they study as part of their Diploma Programme course, and to make connections across the academic areas. The extended essay, a substantial piece of writing of up to 4,000 words, enables students to investigate a topic of special interest that they have chosen themselves. It also encourages them to develop the skills of independent research that will be expected at university. Creativity, action, service involves students in experiential learning through a range of artistic, sporting, physical and service activities.

The IB mission statement and the IB learner profile

The Diploma Programme aims to develop in students the knowledge, skills and attitudes they will need to fulfill the aims of the IB, as expressed in the organization's mission statement and the learner profile. Teaching and learning in the Diploma Programme represent the reality in daily practice of the organization's educational philosophy.

Nature of group 4 subjects

Difference between SL and HL

As a school-based syllabus, Astronomy, unlike mainstream group 4 subject, is only available at SL.

Group 4 subjects and prior learning

Past experience shows that students will be able to study a group 4 science subject at SL successfully with no background in, or previous knowledge of, science. Their approach to study, characterized by the specific IB learner profile attributes-inquirers, thinkers and communicators-will be significant here.

Group 4 subjects and the MYP

Students who have undertaken the MYP sciences, technology and mathematics courses will be well prepared for group 4 subjects. The MYP science objectives and assessment criteria A–F are aligned with the group 4 objectives and IA criteria, and allow for a smooth transition from the MYP to Diploma Programme. In particular, the “One world” objective in MYP sciences is further developed in group 4 science with the increased emphasis on aim 8—that is, to “raise awareness of the moral, ethical, social, economic and environmental implications of using science and technology”. There are specific references to aim 8 implications in assessment statements and teacher’s notes in the syllabus details sections in all Group 4 guides.

Teachers are advised to read the IB document *Science Across the IB Continuum (July 2011)* for additional information.

Group 4 subjects and TOK

In looking at the ways of knowing described in the *Theory of Knowledge guide* (March 2006), scientists could legitimately claim that science encompasses all these. Driven by emotion, using sense perception, enhanced by technology and combined with reason, it communicates through language, principally the universal language of mathematics.

There is no one scientific method, in the strict Popperian sense, of gaining knowledge, of finding explanations for the behaviour of the natural world. Science works through a variety of approaches to produce these explanations, but they all rely on data from observations and experiments and have a common underpinning rigour, whether using inductive or deductive reasoning. The explanation may be in the form of a theory, sometimes requiring a model that contains elements not directly observable. Producing these theories often requires an imaginative, creative leap. Where such a predictive theoretical model is not possible, the explanation may consist of identifying a correlation between a factor and an outcome. This correlation may then give rise to a causal mechanism that can e experimentally tested, leading to an improved explanation. All these explanations require an understanding of the limitations of data, and the extent and limitations of our knowledge. Science requires freedom of thought and open-mindedness, and an essential part of the process of science is the way the international scientific community subjects the findings of scientists to intense critical scrutiny through the repetition of experiments and the peer review of results in scientific journals and at conferences. The syllabus details sections in the group 4 guides give references in teacher’s notes to appropriate topics where these aspects of the scientific way of knowing can be addressed.

Group 4 and the international dimension

Science itself is an international endeavour—the exchange of information and ideas across national boundaries has been essential to the progress of science. This exchange is not a new phenomenon but it has accelerated in recent times with the development of information and communication technologies. Indeed, the idea that science is a Western invention is a myth—many of the foundations of modern-day science were laid many centuries before by Arabic, Indian and Chinese civilizations, among others. Teachers are encouraged to emphasize this contribution in their teaching of various topics, perhaps through the use of time-line web sites. The scientific method in its widest sense, with its emphasis on peer review, open-mindedness and freedom of thought, transcends politics, religion and nationality. Where appropriate within certain topics, the syllabus details sections in the group 4 guides contain assessment statements and teacher's notes illustrating the international aspects of science.

On an organizational level, many international bodies now exist to promote science. United Nations bodies such as UNESCO, UNEP and WMO, where science plays a prominent part, are well known, but in addition there are hundreds of international bodies representing every branch of science. The facilities for large-scale experimental science in, for example, particle physics and the Human Genome Project, are expensive and only joint ventures involving funding from many countries allow this to take place. The data from such research is shared by scientists worldwide. Group 4 students are encouraged to access the extensive web sites of these international scientific organizations to enhance their appreciation of the international dimension.

Increasingly, however, there is a recognition that many scientific problems, from climate change to AIDS, are international in nature and this has led to a global approach to research in many areas. The reports of the intergovernmental panel on climate change are a prime example of this. Some topics in the group 4 guides are specifically written to bring out this global research.

On a practical level, the group 4 project (which all science students must undertake) mirrors the work of real scientists by encouraging collaboration between schools across the regions.

The power of scientific knowledge to transform societies is unparalleled. It has the potential to produce great universal benefits or to reinforce inequalities and cause harm to people and the environment. In line with the IBO mission statement, group 4 students need to be aware of the moral responsibility of scientists to ensure that scientific knowledge and data are available to all countries on an equitable basis and that they have the scientific capacity to use this for developing sustainable societies.

Curriculum Model

A common curriculum model applies to all the Diploma Programme group 4 subjects: biology, chemistry, physics, design technology and astronomy SBS. (There are some differences in this model for design technology and these arise from the design project, which is a unique feature of this subject.) Students study a core syllabus, and this is supplemented by the study of options. Students study two options. There are three kinds of options: those specific to SL students, those specific to HL students and those that can be taken by both SL and HL students.

Students at SL are required to spend 40 hours on practical/investigative work. This includes 10 hours for the group 4 project.

SL group 4 curriculum model

SL	Total teaching hours	150
Theory		**110**
	Core	80
	Options	30
Practical work		**40**
	Investigations	30
	Group 4 project	10

Group 4 project 10

Format of the syllabus details

Note: The order in which the syllabus content is presented is not intended to represent the order in which it should be taught.

The format of the syllabus details section of the group 4 guides is the same for each subject. The structure is as follows.

Topics or options

Topics are numbered and options are indicated by a letter (for example, “Topic 2: The Planets”, or “Option D: Evolution”).

Sub-topics

Sub-topics are numbered and the estimated teaching time required to cover the material is indicated (for example, “2.1.2 The Nebula Theory (3 hours)”). These times are for guidance only and do not include time for practical/investigative work.

Assessment statements (AS)

Assessment statements, which are numbered, are expressed in terms of the outcomes that are expected of students at the end of the course (for example, “2.2.2 Planetary Atmospheres”). These are intended to prescribe to examiners what can be assessed by means of the written examinations. Each one is classified as objective 1, 2 or 3 (see the “Objectives” section) according to the command terms used (see the “Command terms” section). The objective levels are relevant for the examinations and for balance within the syllabus, while the command terms indicate the depth of treatment required for a given assessment statement. It is important that students are made aware of the meanings of the command terms because these will be used in examination questions. (When the command term “define” is used, the word(s) or phrase to be defined is in italics. When the command term “distinguish” is used, the terms or concepts to be distinguished are also in italics.)

Teacher’s notes

Teacher’s notes, which are included alongside some assessment statements, provide further guidance to teachers.

They may also suggest ideas for the promotion of aim 7, aim 8, TOK and the international dimension (Int).

Aims

Through studying any of the group 4 subjects, students should become aware of how scientists work and communicate with each other. While the ‘scientific method’ may take on a wide variety of forms, it is the emphasis on a practical approach through experimental work that distinguishes the group 4 subjects from other disciplines and characterizes each of the subjects within group 4.

It is in this context that all the diploma Programme experimental science courses should aim to:

1. provide opportunities for scientific study and creativity within a global context that will stimulate and challenge students
2. provide a body of knowledge, methods and techniques that characterise science and technology
3. enable students to apply and use a body of knowledge, methods and techniques that characterize science and technology
4. develop an ability to analyse, evaluate and synthesise scientific information
5. engender an awareness of the need for, and value of, effective collaboration and communication during scientific activities
6. develop experimental and investigative scientific skills
7. develop and apply the students’ information and communication technology skills in the study of science
8. raise awareness of the moral, ethical, social, economic and environmental implications of using science and technology
9. develop an appreciation of the possibilities and limitations associated with science and scientists
10. encourage an understanding of the relationships between scientific disciplines and the overarching nature of the scientific method.

Astronomy aims

The group 4 Astronomy course aims to:

1. provide opportunities for scientific study, using a body of knowledge, methods and techniques that characterize science and technology. In part this is done through the development of an ability to analyse, evaluate and synthesize scientific information
2. engender an awareness of the need for effective collaboration and communication during scientific activities. This includes an understanding of the relationships between scientific disciplines
3. develop the student’s experimental, investigative and ICT skills
4. promote understanding of the general scientific ideas used to describe the birth, life and death of stars (from mass to large mass)
5. develop understanding of how the solar system formed, how the Earth has developed and how we are presently looking for other intelligence in the universe
6. understand the basic properties of galaxies, understand their nomenclature and know how their study leads to the discovery of dark matter
7. raise awareness of the present ideas on the birth, life and death of the universe, including the importance of redshift and the cosmic background radiation

Assessment objectives

The assessment objectives for all group 4 subjects reflect those parts of the aims that will be assessed. Wherever appropriate, the assessment will draw upon environmental and technological contexts and identify the social, moral and economic effects of science.

It is the intention of all the Diploma Programme experimental science courses that students achieve the following objectives.

1. Demonstrate an understanding of:
    a. scientific facts and concepts
    b. scientific methods and techniques
    c. scientific terminology
    d. methods of presenting scientific information.
2. Apply and use:
    a. scientific facts and concepts
    b. scientific methods and techniques
    c. scientific terminology to communicate effectively
    d. appropriate methods to present scientific information.
3. Construct, analyse and evaluate:
    a. hypotheses, research questions and predictions
    b. scientific methods and techniques
    c. scientific explanations.
4. Demonstrate the personal skills of cooperation, perseverance and responsibility appropriate for effective scientific investigation and problem solving.
5. Demonstrate the manipulative skills necessary to carry out scientific investigations with precision and safety.

Astronomy assessment objectives

As group 4 assessment objectives.

Command Terms with definitions

These command terms indicate the depth of treatment required for a given assessment statement. These command terms will be used in examination questions, so it is important that students are familiar with the following definitions.

Objective 1

Define	Give the precise meaning of a word, phrase or physical quantity.
Draw	Represent by means of pencil lines.
Label	Add labels to a diagram.
List	Give a sequence of names or other brief answers with no explanation.
Measure	Find a value for a quantity.
State	Give a specific name, value or other brief answer without explanation or calculation.

Objective 2

Annotate	Add brief notes to a diagram or graph.
Apply	Use an idea, equation, principle, theory or law in a new situation.
Calculate	Find a numerical answer showing the relevant stages in the working (unless instructed not to do so).
Describe	Give a detailed account.
Distinguish	Give the differences between two or more different items.
Estimate	Find an approximate value for an unknown quantity.
Identify	Find an answer from a given number of possibilities.
Outline	Give a brief account or summary.

Objective 3

Analyse	Interpret data to reach conclusions.
Comment	Give a judgment based on a given statement or result of a calculation.
Compare	Give an account of similarities and differences between two (or more) items, referring to both (all) of them throughout.
Construct	Represent or develop in graphical form. **A**
Deduce	Reach a conclusion from the information given.

Derive	Manipulate a mathematical relationship(s) to give a new equation or relationship.
Design	Produce a plan, simulation or model.
Determine	Find the only possible answer.
Discuss	Give an account including, where possible, a range of arguments for and against the relative importance of various factors, or comparisons of alternative hypotheses.
Evaluate	Assess the implications and limitations.
Explain	Give a detailed account of causes, reasons or mechanisms.
Predict	Give an expected result.
Show	Give the steps in a calculation or derivation.
Sketch	Represent by means of a graph showing a line and labelled but unscaled axes but with important features (for example, intercept) clearly indicated.
Solve	Obtain an answer using algebraic and/or numerical methods.
Suggest	Propose a hypothesis or other possible answer.

General

Assessment is an integral part of teaching and learning. The most important aims of assessment in the Diploma Programme are that it should support curricular goals and encourage appropriate student learning. Both external and internal assessment are used in the Diploma Programme. IB examiners mark work produced for external assessment, while work produced for internal assessment is marked by teachers and externally moderated by the IB.

There are two types of assessment identified by the IB.

- Formative assessment informs both teaching and learning. It is concerned with providing accurate and helpful feedback to students and teachers on the kind of learning taking place and the nature of students' strengths and weaknesses in order to help develop students' understanding and capabilities. Formative assessment can also help to improve teaching quality, as it can provide information to monitor progress towards meeting the course aims and objectives.

- Summative assessment gives an overview of previous learning and is concerned with measuring student achievement.

The Diploma Programme primarily focuses on summative assessment designed to record student achievement at or towards the end of the course of study. However, many of the assessment instruments can also be used formatively during the course of teaching and learning, and teachers are encouraged to do this. A comprehensive assessment plan is viewed as being integral with teaching, learning and course organization. For further information, see the IB *Programme standards and practices* document.

The approach to assessment used by the IB is criterion-related, not norm-referenced. This approach to assessment judges students' work by their performance in relation to identified levels of attainment, and not in relation to the work of other students. For further information on assessment within the Diploma Programme., please refer to the publication *Diploma Programme assessment: Principles and practice*.

To support teachers in the planning, delivery and assessment of the Diploma Programme courses, a variety of resources can be found on the OCC or purchased from the IB store (http://store.ibo.org). Teacher support materials, subject reports, internal assessment guidance, grade descriptors, as well as resources from other teachers, can be found on the OCC. Specimen and past examination papers, as well as markschemes, can be purchased from the IB store.

Special assessment arrangements are provided for candidates with special assessment needs. These arrangements enable candidates with diverse needs to access the examinations and demonstrate their knowledge and understanding of the constructs being assessed. For candidates who use sign language to access the examination, translations or transcriptions would be justified for assessment.

The IB document, *Candidates with special assessment needs* provides details on all the special assessment arrangements available to candidates with special needs. The IB document, *Special educational needs within the International Baccalaureate programmes* outlines the position of the IB with regard to candidates with diverse learning needs in the IB programmes. For candidates affected by adverse circumstances, the IB documents, *General regulations: Diploma Programme* and the *Handbook of procedures* provide details on special consideration.

The IB uses several methods to assess work produced by students.

Assessment criteria

Assessment criteria are used when the assessment task is open-ended. Each criterion concentrates on a particular skill that students are expected to demonstrate. An assessment objective describes what students should be able to do, and assessment criteria describe how well they should be able to do it. Using assessment criteria allows discrimination between different answers and encourages a variety of responses. Each criterion comprises a set of hierarchically ordered level descriptors. Each level descriptor is worth one or more marks. Each criterion is applied independently using a best-fit model. The maximum marks for each criterion may differ according to the criterion's importance. The marks awarded for each criterion are added together to give the total mark for the piece of work.

Markbands

Markbands are a comprehensive statement of expected performance against which responses are judged. They represent a single holistic criterion divided into level descriptors. Each level descriptor corresponds to a range of marks to differentiate student performance. A best-fit approach is used to ascertain which particular mark to use from the possible range for each level descriptor.

Markschemes

This generic term is used to describe analytic markschemes that are prepared for specific examination papers. Analytic markschemes are prepared for those examination questions that expect a particular kind of response and/or a given final answer from the students. They give detailed instructions to examiners on how to break down the total mark for each question for different parts of the response. A markscheme may include the content expected in the responses to questions or may be a series of marking notes giving guidance on how to apply criteria.

Acknowledging the ideas or work of another person

Coordinators and teachers are reminded that candidates must acknowledge all sources used in work submitted for assessment. The following is intended as a clarification of this requirement.

Diploma Programme candidates submit work for assessment in a variety of media that may include audio/visual material, text, graphs, images and/or data published in print or electronic sources. If a candidate uses the work or ideas of another person the candidate must acknowledge the source using a standard style of referencing in a consistent manner. A candidate's failure to acknowledge a source will be investigated by the IB as a potential breach of regulations that may result in a penalty imposed by the IB final award committee.

The IB does not prescribe which style(s) of referencing or in-text citation should be used by candidates; this is left to the discretion of appropriate faculty/staff in the candidate's school. The wide range of subjects, three response languages and the diversity of referencing styles make it impractical and restrictive to insist on particular styles. In practice, certain styles may prove most commonly used, but schools are free to choose a style that is appropriate for the subject concerned and the language in which candidates' work is written. Regardless of the reference style adopted by the school for a given subject, it is expected that the minimum information given includes: name of author, date of publication, title of source, and page numbers as applicable.

Candidates are expected to use a standard style and use it consistently so that credit is given to all sources used, including sources that have been paraphrased or summarized. When writing text a candidate must clearly distinguish between their words and those of others by the use of quotation marks (or other method like indentation) followed by an appropriate citation that denotes an entry in the bibliography. If an electronic source is cited, the date of access must be indicated. Candidates are not expected to show faultless expertise in referencing, but are expected to demonstrate that all sources have been acknowledged. Candidates must be advised that audio/visual material, text, graphs, images and/or data published in print or in electronic sources that is not their own must also attribute the source. Again, an appropriate style of referencing/citation must be used.

Practical work and internal assessment

General introduction

The internal assessment (IA) requirements are the same for all group 4 subjects, with the exception of design technology, which has an additional element. The IA, worth 24% of the final assessment (or 36% for design technology), consists of an interdisciplinary project, a mixture of short- and long-term investigations (such as practicals and subject-specific projects) and, for design technology only, the design project.

Student work is internally assessed by the teacher and externally moderated by the IBO. The performance in IA is marked against assessment criteria, with each criterion having a maximum mark of 6.

Rationale for practical work

Although the requirements for IA are mainly centred on the assessment of practical skills, the different types of experimental work that a student may engage in serve other purposes, including:

- illustrating, teaching and reinforcing theoretical concepts
- developing an appreciation of the essential hands-on nature of scientific work
- developing an appreciation of the benefits and limitations of scientific methodology.

Therefore, there may be good justification for teachers to conduct further experimental work beyond that required for the IA scheme.

Practical scheme of work

The practical scheme of work (PSOW) is the practical course planned by the teacher and acts as a summary of all the investigative activities carried out by a student. Students in the same subject may carry out some of the same investigations.

Syllabus coverage

The range of investigations carried out should reflect the breadth and depth of the subject syllabus at each level, but it is not necessary to carry out an investigation for every syllabus topic. However, all students must participate in the group 4 project and the IA activities should ideally include a spread of content material from the core, options and, where relevant, AHL material. A minimum number of investigations to be carried out is not specified.

Choosing investigations

Teachers are free to formulate their own practical schemes of work by choosing investigations according to the requirements outlined. Their choices should be based on:

- subjects, levels and options taught
- the needs of their students
- available resources
- teaching styles.

Each scheme must include some complex investigations that make greater conceptual demands on students. A scheme made up entirely of simple experiments, such as ticking boxes or exercises involving filling in tables, will not provide an adequate range of experience for students.

Teachers are encouraged to use the online curriculum centre (OCC) to share ideas about possible investigations by joining in the discussion forums and adding resources in the subject home pages.

Note: Any investigation or part investigation that is to be used to assess students should be specifically designed to match the relevant assessment criteria.

Flexibility

The IA model is flexible enough to allow a wide variety of investigations to be carried out. These could include:

- short laboratory practicals over one or two lessons and long-term practicals or projects extending over several weeks
- computer simulations
- data-gathering exercises such as questionnaires, user trials and surveys
- data-analysis exercises
- general laboratory work and fieldwork.

The group 4 project

The group 4 project is an interdisciplinary activity in which all Diploma Programme science students must participate. The intention is that students from the different group 4 subjects analyse a common topic or problem. The exercise should be a collaborative experience where the emphasis is on the **processes** involved in scientific investigation rather than the **products** of such investigation.

In most cases all students in a school would be involved in the investigation of the same topic. Where there are large numbers of students, it is possible to divide them into several smaller groups containing representatives from each of the science subjects. Each group may investigate the same topic or different topics—that is, there may be several group 4 projects in the same school.

Practical work documentation

Details of an individual student's practical scheme of work are recorded on **form 4/PSOW** provided in section 4 of the Handbook of Procedures. Electronic versions may be used as long as they include all necessary information. In addition, the laboratory work corresponding to the best two marks achieved by each student when assessed using the internal assessment criteria (design, data collection and processing, and conclusion and evaluation) and the instructions given by the teacher for the laboratory work must be retained for possible inclusion in the sample work sent to an internal assessment moderator.

Time allocation for practical work

The recommended teaching times for all Diploma Programme courses are 150 hours at SL. Students at SL are required to spend 40 hours on practical activities (excluding time spent writing up work). These times include 10 hours for the group 4 project. Only 2–3 hours of investigative work can be carried out after the deadline for submitting work to the moderator and still be counted in the total number of hours for the practical scheme of work.

Note: For design technology, students at SL are required to spend 55 hours, and students at HL 81 hours, on practical activities.

Only some of the 40/60 hours of practical work need be allocated to the practical work that is assessed using the IA criteria. This will normally be done during the latter part of the course when students have become more familiar with the criteria and can be assessed in complex practical work.

Guidance and authenticity

All students should be familiar with the requirements for IA. It should be made clear to them that they are entirely responsible for their own work. It is helpful if teachers encourage students to develop a sense of responsibility for their own learning so that they accept a degree of ownership and take pride in their own work.

In responding to specific questions from students concerning investigations, teachers should (where appropriate) guide students into more productive routes of inquiry rather than respond with a direct answer. As part of the learning process, teachers can give general advice to students on a first draft of their work for IA. However, constant drafting and redrafting is not allowed and the next version handed to the teacher after the first draft must be the final one. This is marked by the teacher using the IA criteria. It is useful to annotate this work with the levels awarded for each aspect—"c" for complete, "p" for partial and "n" for not at all, to assist the moderator should the work be selected as part of the sample.

In assessing student work using the IA criteria, teachers should only mark and annotate the final draft.

When completing an investigation outside the classroom, students should work independently. Teachers are required to ensure that work submitted is the student's own. If any doubt exists, authenticity may be checked by one or more of the following methods.

• Discussion with the student

• Asking the student to explain the methods used and to summarize the results

• Asking the student to repeat the investigation

Teachers are required to sign the IA coversheet to confirm that the work of each student is his or her own unaided work.

Safety

While teachers are responsible for following national or local guidelines, which may differ from country to country, attention should be given to the mission statement below, which was developed by the International Council of Associations for Science Education (ICASE) Safety Committee.

ICASE Safety Committee

Mission statement

The mission of the ICASE Safety Committee is to promote good quality, exciting practical science, which will stimulate students and motivate their teachers, in a safe and healthy learning environment. In this way, all individuals (teachers, students, laboratory assistants, supervisors, visitors) involved in science education are entitled to work under the safest possible practicable conditions in science classrooms and laboratories. Every reasonable effort needs to be made by administrators to provide and maintain a safe and healthy learning environment and to establish and require safe methods and practices at all times. Safety rules and regulations need to be developed and enforced for the protection of those individuals carrying out their activities in science classrooms and laboratories, and experiences in the field. Alternative science activities are encouraged in the absence of sufficiently safe conditions.

It is a basic responsibility of everyone involved to make safety and health an ongoing commitment. Any advice given will acknowledge the need to respect the local context, the varying educational and cultural traditions, the financial constraints and the legal systems of differing countries.

Internal assessment criteria

General information

The method of assessment used for internal assessment is criterion-related. That is to say, the method of assessment judges each student in relation to identified assessment criteria and not in relation to the work of other students.

The internal assessment component in all group 4 courses is assessed according to sets of assessment criteria and achievement level descriptors. The internal assessment criteria are for the use of teachers.

• For each assessment criterion, there are a number of descriptors that each describes a specific level of achievement.

• The descriptors concentrate on positive achievement, although for the lower levels failure to achieve may be included in the description.

Using the internal assessment criteria

Teachers should judge the internal assessment exercise against the descriptors for each criterion. The same internal assessment criteria are used in group 4 for both SL and HL.

• The aim is to find, for each criterion, the descriptor that conveys most adequately the achievement level attained by the student. The process, therefore, is one of approximation. In the light of any one criterion, a student's work may contain features denoted by a high achievement level descriptor combined with features appropriate to a lower one. A professional judgment should be made in identifying the descriptor that approximates most closely to the work.

• Having scrutinized the work to be assessed, the descriptors for each criterion should be read, starting with level 0, until one is reached that describes an achievement level that the work being assessed does not match as well as the previous level. The work is, therefore, best described by the preceding achievement level descriptor and this level should be recorded. Only whole numbers should be used, not partial points such as fractions or decimals.

• The highest descriptors do not imply faultless performance and moderators and teachers should not hesitate to use the extremes, including zero, if they are appropriate descriptions of the work being assessed.

• Descriptors should not be considered as marks or percentages, although the descriptor levels are ultimately added together to obtain a total. It should not be assumed that there are other arithmetical relationships; for example, a level 2 performance is not necessarily twice as good as a level 1 performance.

• A student who attains a particular achievement level in relation to one criterion will not necessarily attain similar achievement levels in relation to the others. It should not be assumed that the overall assessment of the students will produce any particular distribution of scores.

• The assessment criteria should be available to students at all times.

Criteria and aspects

There are five assessment criteria that are used to assess the work of students.

• Design—D

• Data collection and processing—DCP

• Conclusion and evaluation—CE

• Manipulative skills—MS

• Personal skills—PS

The first three criteria—design (D), data collection and processing (DCP) and conclusion and evaluation (CE)—are each assessed twice.

Manipulative skills (MS) is assessed summatively over the whole course and the assessment should be based on a wide range of manipulative skills.

Personal skills (PS) is assessed once only and this will be during the group 4 project.

Each of the assessment criteria can be separated into three **aspects** as shown in the following sections. Descriptions are provided to indicate what is expected in order to meet the requirements of a given aspect **completely (c)** and **partially (p)**. A description is also given for circumstances in which the requirements are not satisfied, **not at all (n)**.

A **"complete"** is awarded 2 marks, a **"partial"** 1 mark and a **"not at all"** 0 marks.

The maximum mark for each criterion is 6 (representing three "completes").

D × 2 = 12

DCP × 2 = 12

CE × 2 = 12

MS × 1 = 6

PS × 1 = 6

This makes a total mark out of 48.

The marks for each of the criteria are added together to determine the final mark out of 48 for the IA component. This is then scaled at IBCA to give a total out of 24%.

General regulations and procedures relating to IA can be found in the Handbook of Procedures for the year in which the IA is being submitted.

Design

	Aspect 1	Aspect 2	Aspect 3
Levels/marks	Defining the problem and selecting variables	Controlling variables	Developing a method for collection of data
Complete/2	Formulates a focused problem/research question and identifies the relevant variables.	Designs a method for the effective control of the variables.	Develops a method that allows for the collection of sufficient relevant data.
Partial/1	Formulates a problem/research question that is incomplete **or** identifies only some relevant variables.	Designs a method that makes some attempt to control the variables.	Develops a method that allows for the collection of insufficient relevant data.
Not at all/0	Does not identify a problem/research	Designs a method that does not control the	Develops a method that does not allow for any

	question **and** does not identify any relevant variables.	variables.	relevant data to be collected.

Data collection and processing

	Aspect 1	Aspect 2	Aspect 3
Levels/marks	Recording raw data	Processing raw data	Presenting processed data
Complete/2	Records appropriate quantitative and associated qualitative raw data, including units and uncertainties where relevant.	Processes the quantitative raw data correctly.	Presents processed data appropriately and, where relevant, includes errors and uncertainties.
Partial/1	Records appropriate quantitative and associated qualitative raw data, but with some mistakes or omissions.	Processes quantitative raw data, but with some mistakes and/or omissions.	Presents processed data appropriately, but with some mistakes and/or omissions.
Not at all/0	Does not record any appropriate quantitative raw data **or** raw data is incomprehensible.	No processing of quantitative raw data is carried out **or** major mistakes are made in processing.	Presents processed data inappropriately **or** incomprehensibly.

Conclusion and evaluation

	Aspect 1	Aspect 2	Aspect 3
Levels/marks	Concluding	Evaluating procedure(s)	Improving the investigation
Complete/2	States a conclusion, with justification, based on a reasonable interpretation of the data.	Evaluates weaknesses and limitations.	Suggests realistic improvements in respect of identified weaknesses and limitations.
Partial/1	States a conclusion based on a reasonable interpretation of the data.	Identifies some weaknesses and limitations, but the evaluation is weak or missing.	Suggests only superficial improvements.
Not at all/0	States no conclusion **or** the conclusion is based on an unreasonable interpretation of the data.	Identifies irrelevant weaknesses and limitations.	Suggests unrealistic improvements.

Manipulative skills (assessed summatively)

This criterion addresses objective 5.

	Aspect 1	Aspect 2	Aspect 3
Levels/marks	Following instructions*	Carrying out techniques	Working safely
Complete/2	Follows instructions accurately, adapting to new circumstances (seeking assistance when required).	Competent and methodical in the use of a range of techniques and equipment.	Pays attention to safety issues.
Partial/1	Follows instructions but requires assistance.	Usually competent and methodical in the use of a range of techniques and equipment.	Usually pays attention to safety issues.
Not at all/0	Rarely follows instructions **or** requires constant supervision.	Rarely competent and methodical in the use of a range of techniques and equipment.	Rarely pays attention to safety issues.

* Instructions may be in a variety of forms; oral, written worksheets, diagrams, photographs, videos, flow charts, audio tapes, models, computer programs, and so on, and need not originate from the teacher.

See “The group 4 project” section for the personal skills criterion.

Design

Aspect 1: defining the problem and selecting variables

It is essential that teachers give an open-ended problem to investigate, where there are several independent variables from which a student could choose one that provides a suitable basis for the investigation. This should ensure that a range of plans will be formulated by students and that there is sufficient scope to identify both independent and controlled variables.

Although the general aim of the investigation may be given by the teacher, students must identify a focused problem or specific research question. Commonly, students will do this by modifying the general aim provided and indicating the variable(s) chosen for investigation.

The teacher may suggest the general research question only. Asking students to investigate some physical property of a bouncing ball, where no variables are given, would be an acceptable teacher prompt. This could be focused by the student as follows: “I will investigate the relationship between the rebound height and the drop height of a bouncing ball.”

Alternatively, the teacher may suggest the general research question and specify the dependent variable. An example of such a teacher prompt would be to ask the student to investigate the deflection of a cantilever. This could then be focused by the student as follows: “I propose to investigate how the deflection of a cantilever is affected by the load attached to one end.” It is not sufficient for the student merely to restate the research question provided by the teacher.

Variables are things that can be measured and/or controlled. Independent variables are those that are manipulated, and the result of this manipulation leads to the measurement of the dependent variable. A controlled variable is one that should be held constant so as not to obscure the effect of the independent variable on the dependent variable.

The variables need to be explicitly identified by the student as the dependent (measured), independent (manipulated) and controlled variables (constants). Relevant variables are those that can reasonably be expected to affect the outcome. For example, in the investigation of the bouncing ball, the drop height would be the independent variable and the rebound height would be the dependent variable. Controlled variables would include using the same ball and the same surface for all measurements.

Students should **not** be:

- given a focused research question
- told the outcome of the investigation
- told which independent variable to select
- told which variables to hold constant.

Aspect 2: controlling variables

“Control of variables” refers to the manipulation of the independent variable and the attempt to maintain the controlled variables at a constant value. The method should include explicit reference to how the control of variables is achieved. If the control of variables is not practically possible, some effort should be made to monitor the variable(s).

Students should **not** be told:

- which apparatus to select
- the experimental method.

Aspect 3: developing a method for collection of data

The definition of “sufficient relevant data” depends on the context. The planned investigation should anticipate the collection of sufficient data so that the aim or research question can be suitably addressed and an evaluation of the reliability of the data can be made.

The collection of sufficient relevant data usually implies repetitive measurements. For example, to find the period of a pendulum, the time for a number of oscillations is measured in order to find the time for one oscillation. Measuring the time for just one oscillation for a given pendulum length would not earn a “complete”. Or, for example, measuring the time for a ball to roll a given distance down an inclined plane can be repeated a number of times and then an average time can be determined.

The data range and the amount of data in that range are also important. For example, in the pendulum experiment, a length range of 10 cm to 100 cm might be used, but measuring the period for only three points within that range would not be appropriate. Similarly, measuring the period for 10 data points in a range from 80 cm to 90 cm would also be inappropriate.

Students should **not** be told:

- how to collect the data
- how much data to collect.

Data collection and processing

Ideally, students should work on their own when collecting data.

When data collection is carried out in groups, the actual recording and processing of data should be independently undertaken if this criterion is to be assessed.

Aspect 1: recording raw data

Raw data is the actual data measured. This may include associated qualitative data. It is permissible to convert handwritten raw data into word-processed form. The term “quantitative data” refers to numerical measurements of the variables associated with the investigation. Associated qualitative data are considered to be those observations that would enhance the interpretation of results.

Uncertainties are associated with all raw data and an attempt should always be made to quantify uncertainties. For example, when students say there is an uncertainty in a stopwatch measurement because of reaction time, they must estimate the magnitude of the uncertainty. Within tables of quantitative data, columns should be clearly annotated with a heading, units and an indication of the uncertainty of measurement. The uncertainty need not be the same as the manufacturer’s stated precision of the measuring device used. Significant digits in the data and the uncertainty in the data must be consistent. This applies to all measuring devices, for example, digital meters, stopwatches, and so on. The number of significant digits should reflect the precision of the measurement.

There should be no variation in the precision of raw data. For example, the same number of decimal places should be used. For data derived from processing raw data (for example, means), the level of precision should be consistent with that of the raw data.

Students should **not** be told how to record the raw data. For example, they should not be given a pre-formatted table with any columns, headings, units or uncertainties.

Aspect 2: processing raw data

Data processing involves, for example, combining and manipulating raw data to determine the value of a physical quantity (such as adding, subtracting, squaring, dividing), and taking the average of several measurements and transforming data into a form suitable for graphical representation. It might be that the data is already in a form suitable for graphical presentation, for example, light absorbance readings plotted against time readings. If the raw data is represented in this way and a best-fit line graph is drawn and the gradient determined, then the raw data has been processed. Plotting raw data (without a graph line) does not constitute processing data.

The recording and processing of data may be shown in one table provided they are clearly distinguishable.

Most processed data will result in the drawing of a graph showing the relationship between the independent and dependent variables.

Students should **not** be told:

- how to process the data
- what quantities to graph/plot.

Aspect 3: presenting processed data

When data is processed, the uncertainties associated with the data must also be considered. If the data is combined and manipulated to determine the value of a physical quantity (for example, specific heat capacity), then the uncertainties in the data must be propagated (see sub-topic 1.2). Calculating the percentage difference between the measured value and the literature value does not constitute error analysis. The uncertainties associated with the raw data must be taken into account.

Graphs need to have appropriate scales, labelled axes with units, and accurately plotted data points with a suitable best-fit line or curve (not a scatter graph with data-point to data-point connecting lines).

In order to fulfill aspect 3 completely, students should include a treatment of uncertainties and errors with their processed data.

The complete fulfillment of aspect 3 requires the students to:

- include uncertainty bars where significant
- explain where uncertainties are not significant
- draw lines of minimum and maximum gradients
- determine the uncertainty in the best straight-line gradient.

See the treatment of uncertainties and errors in sub-topic 1.2 of this guide.

Conclusion and evaluation

Aspect 1: concluding

Conclusions that are supported by the data are acceptable even if they appear to contradict accepted theories. However, the conclusion must take into account any systematic or random errors and uncertainties. A percentage error should be compared with the total estimated random error as derived from the propagation of uncertainties.

In justifying their conclusion, students should discuss whether systematic error or further random errors were encountered. The direction of any systematic errors should be appreciated. Analysis may include comparisons of different graphs or descriptions of trends shown in graphs. The explanation should contain observations, trends or patterns revealed by the data.

When measuring an already known and accepted value of a physical quantity, students should draw a conclusion as to their confidence in their result by comparing the experimental value with the textbook or literature value. The literature consulted should be fully referenced.

Aspect 2: evaluating procedure(s)

The design and method of the investigation must be commented upon as well as the quality of the data. The student must not only list the weaknesses but must also appreciate how significant the weaknesses are. Comments about the precision and accuracy of the measurements are relevant here. When evaluating the procedure used, the student should specifically look at the processes, use of equipment and management of time.

Aspect 3: improving the investigation

Suggestions for improvement should be based on the weaknesses and limitations identified in aspect 2. Modifications to the experimental techniques and the data range can be addressed here. The modifications should address issues of precision, accuracy and reproducibility of the results. Students should suggest how to reduce random error, remove systematic error and/or obtain greater control of variables. The modifications proposed should be realistic and clearly specified. It is not sufficient to state generally that more precise equipment should be used.

Manipulative skills

(This criterion must be assessed summatively.)

Aspect 1: following instructions

Indications of manipulative ability are the amount of assistance required in assembling equipment, the orderliness of carrying out the procedure(s) and the ability to follow the instructions accurately. The adherence to safe working practices should be apparent in all aspects of practical activities.

A wide range of complex tasks should be included in the scheme of work.

Aspect 2: carrying out techniques

It is expected that students will be exposed to a variety of different investigations during the course that enables them to experience a variety of experimental situations.

Aspect 3: working safely

The student's approach to safety during investigations in the laboratory or in the field must be assessed. Nevertheless, the teacher must not put students in situations of unacceptable risk.

The teacher should judge what is acceptable and legal under local regulations and with the facilities available. See the "Safety" section in this guide.

Personal skills

Note: The personal skills criterion is assessed in the group 4 project only and is to be found in "The group 4 project" section.

The use of ICT

In accordance with aim 7—that is, to “develop and apply the students’ information and communication technology skills in the study of science”—the use of information and communication technology (ICT) is encouraged in practical work throughout the course, whether the investigations are assessed using the IA criteria or otherwise.

Section A: use of ICT in assessment

Data-logging software may be used in experiments/investigations assessed using the IA criteria provided that the following principle is applied.

The student’s contribution to the experiment must be evident so that this alone can be assessed by the teacher. This student’s contribution can be in the selection of settings used by the data-logging and graphing equipment, or can be demonstrated in subsequent stages of the experiment.

(When data logging is used, raw data is defined as any data produced by software and extracted by the student from tables or graphs to be subsequently processed by the student.)

The following categories of experiments exemplify the application of this principle.

1. Data logging within a narrowly focused task

Data-logging software may be used to perform a traditional experiment in a new way.

Use of data-logging software is appropriate with respect to assessment if the student decides and inputs most of the relevant software settings. For example, suppose that a student wants to measure the acceleration of a trolley as it moves down an inclined plane. A sonic motion detector is used to gather data and generate graphs. This investigation can be both appropriate and inappropriate for IA marking, depending on the contributions of the student.

This investigation would be appropriate for IA if the student contributes to the setting-up of the equipment and software by the selection of parameters and the overall presentation of the data and results. For instance, the student might calibrate the sonic detector before running the experiment. The detector uses the speed of sound, and this varies depending on the classroom conditions, such as temperature. Next, the student may decide on the sampling rate and its duration time. When there is no motion, the read-out of the sonic detector exhibits some random noise. The student uses the range of this noise to estimate an uncertainty in the raw data. Knowing that the computer generates data for position, speed and acceleration as functions of time by using consecutive measurements of the reflected or echo time and the known speed of sound, the student accepts the distance and speed measured but not the acceleration measurement. The student uses the experimental data to generate a speed versus time graph, and from the gradient of this graph the average acceleration is determined. This method eliminates systematic errors from the data and yields a more reliable result. Uncertainties and significant figures are all accounted for. The student’s work is appropriate for IA marking.

Data logging in which the software automatically determines the various settings and generates the data tables and graphs is inappropriate with regard to assessment.

For example, the same experimental investigation could be carried out with little or no student input and as such would be inappropriate for IA marking. Nonetheless, it would provide the student with data-logging experience and, as such, it would be a worthwhile investigation. Here, for instance, the parameters of the software program would be pre-set, no calibration would be made, and no attention to significant figures or uncertainties would be made. After releasing the trolley and starting the data-logging software, the computer automatically generates graphs of position, speed and acceleration, all as functions of time. The student would accept this output without question.

If the experiment is suitable for assessment the following guidelines must be followed for the DCP criterion.

Data collection and processing: aspect 1

Students may present raw data collected using data logging as long as they are responsible for the majority of software settings. The numerical raw data may be presented as a table, or, where a large amount of data has been generated, by graphical means. Students must annotate the data correctly, for example, by means of table or graph titles, columns or graph axes labelled with units, indications of uncertainties, associated qualitative observations, and so on.

The number of decimal places used in recorded data should not exceed that expressed by the sensitivity of the instrument used. In the case of electronic probes used in data logging, students will be expected to record the sensitivity of the instrument.

Data collection and processing: aspects 2 and 3

Use of software for graph drawing is appropriate as long as the student is responsible for most of the decisions, such as:

- what to graph
- selection of quantities for axes
- appropriate units
- graph title
- appropriate scale
- how to graph, for example, linear graph line and not scatter.

Note: A computer-calculated gradient is acceptable.

Analysis carried out using calculators or calculations using spreadsheets are acceptable provided that the student selects the data to be processed and chooses the method of processing. In both cases, the student must show one example in the written text. For example, the student must quote the formula used by or entered into a calculator and define the terms used, or the student must write the formula used in a spreadsheet if it is not a standard part of the program's menu of functions (for example, mean, standard deviation).

2. Data logging in an open-ended investigation

Data-logging software can enhance data collection and transform the sort of investigations possible. In this case fully automated data-logging software is appropriate with regard to assessment if it is used to enable a broader, complex investigation to be undertaken where students can develop a range of responses involving independent decision-making.

For example, consider an open-ended investigation into the phenomenon of a bouncing ball. The student designed the investigation making extensive use of ICT. The student's work could be assessed for design and DCP as follows.

Design: aspect 1

The teacher prompt was to investigate a bouncing ball. The student then came up with a research question: "How does the rebound height of a bouncing ball vary with the number of bounces?"

The student identified the controlled variables as the initial drop height, the ball and the surface with which the ball collides, the independent variable as the number of bounces, and the dependent variable as the rebound height.

Design: aspect 2

To qualify for assessment of aspect 2, the student needs to describe an effective method to control the variables.

The student uses a microphone with an interface connected to a computer in order to record the sound intensity of the bouncing ball as a function of time. The software program was fully automatic and all the settings were pre-set. From the generated graph of sound intensity against time, information about the bounce number will be identified and the time interval between bounces can be calculated. Using the equations of motion, the time interval is used to find the rebound height for consecutive bounces. Other details of the method were discussed and aspect 2 was assessed here.

Design: aspect 3

The student carried out a preliminary experiment dropping the ball from different heights to identify an acceptable drop height that produces a reasonable data set. No ICT was used here. The student decided on about 20 bounces and a drop height of 15 cm.

The student repeated the experiment twice, producing three sets of data, to assess reliability.

Data collection and processing: aspect 1

The first graph produced was intensity against time. This was not assessed under the IA criteria because the software automatically generated it. The student then used the time and the bounce number from this graph to produce a data table containing the time that each consecutive bounce occurred and the bounce number. This data table included the units, significant figures, uncertainties and repeats. This was assessed under DCP aspect 1.

Data collection and processing: aspect 2

The student then produced a third column in the data table where the time interval between consecutive bounces was calculated and the rebound height of each bounce was calculated (using half the interval time). The results included uncertainties. This was assessed as processed data.

Data collection and processing: aspect 3

The student inputs information from the previous graph into graphing software to construct a plot of rebound height against bounce number, including uncertainty bars constructed by the student for one of the axes. This graph appeared to reveal an exponential decay, and so the student constructed another graph, this time using logarithms. Uncertainty bars were drawn and maximum and minimum gradients were drawn. The gradient of the best-fit line was identified as the decay constant and a half-life was calculated. The maximum and minimum gradients were then used to express an uncertainty for the decay constant. The result showed exponential decay for the bouncing ball when compared to bounce number. The last two graphs were assessed under DCP aspect 3.

Section B: use of ICT in non-assessed practical work

It is not necessary to use ICT in assessed investigations but, in order to carry out aim 7 in practice, students will be required to use each of the following software applications at least once during the course.

- Data logging in an experiment
- Software for graph plotting
- A spreadsheet for data processing
- A database
- Computer modelling/simulation

There are many examples of the above in the ICT resources for biology, chemistry and physics on the OCC.

Apart from sensors for data logging, all the other components involve software that is free and readily available on the Internet. As students only need to use data-logging software and sensors once in the course, class sets are not required.

The use of each of the above five elements of the use of ICT by students would be authenticated by means of entries in the students' practical scheme of work, form 4/PSOW. For example, if a student used a spreadsheet in an investigation, this should be recorded on form 4/PSOW. Any other applications of ICT can also be recorded on form 4/PSOW.

The group 4 project

Summary of the group 4 project

The group 4 project is a collaborative activity where students from different group 4 subjects work together on a scientific or technological topic, allowing for concepts and perceptions from across the disciplines to be shared in line with aim 10—that is, to "encourage an understanding of the relationships between scientific disciplines and the overarching nature of the scientific method". The project can be practically or theoretically based. Collaboration between schools in different regions is encouraged.

The group 4 project allows students to appreciate the environmental, social and ethical implications of science and technology. It may also allow them to understand the limitations of scientific study, for example, the shortage of appropriate data and/or the lack of resources. The emphasis is on interdisciplinary cooperation and the processes involved in scientific investigation, rather than the products of such investigation.

The choice of scientific or technological topic is open but the project should clearly address aims 7, 8 and 10 of the group 4 subject guides.

Ideally, the project should involve students collaborating with those from other group 4 subjects at all stages. To this end, it is not necessary for the topic chosen to have clearly identifiable separate subject components. However, for logistical reasons some schools may prefer a separate subject "action" phase (see the following "Project stages" section).

Project stages

The 10 hours allocated to the group 4 project, which are part of the teaching time set aside for IA, can be divided into three stages: planning, action and evaluation.

Planning

This stage is crucial to the whole exercise and should last about two hours.

- The planning stage could consist of a single session, or two or three shorter ones.
- This stage must involve all group 4 students meeting to "brainstorm" and discuss the central topic, sharing ideas and information.
- The topic can be chosen by the students themselves or selected by the teachers.
- Where large numbers of students are involved, it may be advisable to have more than one mixed subject group.

After selecting a topic or issue, the activities to be carried out must be clearly defined before moving from the planning stage to the action and evaluation stages.

A possible strategy is that students define specific tasks for themselves, either individually or as members of groups, and investigate various aspects of the chosen topic. At this stage, if the project is to be experimentally based, apparatus should be specified so that there is no delay in carrying out the action stage. Contact with other schools, if a joint venture has been agreed, is an important consideration at this time.

Action

This stage should last around six hours and may be carried out over one or two weeks in normal scheduled class time. Alternatively, a whole day could be set aside if, for example, the project involves fieldwork.

- Students should investigate the topic in mixed subject groups or single subject groups.

- There should be collaboration during the action stage; findings of investigations should be shared with other students within the mixed/single subject group. During this stage, in any practically based activity, it is important to pay attention to safety, ethical and environmental considerations.

Note: Students studying two group 4 subjects are not required to do two separate action phases.

Evaluation

The emphasis during this stage, for which two hours is probably necessary, is on students sharing their findings, both successes and failures, with other students. How this is achieved can be decided by the teachers, the students or jointly.

- One solution is to devote a morning, afternoon or evening to a symposium where all the students, as individuals or as groups, give brief presentations.
- Alternatively, the presentation could be more informal and take the form of a science fair where students circulate around displays summarizing the activities of each group.

The symposium or science fair could also be attended by parents, members of the school board and the press. This would be especially pertinent if some issue of local importance has been researched. Some of the findings might influence the way the school interacts with its environment or local community.

Addressing aims 7 and 8

Aim 7—“develop and apply the students’ information and communication technology skills in the study of science”.

Aim 7 may be partly addressed at the planning stage by using electronic communication within and between schools. It may be that ICT (for example, data logging, spreadsheets, databases, and so on) will be used in the action phase and certainly in the presentation/evaluation stage (for example, use of digital images, presentation software, web sites, digital video, and so on).

Aim 8—“raise awareness of the moral, ethical, social, economic and environmental implications of using science and technology”.

The choice of topic should enable one or more elements of aim 8 to be incorporated into the project.

Addressing internationalism

There are also possibilities in the choice of topic to illustrate the international nature of the scientific endeavour and the increasing cooperation required to tackle global issues involving science and technology. An alternative way to bring an international dimension to the project is to collaborate with a school in another region.

Types of project

While addressing aims 7, 8 and 10 the project must be based on science or its applications.

The project may have a hands-on practical action phase or one involving purely theoretical aspects. It could be undertaken in a wide range of ways.

- Designing and carrying out a laboratory investigation or fieldwork.
- Carrying out a comparative study (experimental or otherwise) in collaboration with another school.
- Collating, manipulating and analysing data from other sources, such as scientific journals, environmental organizations, science and technology industries and government reports.
- Designing and using a model or simulation.

- Contributing to a long-term project organized by the school.

Logistical strategies

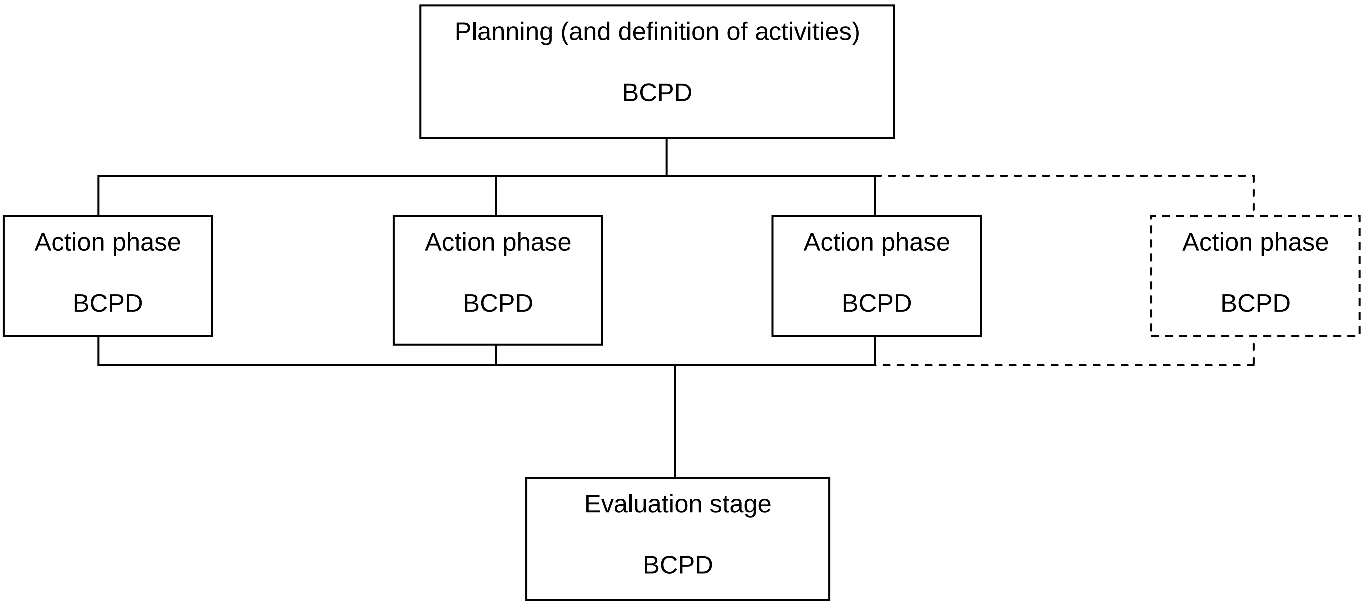
The logistical organization of the group 4 project is often a challenge to schools. The following models illustrate possible ways in which the project may be implemented.

Models A, B and C apply within a single school, and model D relates to a project involving collaboration between schools.

Model A: mixed subject groups and one topic

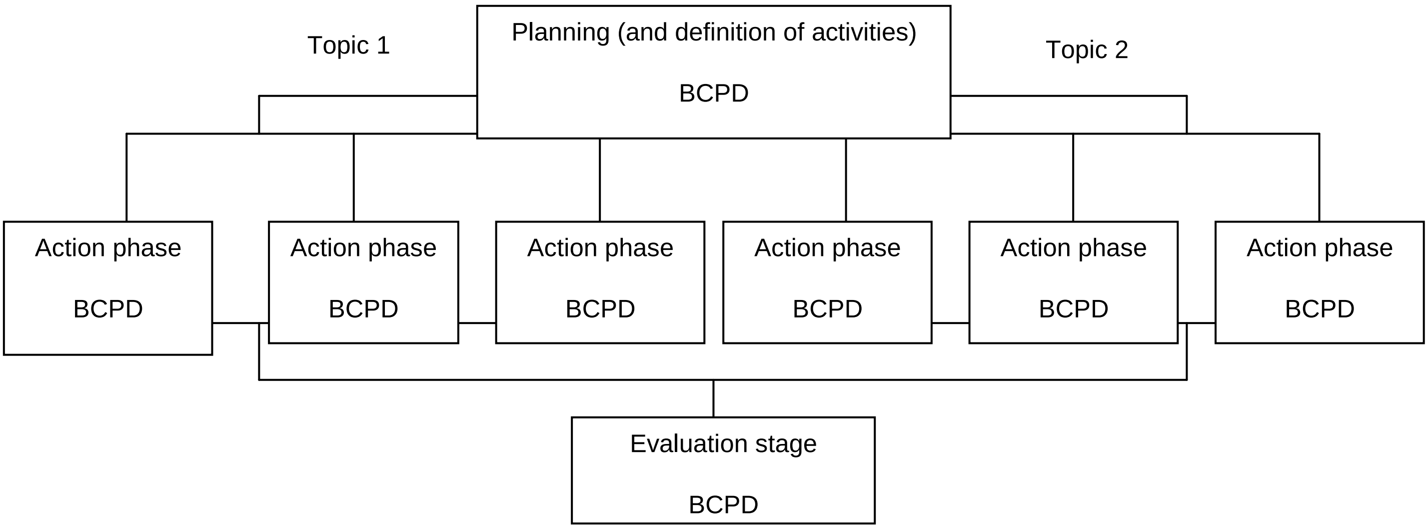
Schools may adopt mixed subject groups and choose one common topic. The number of groups will depend on the number of students. The dotted lines in the model show the addition of more groups as student numbers increase.

B—biology C—chemistry P—physics D—design technology



Model B: mixed subject groups adopting more than one topic

Schools with large numbers of students may choose to do more than one topic.



Model C: single subject groups

For schools opting for single subject groups with one or more topics in the action phase, simply replace the mixed subject groups in model A or B with single subject groups.

Model D: collaboration with another school

The collaborative model is open to any school. To this end, the IBO will provide an electronic collaboration board on the OCC where schools can post their project ideas and invite collaboration from another school. This could range from merely sharing evaluations for a common topic to a full-scale collaborative venture at all stages.

For schools with few diploma students or schools with certificate students, it is possible to work with non-Diploma Programme or non-group 4 students or undertake the project once every two years. However, these schools are encouraged to collaborate with another school. This strategy is also recommended for individual students who may not have participated in the project, for example through illness or because they have transferred to a new school where the project has already taken place.

Timing

The 10 hours that the IBO recommends be allocated to the project may be spread over a number of weeks. The distribution of these hours needs to be taken into account when selecting the optimum time to carry out the project. However, it is possible for a group to dedicate a period of time exclusively to project work if all/most other school work is suspended.

Year 1

In the first year, students' experience and skills may be limited and it would be inadvisable to start the project too soon in the course. However, doing the project in the final part of the first year may have the advantage of reducing pressure on students later on. This strategy provides time for solving unexpected problems.

Year 1-year 2

The planning stage could start, the topic could be decided upon, and provisional discussion in individual subjects could take place at the end of the first year. Students could then use the vacation time to think about how they are going to tackle the project and would be ready to start work early in the second year.

Year 2

Delaying the start of the project until some point in the second year, particularly if left too late, increases pressure on students in many ways: the schedule for finishing the work is much tighter than for the other options; the illness of any student or unexpected problems will present extra difficulties. Nevertheless, this choice does mean students know one another and their teachers by this time, have probably become accustomed to working in a team and will be more experienced in the relevant fields than in the first year.

Selecting a topic

Students may choose the topic or propose possible topics, with the teacher then deciding which one is the most viable based on resources, staff availability, and so on. Alternatively, the teacher selects the topic or proposes several topics from which students make a choice.

Student selection

Students are likely to display more enthusiasm and feel a greater sense of ownership for a topic that they have chosen themselves. A possible strategy for student selection of a topic, which also includes part of the planning stage, is outlined here. At this point, subject teachers may provide advice on the viability of proposed topics.

- Identify possible topics by using a questionnaire or a survey of students.
- Conduct an initial "brainstorming" session of potential topics or issues.
- Discuss, briefly, two or three topics that seem interesting.
- Select one topic by consensus.
- Students make a list of potential investigations that could be carried out. All students then discuss issues such as possible overlap and collaborative investigations.

Assessment

The group 4 project is to be assessed for the personal skills criterion only and this will be the only place where this criterion is assessed. It is up to the school how this assessment takes place.

Note: The group 4 project is not to be used for the assessment of the other criteria.

Personal skills (for group 4 project assessment only)

This criterion addresses objective 4.

	Aspect 1	Aspect 2	Aspect 3
Levels/marks	**Self-motivation and perseverance**	**Working within a team**	**Self-reflection**
Complete/2	Approaches the project with self-motivation and follows it through to completion.	Collaborates and communicates in a group situation and integrates the views of others.	Shows a thorough awareness of their own strengths and weaknesses and gives thoughtful consideration to their learning experience.
Partial/1	Completes the project but sometimes lacks self-motivation.	Exchanges some views but requires guidance to collaborate with others.	Shows limited awareness of their own strengths and weaknesses and gives some consideration to their learning experience.
Not at all/0	Lacks perseverance and motivation.	Makes little or no attempt to collaborate in a group situation.	Shows no awareness of their own strengths and weaknesses and gives no consideration to their learning experience.

The assessment can be assisted by the use of a student self-evaluation form, but the use of such a form is not a requirement.

Astronomy

Nature of the subject

Astronomy is arguably a unique branch of the sciences in being an area of study that many non-scientists consider as their hobby. In this sense, it is a discipline that is open to all. Further, the astronomers' playground (i.e., the sky at night) belongs to everyone and everyone can make discoveries – and there are so many to be made!

The subject's popularity is a result of many combining factors:

- Romance – Astronomy is the stuff of legend. In times past, when religion and superstition were intimately linked to heavenly phenomena, the unexpected was often greeted with grave concern. By observing the motions and properties of objects in the sky, it was possible to understand more about the universe.

- Wonder - Astronomy has been a breeding ground for many science fiction films and programs such as Star Trek and Star Wars. This has resulted in amazing images of star filled panoramas, prominences of the Sun and supernova explosions being brought into everyone's living room.

- The search for the ultimate truth - Everyone can look up into the night sky and *dream*. Are there other planets like ours? Is there life out there? Astronomy promises to explain how we got here and where the universe is going – questions which touch every human on the planet.

The above are just three of the reasons why Astronomy is considered as a *glamour science*. Beyond this, it is a rich and fertile area for scientific research and human endeavour, bringing together areas as diverse as Physics, Biology, Chemistry, Mathematics, Geography, Earth Science, History, Economics and Religion.

Given the interest in this subject, it is surprising that there are so few courses in this area – in stark contrast to the huge number of groups that exist in society. If these reasons were not enough to justify such a course, then simply the sheer amount of science in Astronomy should be. Astronomy pulls together the very limits of our understanding of the world we live in, from the experimental observations of Tycho Brae, through Newton's law of Gravitation, Einstein's theories of relativity and Quantum Mechanics. Astronomy has been the driving force and the universe the natural laboratory for many of the greatest advances in science.

Prior learning

Students undertaking the standard level Astronomy course are expected to:

- know that 'light' is an electromagnetic wave
- know the electromagnetic spectrum
- be familiar with the electromagnetic spectrum from Radio to gamma. Know which end is the high frequency, wavelength and energy
- know the magnetic field shape and direction for a bar magnet, a current-carrying straight wire and a current-carrying solenoid
- white light is a collection of colours (ROYGBIV)
- be aware that all waves show reflection, refraction and diffraction
- be aware of the periodic table of elements – and familiar with the first 10
- know the main three mechanisms for energy transfer are conduction, convection and radiation
- know that radiation is the method used to transfer energy from the Sun to the Earth through space
- know the equations for the volume and area of a circle
- be aware of angles measured in radians and degree.

Syllabus overview

Syllabus component	Teaching hours
Topic 1: The Stars 1. The Sun 2. Measuring stars 3. The Birth, Life and death of stars	28
Topic 2: The Planets 1. The Origin of the Planets 2. Life on Earth 3. The Search for Extra-Terrestrial Life	28
Topic 3: Galaxies 1. The Milky Way 2. Measuring Galaxies 3. Active galaxies	26
Topic 4: Cosmology 1. The Birth, Life and death of the Universe 2. Large Scale Structures in the Universe 3. The Shape of Spacetime	28
Internal assessment	40
Total teaching hours	**150**

Astronomy is available at standard level (SL) and should be taught over 150 hours. It is essential that teachers are allowed the prescribed minimum number of teaching hours necessary to meet the requirements of the Astronomy course.

Syllabus outline

The course has four topics with each one broken into 3 sub-sections.

Topic 1: The Stars

1.1 The Sun

This sub-section begins by looking at our star – the Sun. This is used as an introduction to explain the basic ideas needed to understand stars. It considers the basic structure of the Sun (core, photosphere, radative zone, convection zone) and its atmosphere (i.e., the chromosphere and the corona). It considers the theoretical ideas behind a self-consistent temperature and density profile and how this allows us to explain observations such as limb darkening, granulation, the radiative and convective zones and the size of the core.

The section finishes with a discussion of the nuclear fusion processes within the core – why they occur and how they occur, what determines the rate of fusion and how we can measure this from the Earth.

1.2 Measuring stars

This sub-section considers how we measure temperature, luminosity, size, mass and distance to stars. In order to keep the emphasis away from too much Mathematics, only one method will be explored in detail with others only stated for completeness.

1.3 The birth, life and death of stars

This forms the bulk of the topic. It considers the collapse of a nebula using the Jeans criteria. The development of this into the protostar and main sequence star is followed, using the HR diagram to map it. Finally, the death of stars is considered with a discussion on the different end of a stars life depending on its stellar mass (e.g., white dwarf, neutron star, black hole). The course also discusses the upper and lower mass limits for stars and the different fusion processes that occur in the core. In this final part, emphasis is given to the continuing chemical/isotope development of the universe through planetary nebula and supernova remnants

Topic 2: The Planets

1.4 The origin of the planets

The course discusses the different theories used to explain the creation of the solar system and focuses in detail on the nebula theory. The importance of the Sun's T-Tauri phase and the basic characteristics of the solar system are considered – this allows a number of links to be made with the material from Topic 1 ('The Stars'). The origin of the Moon is briefly discussed.

1.5 Life on earth

This sub-section considers the different ideas associated with how life began on the Earth. It continues with a discussion of the atmospheres of the terrestrial planets (largely ignoring Mercury) and considers how the presence of life has changed the atmosphere of the Earth.

1.6 The search for extra-terrestrial life

This sub-section finishes with a consideration of the present methods used to locate extra solar system planets and the signs we might use to both identify other environments where life could exist and how we would detect it.

Topic 3: Galaxies

1.7 The Milky Way

Like the first sub-section on Topic 1 (‘The Stars’), this starts by using our galaxy as a basis on which to develop the ideas used to describe galaxies in general and to get over some of the terminology. The nuclear bulge, disc and halo are discussed and links to Topic 1 (‘The Stars’) are made where possible to enable the student to see the connections between the structure and form of the galaxy and the birth of stars. The importance of mechanisms responsible for the spiral arms are considered and the oscillatory motion of the Sun around the disc is used to form links with Topic 2 (‘The Planets’).

1.8 Measuring galaxies

The system used to describe and label galaxies is given along with a description of the basic properties of the galaxies (e.g., angular momentum, gas content, stellar types) and how they differ. Methods for measuring the size and distance to galaxies are discussed with emphasis given to the development of the ‘galactic ladder’.

The sub-section finishes with a discussion of the rotation curves for different galaxies and how this leads to the identification of Dark Matter. The main options for this are considered.

1.9 Active galaxies

Active galaxies are discussed. What they are, how they are identified and their importance to our ideas about the beginnings of the universe are considered. The sub-section concludes with a discussion on how the properties of active galaxies are linked to the structure within the nuclear bulge of the Milky Way.

Topic 4: Cosmology

1.10 The birth, life and death of the universe

Our observations of the universe are discussed with a primary focus on ‘redshift’ and the ‘Microwave Background’. The importance of these two pieces of evidence in leading to the Big Bang model of the universe is discussed. Olbers' paradox is discussed. The sub-section will consider how theories of gravitation have developed over the centuries and the link this has to the separation of a unified force into the present four as a natural consequence of the developing universe.

1.11 Large scale structures in the universe

This brief sub-section considers the very large scale structure of the universe i.e., how the galaxies are distributed with the creation of the great wall, etc.

1.12 The fundamental shape of Spacetime

The fundamental shape of Spacetime. The course concludes with a discussion of Spacetime and how the density of the universe determines its fundamental shape. The changes that the different forms of Spacetime have on the properties of the universe are considered along with a discussion of how they produce different ultimate fates.

Syllabus details

Each of the sub-sections is detailed below with an indication of the number of teaching hours and the group 4 disciplines they involve.

Topic 1: The Stars

1.1The Sun

	Topic	Details	Est time (hrs)	Ass't Obj
1.1.1	The Sun – Our Star	• Understand the differences between the Sun and the planets. • Know the historical development of the layout of the solar system (planets, asteroids comets and Oort cloud) and that gravity holds it together with the Sun at the centre due to its huge mass. • Be aware of the positions of the Earth, Moon and Sun for solar and lunar eclipses. • Kepler's Laws. • Know Newton's law of gravitation and how it applies to the solar system and planets with satellites (see sub-section 4.3.1). This includes knowing how Newton's law of gravitation can be used to derive Kepler's 3rd Law. • Know the form of the law of gravitation and how to apply it to calculate: - Orbital period, $T^2 = \left(\frac{4\pi^2}{GM}\right) r^3$ - Gravitational field strength, $g = \frac{GM}{r^2}$ - Kinetic energy, $KE = \frac{GMm}{2r}$ - Orbital speed, $v = \sqrt{\frac{GM}{r}}$ • Understand that gravity produces a centripetal force on the Earth, keeping it in orbit around the Sun. • Understand the mass-distribution curve for the solar system.	3	1, 3
1.1.2	The Photospher e.	• Understand that the Sun's output covers a wide range of the electromagnetic spectrum. • Understand the term 'luminosity' and how the Sun's output approximates to a black body output. • Understand and explain 'limb darkening'. • Understand what sunspots tell us about the activity of the Sun, that they indicate an 11/22 year cycle and that they come in pairs. Know that sunspot activity indicates the differential rotation of the photosphere.	3	1, 2

		• Know that the Sun's surface shows granulation.		
1.1.3	The Sun's Atmosphere.	• Know that the chromosphere and corona may be defined by the temperature profile of the Sun's atmosphere. • Know why observing the chromosphere or corona is normally done using some eclipse method eg. using a coronagraph. • Understand that the atmosphere can be viewed using restricted wavelength images (egg., $H_\propto$ views). • Know the terms : plages, filaments, prominences.	3	1, 2
1.1.4	The Sun.	• Know the general layout of the Sun's interior. This should include in particular, composition, temperature and energy transport mechanisms. • Appreciate in a general sense, how composition, temperature profile and transport mechanism rely on each other to produce self-consistent equations (no knowledge of these equations is needed). • Understand electrostatic repulsion between like charges and how this requires a high temperature in order to allow fusion to occur. • Appreciate the role of fusion in supporting the star, defining the size of the stellar core and changing the overall composition of the star. • Understand a simplified ppI reaction and forms of energy it releases (e.g., gamma radiation and neutrinos). • Understand how the gamma radiation travels from the stellar core to the Earth. This includes the random walk through the Sun (requiring local thermodynamic equilibrium), the production of 'black-body' output and the relatively fast travel to the Earth through space. • Know about the evidence for the solar interior based on neutrino detection and solar oscillations.	3	1, 2, 3

1.2Measuring stars

	Topic	Details	Est time (hrs)	Ass't Obj
1.2.1	The Constellations.	• Be aware that stars have historically been set out in constellations. • Be able to give brief details of at least one grouping of stars (names, types, etc). • Understand the use of a Planisphere to find: - The rising and setting time for an appropriate star (not examinable). - How to locate a given star throughout the year (not examinable). • Be aware that light pollution seriously compromises observational astronomy and may often represent a significant waste of energy.	2	1, 2

1.2.2	Measuring the Properties of Stars.	• Understand that the stars are not fixed in space – they move with a transverse and radial velocity. • **Distance.** Understand how to measure the distance to a star using trigonometric parallax. Also understand the 'light year' and 'parsec'. • **Size.** Understand how to measure the size of a star using their angular diameter. • **Surface Temperature.** Understand how to measure the surface temperature using Wien's displacement law. • Be aware of the Harvard Spectral Classification, know where the Sun lies. • **Luminosity.** Understand how to measure the luminosity of a star based on a measurement of flux density.	3	1, 2
1.2.3	Stefan's Law.	• Know that Stefan's law links a stars luminosity, radius and temperature.	2	2
1.2.4	The Hertzsprung-Russell Diagram.	• Know that the Hertzsprung-Russell diagram is a convenient way of organising the stars and viewing their evolution.	2	2

1.3The Birth, Life and Death of Stars

	Topic	Details	Est time (hrs)	Ass't Obj
1.3.1	The Birth of Stars.	• Understand how stars are formed from a nebula. • Appreciate the Jeans criterion for the collapse of a nebula into a star. • Be aware of cloud fragmentation leading to star clusters. • Understand the physics behind the collapse of a gas cloud into a star: - Gravity to start the collapse. - Gravitational potential energy reducing. - Conservation of total energy leading to an increase in kinetic energy. - Rising kinetic energy relating to a rise in temperature. - The rising nebula density producing reduced radiation loss from the nebula. - The greater temperature finally producing a plasma. - The greater kinetic energy resulting in fusion (against the electrostatic repulsion). • Know how the condensing nebula produces a protostar and how this is seen on the Hertzsprung-Russell diagram (Hayashi tracks).	2	1, 2

		• Know about the instability strip for a protostar and be able to describe how this affects the luminosity. • Know about the T-Tauri phase.		
1.3.2	The Life of Stars.	• Understand main sequence stars. • Understand that main sequence stars are defined by the fusion occurring in their cores. • Appreciate that the rate of fusion in the core strongly depends on the temperature of the core (equation are not needed). • Know that the main sequence lifetime is reduced for larger stars. • Be aware of ppI and CNO fusion and know where they apply. • Understand why there is a lower limit and upper limit for star size: - Lower limit due to a requirement to *trigger* fusion. - Upper limit due to increased stellar wind. • Know about brown dwarfs. • Be aware that the larger a star, the shorter the lifetime and the smaller their abundance.	2	1, 2
1.3.3	The Death of Stars.	• Be aware of the three main ways a star will end its life. • Be aware of degeneracy pressure and that it may support a star. • Know that small stars end their life as a white dwarf with the ejection of a planetary nebula. • Know that medium sized stars end their life as a neutron star with the ejection of a supernova remnant. • Know that massive stars end their life as a black hole with the ejection of a supernova remnant. • Be aware that the stellar core shrinks when hydrogen burning stops. • Be aware that the outside of the star expands when the hydrogen burning stops. • Be aware of the $3_{\propto}$ process and why it occurs rather than helium burning to produce beryllium. • Be aware that secondary fusion reactions occur with greater temperatures up to the creation of iron. • Know that electron degeneracy pressure supports a white dwarf and neutron degeneracy pressure supports a neutron star. • Know that via the r-processes, elements greater than iron are produced in a supernova explosion. • Understand the terms: white dwarf, neutron star, black hole, planetary nebula, supernova remnant, red giant, supergiant, pulsar. • Be aware of the general form of the path the star takes	3	1, 2

		on a Hertzsprung-Russell diagram when it dies. • Understand the concept of escape velocity and how it applies to a black hole. • Appreciate the importance of the solar abundances and the implication that the Sun is not a first generation star. Also appreciate the fact that the elements of life on earth must also have been created in a previous supernova explosion.		

Topic 2: The Planets

1.4The Origin of the Planets

	Topic	Details	Est time (hrs)	Ass't Obj
2.1.1	Models for Planetary Creation.	• Be aware of the different models considered to explain the origin of the planets: - Nebular Theories. - Accretion Theories. - Tidal Theories. - Turbulence Theories. • Know that an origin theory needs to explain the following: - Planetary orbits are close to the plane of the Earth's orbit. - Planetary orbits are largely circular. - All planets rotate in the same sense around the Sun. - Only 2% of the solar system's angular momentum is contained in the Sun (Jupiter $\approx$ 65%).	2	3
2.1.2	The Nebular Theory.	• Understand the specifics of the solar nebula model. • Know the differences between the minimum and maximum models. • Understand that condensation and coagulation lead to the creation of the planetesimals, through to planetary embryos, runaway growth and finally the planets themselves. • Understand the significance of the Sun's T-Tauri phase for the composition of the planets. • Appreciate how planetary growth was affected by the distance from the Sun. • Appreciate the significance of the gravitational and electric forces in creating the planets. • Understand the origin of the Asteroids based on the	3	1, 2

		gravitational influence of Jupiter. • Be aware of the Oort Cloud. • Be able to describe the origin of the Moon due to a giant impact.		
2.1.3	Planetary Differentiation.	• Understand planetary differentiation. • Know that homogeneous and heterogeneous accretion depend on the planet's growth rate compared with the nebulas cooling rate. • Understand the different forms of heating with a planet: - Accretional heating - Radiogenic heating - Core formation heating - Tidal heating • Know that differentiation requires enough heat and material mobility. • Know how differentiation is probably needed in order to create the Earth's magnetic field.	2	1, 2
2.1.4	Planetary Study.	• Study in detail one terrestrial planet (ignoring Mercury) and one gas giant. In particular be aware of: - Internal structure. - Differentiated or not. - Details of satellites. - Volcanic activity – active or not and why. - Details of magnetic field configuration – type and possible origin.	5	1, 2

1.5Life on Earth

	Topic	Details	Est time (hrs)	Ass't Obj
2.2.1	Evidence for Differentiation.	• Understand at least two forms of evidence that the Earth is a differentiated planet (eg. magnetism and average density).	1	2
2.2.2	Planetary Atmospheres.	• Know that the original atmospheres of the terrestrial planets were hydrogen and helium. • Know that the T-Tauri phase removed the original planet's atmosphere. • Know the three major constituents of the atmospheres of Venus, Earth and Mars. • Know how the atmospheres of Venus, Earth and Mars have developed to produce the situation today.	3	1, 2, 3

		• Appreciate the differences that have produced Earth's life-supporting atmosphere. • Know the importance of the 'escape velocity' for a planet in discussing which gases can be held in the atmosphere and which cannot. • Be aware of the general effect of solar radiation on a planet's weather. This includes the generation of Hadley cells within the atmospheric structure, comparing Venus, Earth and Jupiter.		
2.2.3	Global Warming.	• Understand how the effects of global warming could compromise life on Earth. • Understand the greenhouse effect. • Know how CFCs contribute to the greenhouse effect. • Appreciate the upper and lower temperatures for life: - Lower: not enough energy for reactions. - Higher : denaturing proteins	2	1, 2
2.2.4	Asteroid Impacts.	• Understand the significance of asteroids and asteroid impact impacts to the production of life on Earth. • Be aware of the evidence for impactors based on the surface of the Moon. • Be aware of the evidence for impacts on Earth: - Meteor Crater - Tunguska - Africa • Be aware of the fact that there are a significant number of impacts that occur on the Earth each year. • Be aware that it is thought that life on Earth has been compromised a number of times in the past.	2	1, 2

1.6The Search for Extra-Terrestrial Life

	Topic	Details	Est time (hrs)	Asst Obj
2.3.1	SETI.	• Be aware of the Fermi paradox. • Be aware of at least two initiatives carried out since the late 1950s to further the search for extra-terrestrial life. Examples include 'Suitcase SETI', 'Project Sentinel', 'Project META', 'The internet SETI project', 'Project Phoenix'. • Be aware of the significance of radio astronomy in the search for life and in particular, radio frequencies between 18 and 21 cm. • Be aware of how the discovery of the Pulsar was thought to have been a possible signal from extra-terrestrials.	4	

2.3.2	Probing the solar system.	• Know the details of at least one probe within the solar system which was designed to looked for life (eg. pathfinder mission, mars explorer, Spirit and Odyssey). • Know and understand that the major candidates for life within the solar system outside Earth, are presently thought to be Mars and Europa.	3	
2.3.3	The Drake equation.	• Be aware of the Drake equation for life probability. • $N = R_{*} \,.\, f_p \,.\, n_e \,.\, f_l \,.\, f_i \,.\, f_c \,.\, L$ • Know what each part refers to and that the assessed values change as our knowledge increases.	1	

Topic 3: Galaxies

3.1 The Milky Way

	Topic	Details	Est time (hrs)	Asst Obj
3.1.1	The Milky Way – Our Galaxy.	• Know that the Milky Way is our galaxy. • Know the basic size and structure of the Milky Way, including the disc, halo and nuclear bulge. • Know where the Sun lies in the Milky Way, how it oscillates about the disc. • Know that the Sun's oscillations may produce a disturbance of the Oort cloud and this may then produce comet motion through the solar system.	2	1
3.1.2	Constituents of the Milky Way.	• Know the constituents of the Milky Way. • Stars: - Population I and II stars. - Metallicity. - Age. - Orbits. • Gas. - 75% hydrogen and 25% helium - the form depends on temperature. - Around $10^{10} M_{\odot}$. • Dust. - $0.1 - 1 \mu m$ particles. - Around $10^{8} M_{\odot}$. - Restricts our ability to make optical measurements in the disc.	1	1, 2

		• Cosmic rays. - 85% protons, 12% helium, 2% electrons and 1% heavy nuclei. • Magnetic field. - Mainly aligned with the disc. • Electromagnetic radiation. • Neutrinos.		
3.1.3	The Rotation Curve.	• Be aware of the rotation curve for the Milky Way. • Know how the *mass distribution* curve and the *rotation curve* are linked. • Know the mass distribution curves for - a galaxy with a central mass - a uniform density. • Know the rotation curves for - a galaxy with a central mass - a uniform density. • Know the rotation curve for the Milky Way, what it tells us about the edge of the galaxy and how it provides evidence for dark matter.	4	2, 3
3.1.4	Dark Matter.	• Understand the significance of dark matter as the majority of the galaxy's mass.	2	2, 3
3.1.5	Spiral Arms.	• Know that the spiral arms are centres of light output not stellar density. • Understand the *winding dilemma*.	2	1, 2
3.1.6	The Halo.	• Know that the halo contains globular clusters.	1	1, 2
3.1.7	The Nuclear Bulge.	• Know that the bulge largely consists of population II stars and stars seem to have random movements. • Know that it is thought that there is a giant black hole at the centre of the galaxy surrounded by a ring of molecular clouds.	2	1, 2

3.2 Measuring Galaxies

	Topic	Details	Est time (hrs)	Asst Obj
3.2.1	The Hubble Classification of Galaxies.	• Know the Hubble classification for naming galaxies, using the 'tuning fork' diagram. • Ellipticals. - Elliptical outline. - Featureless appearance.	2	1

		- Flattening factor. • Lenticulars - Lens shaped. - Disc and bulge but no spiral arms. - May be barred. • Spirals - Disc, bulge and spiral arms. - May be barred. • Irregular galaxies.		
3.2.2	Density Fluctuations.	• Know that galaxies are thought to have formed as a result of density fluctuations in the expanding cosmic gas produced by the big bang. • Know of ellipticals, lenticulars, spirals and irregular galaxies.	1	1
3.2.3	The Galactic Ladder.	• Be aware of the galactic ladder and know two methods from it plus Hubble's law. Suggestions are: - Trigonometric parallax: using angle measurement and trigonometry. - Cepheid variables: Period-luminosity relationship. - Tully Fisher (spirals): Luminosity $\propto$ (rotational speed)$^4_{max}$ - Type Ia Supernovae: Maximum luminosity if a constant. • Know that Hubble's constant can be used to estimate the age of the universe.	2	2

3.3 Active Galaxies

	Topic	Details	Est time (hrs)	Asst Obj
3.3.1	Galactic Spectra.	• Know that active galaxies have a spectral peculiarity. • Know that there is a very high energy output from an Active Galactic Nucleus.	1	1
3.3.2	Types of Active Galaxy.	• Seyfert galaxies. - Far-infrared excess. - AGN has at least four times the luminosity of the rest of the galaxy. • Quasars.	3	1, 2

		- Significant redshifts. - High luminosity. • Radio galaxies. - Dominate the sky's radio emissions. • BL Lacertae objects. - No spectral lines because there is no surrounding gas.		
3.3.3	The AGN.	• Be aware of the typical schematic of an AGN with a surrounding dust cloud, producing two radio lobes.	3	1, 2

Topic 4: Cosmology

3.4 The Birth, Life and Death of the Universe

	Topic	Details	Est time (hrs)	Asst Obj
4.1.1	The Expanding Universe	• Understand the cosmological redshift. • Understand Hubble's law and how it can predict the age of the universe. • Know that cosmological theories embody the *cosmological principle*. • Know how redshift data indicates the universe is expanding and how this leads to the idea of the big bang.	4	1, 2
4.1.2	Olbers' Paradox.	• Understand Olber's paradox, what it implies and how it is explained. - Know about the cosmological redshift.	2	1, 2, 3
4.1.3	Evidential support for the Big Bang.	• Hubble's law. • Cosmic microwave background radiation.	4	1, 2, 3
4.1.4	Nuclear Abundance.	• Be aware of the elements considered to have been created in the big bang (H to Li). • Be aware of how the elemental abundance is changing over time through the birth, life and death of stars (linking to Topic 1) and the importance of these heavier elements to the creation of life (linking Topic 2).	2	1

3.5 Large Scale Structures in the Universe

	Topic	Details	Est time (hrs)	Asst Obj
4.2.1	Galactic	• Know that galaxies are concentrated in clusters, held with	2	2

	Distribution.	gravity. • Know that the *local group* consists of about 30 galaxies. - Be aware of the nearest galaxy to the Milky Way (small magellanic cloud). • Know that clusters are concentrated into superclusters. • Know that large *walls* of galaxies exist with one called the *Great Wall*.		
4.2.2	Galactic Arrangement.	• The galactic arrangement in the universe.	1	2
4.2.3	The Giant Wall.		1	2

3.6 The Shape of Spacetime

	Topic	Details	Est time (hrs)	Asst Obj
4.3.1	The Development of a Theory of Gravity.	• The ancient Greeks. • Galileo Galilei and falling objects. • Isaac Newton and the universal Law of gravitation. • Albert Einstein and General Relativity.	4	1, 2, 3
4.3.2	General Relativity.	• Know that the effect of gravity is equivalent to the acceleration of an object. • Know that relativistic ideas about time and space can be reconciled by describing these things together as four-dimensional *spacetime.*	3	1, 2, 3
4.3.3	Spacetime.	• Know that there are three possible geometries for spacetime. - Flat (flat plane). • Straight lines extend to infinity. • Parallel straight lines do not intersect. • Internal angles of a triangle add up to 180°. • Circumference of a circle = $2\pi r$. - Spherical (sphere). • Straight lines come back to the same point. • Parallel straight lines do intersect (eg. at the poles). • Internal angles of a triangle > 180°. • Circumference of a circle < $2\pi r$.	3	1, 2

		- Hyperbolic (saddle shaped). • Straight lines continue to infinity. • Parallel lines diverge. • Internal angles of a triangle < 180°. • Circumference of a circle > 2πr.		
4.3.4	The Inflationary Model.	• Know that the Big Bang theory of cosmology raises questions. • Know that a phase of rapid expansion known as inflation is thought to have occurred.	2	1, 2

Assessment outline

First examinations 2008

The assessment of the Astronomy course has two parts – internal and external. The details of this are shown below and broadly based on the assessment used for present SL group 4 subjects.

Assessment component	Weighting
External assessment (2 hours 15 minutes)	**76%**
Paper 1 (45 minutes) ONE short answer Exam Paper (30 marks)	**26%**
Paper 2 (90 minutes) ONE Short Answer Exam Paper: Section A : 4 Short answer (40 Marks) Section B : Data Response (1 Q from 2) (20 Marks)	**50%**
Internal assessment (40 hours) This component is internally assessed by the teacher and externally moderated by the IB at the end of the course. **Practical work (40 hours)** Assessment of the 5 strands (D, DCP, CE, MS, PS) for a range of experiments – each assessed a minimum of two times.	**24%**

External assessment

External examiners will use one method to assess students.

For paper 1, there are markschemes.

For paper 2, there are markschemes.

The markschemes are related to the assessment objectives established for the Astronomy course and the group 4 grade descriptors. The markschemes are specific to each examination.

External assessment details

The external assessment consists of two written papers.

Paper 1

Duration: 45 minutes

Weighting: 26%

Paper 1 is 30 marks from short answer, single-part questions which test knowledge of the full syllabus. It is expected that the questions will broadly cover the four Topics from the course evenly.

The questions are designed to be short, one- or two-stage problems that address group 4 assessment objectives 1 and 2 (page 14).

No marks are deducted for incorrect responses.

Calculators are permitted.

Paper 2

Duration: 90 minutes

Weighting: 50%

Paper 2 is a short answer exam with questions usually containing a number of parts, generally following from each other. An element of both compulsory questions and some choice given, testing knowledge of the full syllabus. The questions address G4 assessment objectives 1, 2 and 3 (page 14) and the paper is divided into two sections.

Section A will have four questions – one per topic – each question will have 10 marks associated with it.

Section B will have two questions with the student having to choose one. There will be some element of 'data response' associated with each question. It is assumed that one question will be generally based on Topics 1, 3 and 4 and one will be based on Topic 2. Each question will be worth 20 marks.

Internal Assessment

The internal assessment (IA) is 24% of the total assessment of the SL Astronomy course. This weighting should be reflected in the time that is allocated to teaching the knowledge, skills and understanding required to undertake the work, as well as the total time allocated to undertake the work.

It is recommended that a total of approximately 40 hours should be allocated to the IA. This should include:

- time for the teacher to explain to students the requirements of the internal assessment
- class time for students to work on the internal assessment component
- time for consultation between the teacher and each student
- time to review and monitor progress, and to check authenticity.

Using assessment criteria for internal assessment

Follow group 4 guidelines (pages 23-40).

Internal assessment details

Duration: 40 hours (including 10–15 hours on G4 project)

Weighting: 24%

The IA is based on the standard IA for Group 4 subjects i.e., pieces of work are taken from the students Practical Scheme of Work (PSOW) and marked under the eight standard categories. These are to be assessed a minimum of twice over the two years and the two best marks are taken forward by the student.

Possible Practical scheme of work

The following is a suggestion of some possible experiments that could form part of a PSOW for SL Astronomy. It is given purely as an indication that the requirements for a group 4 PSOW are relatively easy to meet and comply with the group 4 assessment objectives 4 and 5.

Experiment details	Hours
An eclipse method for measuring the distance to the Moon	3.0
Using a Bunsen photometer to measure the luminosity of the Sun	1.5
Measuring the difference between sidereal and mean solar time	3.0
Centripetal Forces	2.0
Emission spectra for hydrogen, helium, neon, mercury, etc	1.0
Analysis of emissions for the element mercury	2.0
Sunspot viewing	2.0
Photographing the Sun’s photosphere	1.5

Using a Planisphere	1.0
Assessing limiting visual stellar magnitudes	1.0
Refraction to produce a visible spectrum	0.5
Diffraction to produce a visible spectrum	0.5
Diffraction to measure wavelength	0.5
Build a spectrometer	3.0
Phases of the Moon	3.0
Study of a constellation (*e.g.,* Orion)	1.0
Transfer of energy via conduction	1.0
Transfer of energy via convection	1.0
Transfer of energy via radiation	1.0
Convection rates *vs* temperature	2.5
Mapping out magnetic field patterns with a compass needle	0.5
Looking at the magnetic field lines of a straight wire and a solenoid	0.5
Radiation emission *vs* temperature	2.5
Radiation output using a * cube	1.5
The lens formula	1.0
Magnification of a lens system	1.0
The Doppler effect	1.0
Group 4 Project	10-15

Resource materials and bibliography

All documentation for the course was written by Dr John Chilton (Oakham School). The following resources are recommended as support materials:

- Planisphere
- Universe (7^{th} Edition), Freedman and Kaufmann, W H Freeman, ISBN: 0-71676-995-6
- The Sun and Stars, Green and Jones, The Open University, ISBN : 0-7492-56680
- Planetary Landscapes (2^{nd} Edition), Greeley, Chapman and Hall, ISBN : 0-412-05181-8
- Astronomy – The Evolving Universe (7^{th} edition), Zeilik, Wiley, ISBN : 0-471-59739-2
- Space – Our Final Frontier, Gribbin, BBC, ISBN : 0-563-53713-2