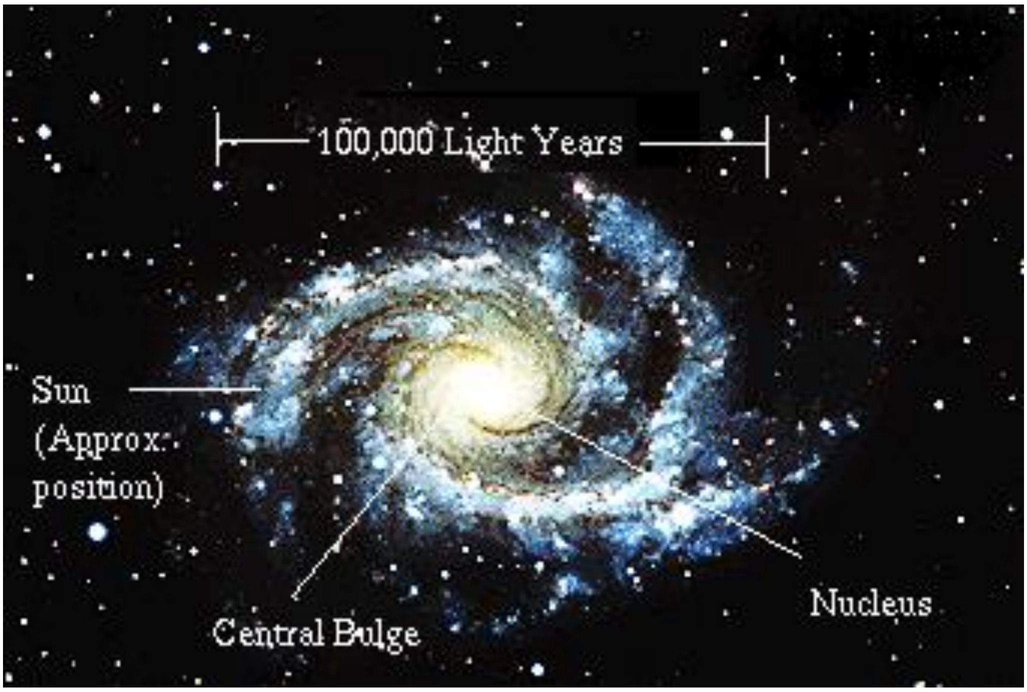
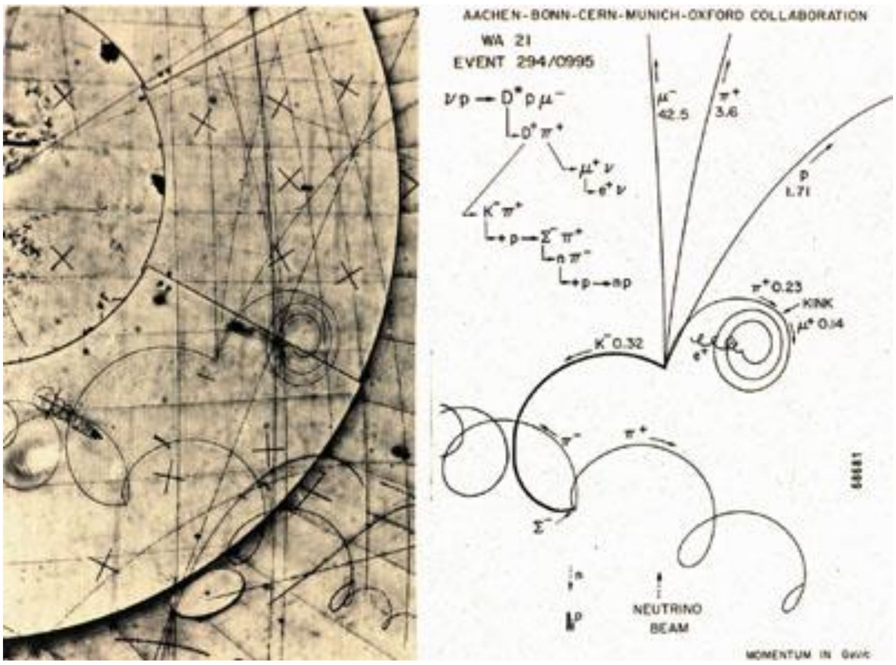


ANATOLIA COLLEGE IBDP PROGRAM

PHYSICS SUBJECT GUIDE (FIRST EXAM 2016)



Last revised June 2018

Table of Contents

1. Nature of the subject

Physics is the most fundamental of the experimental sciences, as it seeks to explain the universe itself from the very smallest particles—currently accepted as quarks, which may be truly fundamental—to the vast distances between galaxies.

Classical physics, built upon the great pillars of Newtonian mechanics, electromagnetism and thermodynamics, went a long way in deepening our understanding of the universe. From Newtonian mechanics came the idea of predictability in which the universe is deterministic and knowable. This led to Laplace's boast that by knowing the initial conditions—the position and velocity of every particle in the universe—he could, in principle, predict the future with absolute certainty. Maxwell's theory of electromagnetism described the behavior of electric charge and unified light and electricity, while thermodynamics described the relation between energy transferred due to temperature difference and work and described how all-natural processes increase disorder in the universe.

However, experimental discoveries dating from the end of the 19th century eventually led to the demise of the classical picture of the universe as being knowable and predictable. Newtonian mechanics failed when applied to the atom and has been superseded by quantum mechanics and general relativity. Maxwell's theory could not explain the interaction of radiation with matter and was replaced by quantum electrodynamics (QED). More recently, developments in chaos theory, in which it is now realized that small changes in the initial conditions of a system can lead to completely unpredictable outcomes, have led to a fundamental rethinking in thermodynamics.

While chaos theory shows that Laplace's boast is hollow, quantum mechanics and QED show that the initial conditions that Laplace required are impossible to establish. Nothing is certain and everything is decided by probability. But there is still much that is unknown and there will undoubtedly be further paradigm shifts as our understanding deepens.

Despite the exciting and extraordinary development of ideas throughout the history of physics, certain aspects have remained unchanged. Observations remain essential to the very core of physics, sometimes requiring a leap of imagination to decide what to look for. Models are developed to try to understand observations, and these themselves can become theories that attempt to explain the observations. Theories are not always directly derived from observations but often need to be created. These acts of creation can be compared to those in great art, literature and music, but differ in one aspect that is unique to science: the predictions of these theories or ideas must be tested by careful experimentation. Without these tests, a theory cannot be quantified. A general or concise statement about how nature behaves, if found to be experimentally valid over a wide range of observed phenomena, is called a law or a principle.

The scientific processes carried out by the most eminent scientists in the past are the same ones followed by working physicists today and, crucially, are also accessible to students in schools. Early in the development of science, physicists were both theoreticians and experimenters (natural philosophers). The body of scientific knowledge has grown in size and complexity, and the tools and skills of theoretical and experimental physicists have become so specialized that it is difficult (if not impossible) to be highly proficient in both areas. While students should be aware of this, they should also know that the free and rapid interplay of theoretical ideas and experimental results in the public scientific literature maintains the crucial links between these fields.

At the school level both theory and experiments should be undertaken by all students. They should complement one another naturally, as they do in the wider scientific community. The Diploma Programme physics course allows students to develop traditional practical skills and techniques and increase their abilities in the use of mathematics, which is the language of physics. It also allows students to develop interpersonal and digital communication skills which are essential in modern scientific endeavour and are important life-enhancing, transferable skills in their own right.

Alongside the growth in our understanding of the natural world, perhaps the more obvious and relevant result of physics to most of our students is our ability to change the world. This is the technological side of physics, in which physical principles have been applied to construct and alter the material world to suit our needs, and have had a profound influence on the daily lives of all human beings. This raises the issue of the impact of physics on society, the moral and ethical dilemmas, and the social, economic and environmental implications of the work of physicists. These concerns have become more prominent as our power over the environment has grown, particularly among young people, for whom the importance of the responsibility of physicists for their own actions is self-evident.

Physics is therefore, above all, a human activity, and students need to be aware of the context in which physicists work. Illuminating its historical development places the knowledge and the process of physics in a context of dynamic change, in contrast to the static context in which physics has sometimes been presented. This can give students insights into the human side of physics: the individuals; their personalities, times and social milieux; their challenges, disappointments and triumphs.

The Diploma Programme physics course includes the essential principles of the subject but also, through selection of an option, allows teachers some flexibility to tailor the course to meet the needs of their students. The course is available at both SL and HL, and therefore accommodates students who wish to study physics as their major subject in higher education and those who do not.

International mindedness

As already said, physics has been recognized as the most fundamental of the experimental sciences. This statement already implies that it targets the most fundamental questions which have been raised by humans in all the ages. The questions cover topics that span at every scale imaginable: from the birth and evolution of the universe, our common home, to the behavior of particles in the sub-atomic level. Being the center of a shared objective inside every mind across the globe and throughout history, it has consequently evolved through the contributions by a wide variety of scientists from different cultural backgrounds and nations. Besides, since Galileo claimed that "the universe is written in the language of mathematics", physics uses this language that is commonly understood and "spoken" worldwide. In other words, physicists have the ambition to describe the same phenomenon in a common way everywhere, every time.

All of the above emphasize that Physics is by definition promoting the notion of international mindedness to everyone involved in the process. It can even be said that thinking and working on an international level lies within the foundations of this science – it cannot happen otherwise. It is our duty to remember and effectively communicate this, so that students can simultaneously work locally, on the specific, but never lose the connection to the global, the common.

Teaching approach

There are a variety of approaches to the teaching of physics. By its very nature, physics lends itself to an experimental approach, and it is expected that this will be reflected throughout the course. The order in which the syllabus is arranged is **not** the order in which it should be taught, and it is up to individual teachers to decide on an arrangement that suits their circumstances. Sections of the option material may be taught within the core or the additional higher level (AHL) material if desired, or the option material can be taught as a separate unit.

Science 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 ago 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 timeline websites. The scientific method in its widest sense, with its emphasis on peer review, open-mindedness and freedom of thought, transcends politics, religion, gender and nationality. Where appropriate within certain topics, the syllabus details sections in the group 4 guides contain links 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 research 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 teachers and students are encouraged to access the extensive websites and databases of these international scientific organizations to enhance their appreciation of the international dimension.

Increasingly there is a recognition that many scientific problems 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. 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 IB 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.

Students' attention should be drawn to sections of the syllabus with links to international-mindedness. Examples of issues relating to international-mindedness are given within sub-topics in the syllabus content. Teachers could also use resources found on the Global Engage website (http://globalengage. ibo.org).

Distinction between SL and HL

Group 4 students at standard level (SL) and higher level (HL) undertake a common core syllabus, a common internal assessment (IA) scheme and have some overlapping elements in the option studied. They are presented with a syllabus that encourages the development of certain skills, attributes and attitudes, as described in the "Assessment objectives" section of the guide.

While the skills and activities of group 4 science subjects are common to students at both SL and HL, students at HL are required to study some topics in greater depth, in the additional higher level (AHL) material and in the common options. The distinction between SL and HL is one of breadth and depth.

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 learning, characterized by the IB learner profile attributes, will be significant here.

However, for most students considering the study of a group 4 subject at HL, while there is no intention to restrict access to group 4 subjects, some previous exposure to formal science education would be necessary. Specific topic details are not specified but students who have undertaken the IB Middle Years Programme (MYP) or studied an equivalent national science qualification or a school-based science course would be well prepared for an HL subject.

Links to the Middle Years Programme

Students who have undertaken the MYP science, design and mathematics courses will be well prepared for group 4 subjects. The alignment between MYP science and Diploma Programme group 4 courses allows for a smooth transition for students between programmes. The concurrent planning of the new group 4 courses and MYP: Next Chapter (both launched in 2014) has helped develop a closer alignment.

Scientific inquiry is central to teaching and learning science in the MYP. It enables students to develop a way of thinking and a set of skills and processes that, while allowing them to acquire and use knowledge, equip them with the capabilities to tackle, with confidence, the internal assessment component of group 4 subjects. The vision of MYP sciences is to contribute to the development of students as 21st-century learners. A holistic sciences programme allows students to develop and utilize a mixture of cognitive abilities, social skills, personal motivation, conceptual knowledge and problem-solving competencies within an inquiry- based learning environment (Rhoton 2010). Inquiry aims to support students' understanding by providing them with opportunities to independently and collaboratively investigate relevant issues through both research and experimentation. This forms a firm base of scientific understanding with deep conceptual roots for students entering group 4 courses.

In the MYP, teachers make decisions about student achievement using their professional judgment, guided by criteria that are public, precise and known in advance, ensuring that assessment is transparent. The IB describes this approach as "criterion-related"—a philosophy of assessment that is neither "norm-referenced" (where students must be compared to each other and to an expected distribution of achievement) nor "criterion-referenced" (where students must master all strands of specific criteria at lower achievement levels before they can be considered to have achieved the next level). It is important to emphasize that the single most important aim of MYP assessment (consistent with the PYP and DP) is to support curricular goals and encourage appropriate student learning. Assessments are based upon evaluating course aims and objectives and, therefore, effective teaching to the course requirements also ensures effective teaching for formal assessment requirements. Students need to understand what the assessment expectations, standards and practices are and these should all be introduced early and naturally in teaching, as well as in class and homework activities. Experience with criterion-related assessment greatly assists students entering group 4 courses with understanding internal assessment requirements.

MYP science is a concept-driven curriculum, aimed at helping the learner construct meaning through improved critical thinking and the transfer of knowledge. At the top level are key concepts which are broad, organizing, powerful ideas that have relevance within the science course but also transcend it, having relevance in other subject groups. These key concepts facilitate both disciplinary and interdisciplinary learning as well as making connections with other subjects. While the key concepts provide breadth, the related concepts in MYP science add depth to the programme. The related concept can be considered to be the big idea of the unit which brings focus and depth and leads students towards the conceptual understanding.

Across the MYP there are 16 key concepts with the three highlighted below the focus for MYP science.

The key concepts across the MYP curriculum			
Aesthetics	**Change**	Communication	Communities
Connections	Creativity	Culture	Development
Form	Global interactions	Identity	Logic
Perspective	**Relationships**	**Systems**	Time, place and space

MYP students may in addition undertake an optional onscreen concept-based assessment as further preparation for Diploma Programme science courses.

Science and theory of knowledge

The theory of knowledge (TOK) course (first assessment 2015) engages students in reflection on the nature of knowledge and on how we know what we claim to know. The course identifies eight ways of knowing: reason, emotion, language, sense perception, intuition, imagination, faith and memory. Students explore these means of producing knowledge within the context of various areas of knowledge: the natural sciences, the social sciences, the arts, ethics, history, mathematics, religious knowledge systems and indigenous knowledge systems. The course also requires students to make comparisons between the different areas of knowledge, reflecting on how knowledge is arrived at in the various disciplines, what the disciplines have in common, and the differences between them.

TOK lessons can support students in their study of science, just as the study of science can support students in their TOK course. TOK provides a space for students to engage in stimulating wider discussions about questions such as what it means for a discipline to be a science, or whether there should be ethical constraints on the pursuit of scientific knowledge. It also provides an opportunity for students to reflect on the methodologies of science, and how these compare to the methodologies of other areas of knowledge. It is now widely accepted that there is no one scientific method, in the strict Popperian sense. Instead, the sciences utilize a variety of approaches in order to produce explanations for the behaviour of the natural world. The different scientific disciplines share a common focus on utilizing inductive and deductive reasoning, on the importance of evidence, and so on. Students are encouraged to compare and contrast these methods with the methods found in, for example, the arts or in history.

In this way there are rich opportunities for students to make links between their science and TOK courses. One way in which science teachers can help students to make these links to TOK is by drawing students' attention to knowledge questions that arise from their subject content. Knowledge questions are open- ended questions about knowledge such as:

- How do we distinguish science from pseudoscience?
- When performing experiments, what is the relationship between a scientist's expectation and their perception?
- How does scientific knowledge progress?
- What is the role of imagination and intuition in the sciences?
- What are the similarities and differences in methods in the natural sciences and the human sciences? Examples of relevant knowledge questions are provided throughout this guide within the sub-topics in the syllabus content. Teachers can also find suggestions of interesting knowledge questions for discussion in the "Areas of knowledge" and "Knowledge frameworks" sections of the TOK guide. Students should be encouraged to raise and discuss such knowledge questions in both their science and TOK classes.

2. Aims and assessment objectives

Through studying physics, 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 characterizes these subjects.

The aims enable students, through the overarching theme of the Nature of science, to:

- appreciate scientific study and creativity within a global context through stimulating and challenging opportunities

- acquire a body of knowledge, methods and techniques that characterize science and technology
- apply and use a body of knowledge, methods and techniques that characterize science and technology
- develop an ability to analyse, evaluate and synthesize scientific information
- develop a critical awareness of the need for, and the value of, effective collaboration and communication during scientific activities
- develop experimental and investigative scientific skills including the use of current technologies
- develop and apply 21st-century communication skills in the study of science
- become critically aware, as global citizens, of the ethical implications of using science and technology
- develop an appreciation of the possibilities and limitations of science and technology
- develop an understanding of the relationships between scientific disciplines and their influence on other areas of knowledge.

The assessment objectives for physics reflect those parts of the aims that will be formally assessed either internally or externally. These assessments will centre upon the nature of science. It is the intention of these courses that students are able to fulfill the following assessment objectives:

- Demonstrate knowledge and understanding of:
  - facts, concepts and terminology
  - methodologies and techniques
  - communicating scientific information.
- Apply:
  - facts, concepts and terminology
  - methodologies and techniques

methods of communicating scientific information.

- Formulate, analyse and evaluate:

  hypotheses, research questions and predictions

  methodologies and techniques

  primary and secondary data

  scientific explanations.

- Demonstrate the appropriate research, experimental, and personal skills necessary to carry out insightful and ethical investigations.

3. Subject outline

The content covers classical and modern physics...... (JUST THE SUBJECT AREAS)

Core

- Measurements and uncertainties
- Mechanics
- Thermal physics
- Waves
- Electricity and magnetism
- Circular motion and gravitation
- Atomic, nuclear and particle physics
- Energy production

Additional higher level (AHL)

- Wave phenomena
- Fields
- Electromagnetic induction
- Quantum and nuclear physics

Option

- Astrophysics

Skills to be developed

- thinking skills,
- social skills,
- communication skills,

- self- management skills,
- research skills,
- problem-solving skills

Real life context of material taught (incorporating relevant experiences for students)

During the course, practical work will be undertaken by the students. This will involve:

- Practical investigations in the laboratory. Measurements will be carried out using traditional laboratory equipment as well as sensors connected to computers. The investigations will usually lead to a typewritten laboratory report that includes graphs created by graphing computer software.
- Demonstration experiments.
- Processing of published experimental data using a worksheet software application.
- Computer simulations of physical phenomena.
- An interdisciplinary project work called the Group 4 project. The Group 4 project starts at the end of the IB1 year (April – May of the first year) and finishes with the presentations at the beginning of the IB2 year (September – October of the second year). During an initial brainstorming session, a certain general topic will be chosen by a simple majority vote. In the following weeks, students will split into groups, in order to design an investigation in an area directly related with the general topic, collect, analyze and process data and finally present their results in the form of a poster.

Teaching Methods

1. Lecture by teacher
2. Class discussion conducted by teacher
3. Discussion groups conducted by students
4. Experiment demonstration by teacher
5. Textbook assignments
6. Reading assignments in supplementary books
7. Laboratory Investigations
8. Individual projects
9. Student Poster Sessions
10. Computer simulations

11. Short videos
12. In brainstorming small group, students identify a list of techniques and strategies that best fit their class
13. Peer Evaluation

4. Prior learning

4.1 Physics Background

Prior exposure to a middle-school (e.g. Gymnasio or Lykeio) Physics course or to a General Science course is desirable, but not a prerequisite.

4.2 Mathematics requirements

Physics is a subject closely related to mathematics. Students taking Physics are advised to take Standard Level Mathematics or Higher Level Mathematics. Depending on their overall competency in mathematics, students taking Mathematical Studies SL may experience difficulties in applying certain areas of mathematics for the Physics course (e.g. logarithms or exponential functions such as e^x for Higher Level students).

5. PHYSICS and the IB Learner Profile

Besides the Physics taught during the course, the two-year study teaching plan aims to promote the students' IB learner profile in the following ways:

- Inquirer: through designing investigations and using established physical theories to explore unknown physical phenomena.
- Thinker: through learning to evaluate hypotheses, research questions and methods both in the students' own work and in the work of others.
- Communicator: through collaborating with peers in the Group-4 project and using the appropriate scientific language both in written work and class discussions.
- Principled: through acquiring scientific integrity in handling their own and other people's data and ideas as well as through promoting the school ethics.
- Reflective: through evaluating their own practical and written work and discussing their ideas in class.
- Caring: through understanding the implications of human activities and scientific achievements on environment and society and through helping classmates in peer to peer tutoring groups.

- Risk-taker: in designing investigations.

6. Physics and Core Components

All Diploma Programme students participate in the three course elements that make up the core of the model. Theory of knowledge (TOK) is a course that is fundamentally about critical thinking and inquiry into the process of knowing rather than about learning a specific body of knowledge. The TOK course examines the nature of knowledge and how we know what we claim to know. It does this by encouraging students to analyse knowledge claims and explore questions about the construction of knowledge. The task of TOK is to emphasize connections between areas of shared knowledge and link them to personal knowledge in such a way that an individual becomes more aware of his or her own perspectives and how they might differ from others.

Creativity, action, service (CAS) is at the heart of the Diploma Programme. The emphasis in CAS is on helping students to develop their own identities, in accordance with the ethical principles embodied in the IB mission statement and the IB learner profile. It involves students in a range of activities alongside their academic studies throughout the Diploma Programme. The three strands of CAS are Creativity (arts, and other experiences that involve creative thinking), Action (physical exertion contributing to a healthy lifestyle) and Service (an unpaid and voluntary exchange that has a learning benefit for the student). Possibly more than any other component in the Diploma Programme, CAS contributes to the IB’s mission to create a better and more peaceful world through intercultural understanding and respect.

The extended essay, including the world studies extended essay, offers the opportunity for IB students to investigate a topic of special interest, in the form of a 4,000-word piece of independent research. The area of research undertaken is chosen from one of the students’ Diploma Programme subjects, or in the case of the interdisciplinary world studies essay, two subjects, and acquaints them with the independent research and writing skills expected at university. This leads to a major piece of formally presented, structured writing, in which ideas and findings are communicated in a reasoned and coherent manner, appropriate to the subject or subjects chosen. It is intended to promote high-level research and writing skills, intellectual discovery and creativity. As an authentic learning experience it provides students with an opportunity to engage in personal research on a topic of choice, under the guidance of a supervisor.

7. Course structure and planning

Planning of the course

During Year 1, the following chapters will be covered:

Core

- Measurements and uncertainties
- Mechanics
- Circular
- Thermal physics
- Waves

Additional higher level (AHL)

- Wave phenomena

Option

- Astrophysics (about ½ of the option)

Year 1 material is designed so as to provide the foundations in classical physics and to allow Standard Level Students into a front-loaded program

During Year 2, the following chapters will be covered:

Core

- Electricity and magnetism
- Gravitation
- Atomic, nuclear and particle physics
- Energy production

Additional higher level (AHL)

- Fields
- Electromagnetic induction

- Quantum and nuclear physics

Option

- Astrophysics

The Nature of Science

Through the Nature of Science references, that are spread throughout the Physics syllabus, students explore the history of science, the ethics of science and the role of technology in shaping our community. The international aspect and the resulting diversification of the scientific community are explored through discussions that raise relevant world issues such as Power Production and Global Warming.

Assessment Components

The assessment by the IBO is divided into two components, Internal Assessment and External Assessment

1. INTERNAL ASSESSMENT

The course will involve practical work during the two years, with the most important piece being the Investigation. The Investigation is a practical project leading to a report that will be marked towards 20% of the final grade issued by the IBO. The criteria for assessment of the Investigation include:

a) Personal engagement
b) Exploration
c) Analysis
d) Evaluation
e) Communication

As part of the internal assessment process of science subjects, all students will participate in an interdisciplinary project called the Group 4 project. During an initial brainstorming session, a general topic will be chosen. In the following weeks, students will split into groups, in order to complete an investigation related with the topic and finally present their results on a poster.

2. EXTERNAL ASSESSMENT

The final assessment (at the end of the two-year program) involves 3 written papers:

1) **Paper 1**: For the **Standard Level** students: 30 multiple-choice questions to be answered in 45 minutes. For the **Higher Level** students: 40 multiple-choice questions to be answered in 60 minutes.
2) **Paper 2**: Several short-answer and extended-response questions in 1 hour and 15 minutes (for Standard Level students), or in 2 hours and 15 minutes (for Higher Level students)
3) **Paper 3**: One data-based question, several short-answer questions on experimental work, short-answer questions and extended-response questions from one option in a total of 60 minutes (for Standard Level students) or I hour and 15 minutes (for Higher Level students).

Expected workload

Students are expected to study consistently during all of the Physics course. All the available class time is used, so that the last revision test is sat towards the end of Year 2. A typical workload following a double period class would include review of the newly covered material, study of worked problems in the textbook and working of homework problems. A typical past examinations questions pack before a revision test would consists of several pages that include multiple-choice, short response and extended-response questions. A typical laboratory report assignment would allow students about 10 days to prepare and deliver it.

8. Assessment

In school regular assessment practices

In class, students will be assessed for their participation and work delivery, as well as for their performance in short quizzes and long revision tests.

Formal IBO assessment

The formal IBO assessment consists of the External Assessment (accounting for 80% of the final grade) and of the Internal Assessment (accounting for 20% of the final grade). Further details are provided in Chapter 7.

The Final IB Diploma Grade

The Final IBDP Grade is derived by adding the grade obtained in each of the 6 subjects that a student has selected. Furthermore, the combination of the grade achieved in the Extended Essay and of the grade achieved in the Theory of Knowledge, can lead to a minimum of 0 and a maximum of 3 extra points to be added in the Final IBDP grade.

Subject group grade descriptors

For the Sciences (Group 4 Subjects) there exist specific grade descriptors:

Grade 7

Displays comprehensive knowledge of factual information in the syllabus and a thorough command of concepts and principles. Selects and applies relevant information, concepts and principles in a wide variety of contexts. Analyses and evaluates quantitative and/or qualitative data thoroughly. Constructs detailed explanations of complex phenomena and makes appropriate predictions. Solves most quantitative and/or qualitative problems proficiently. Communicates logically and concisely using appropriate terminology and conventions. Shows insight or originality. Demonstrates personal skills, perseverance and responsibility in a wide variety of investigative activities in a very consistent manner. Works very well within a team and approaches investigations in an ethical manner, paying full attention to environmental impact. Displays competence in a wide range of investigative techniques, pays considerable attention to safety, and is fully capable of working independently.

Grade 6

Displays very broad knowledge of factual information in the syllabus and a thorough understanding of concepts and principles. Selects and applies relevant information, concepts and principles in most contexts. Analyses and evaluates quantitative and/or qualitative data with a high level of competence. Constructs explanations of complex phenomena and makes appropriate predictions. Solves basic or familiar problems and most new or difficult quantitative and/or qualitative problems.

Communicates effectively using appropriate terminology and conventions. Shows occasional insight or originality. Demonstrates personal skills, perseverance and responsibility in a wide variety of investigative activities in a very consistent manner. Works well within a team and approaches investigations in an ethical manner, paying due attention to environmental impact. Displays competence in a wide range of investigative techniques, pays due attention to safety and is generally capable of working independently.

Grade 5

Displays broad knowledge of factual information in the syllabus. Shows sound understanding of most concepts and principles and applies them in some contexts. Analyses and evaluates quantitative and/or qualitative data competently. Constructs explanations of simple phenomena. Solves most basic or familiar problems and some new or difficult quantitative and/or qualitative problems. Communicates clearly with little or no irrelevant material. Demonstrates personal skills, perseverance and responsibility in a variety of investigative activities in a fairly consistent manner. Generally works well within a team and approaches investigations in an ethical manner, paying attention to environmental impact. Displays competence in a range of investigative techniques, pays attention to safety and is sometimes capable of working independently.

Grade 4

Displays reasonable knowledge of factual information in the syllabus, though possibly with some gaps. Shows adequate comprehension of most basic concepts and principles but with limited ability to apply them. Demonstrates some analysis or evaluation of quantitative or qualitative data. Solves some basic or routine problems but shows limited ability to deal with new or difficult situations. Communicates adequately although responses may lack clarity and include some repetitive or irrelevant material. Demonstrates personal skills, perseverance and responsibility in a variety of investigative activities, although displays some inconsistency. Works within a team and generally approaches investigations in an ethical manner, with some attention to environmental impact. Displays competence in a range of investigative techniques, pays some attention to safety although requires some close supervision.

Grade 3

Displays limited knowledge of factual information in the syllabus. Shows a partial comprehension of basic concepts and principles and a weak ability to apply them. Shows some ability to manipulate data and solve basic or routine problems. Communicates with a possible lack of clarity and uses some repetitive or irrelevant material. Demonstrates personal skills, perseverance and responsibility in some investigative activities in an inconsistent manner. Works within a team and sometimes approaches investigations in an ethical manner, with some attention to environmental impact. Displays competence in some investigative techniques, occasionally pays attention to safety, and requires close supervision.

Grade 2

Displays little recall of factual information in the syllabus. Shows weak comprehension of basic concepts and principles with little evidence of application. Exhibits minimal ability to manipulate data and little or no ability to solve problems. Offers responses which are often incomplete or irrelevant. Rarely demonstrates personal skills, perseverance or responsibility in investigative activities. Works within a team occasionally but makes little or no contribution. Occasionally approaches investigations in an ethical manner, but shows very little awareness of the environmental impact. Displays competence in a very limited range of investigative techniques, showing little awareness of safety factors and needing continual and close supervision.

Grade 1

Recalls fragments of factual information in the syllabus and shows very little understanding of any concepts or principles. Rarely demonstrates personal skills, perseverance or responsibility in investigative activities. Does not work within a team. Rarely approaches investigations in an ethical manner, or shows an awareness of the environmental impact. Displays very little competence in investigative techniques generally pays no attention to safety and requires constant supervision.

9. Academic Honesty

Academic honesty in the Diploma Programme is a set of values and behaviours informed by the attributes of the learner profile. In teaching, learning and assessment, academic honesty serves to promote personal integrity, engender respect for the integrity of others and their work, and ensure that all students have an equal opportunity to demonstrate the knowledge and skills they acquire during their studies. All coursework—including work submitted for assessment—is to be authentic, based on the student's individual and original ideas with the ideas and work of others fully acknowledged. Assessment tasks that require teachers to provide guidance to students or that require students to work collaboratively must be completed in full compliance with the detailed guidelines provided by the IB for the relevant subjects.

Appendix 1: Syllabus details

Core

Topic 1: Measurements and uncertainties

1.1 – Measurements in physics

1.2 – Uncertainties and errors

1.3 – Vectors and scalars

Topic 2: Mechanics

2.1 – Motion

2.2 – Forces

2.3 – Work, energy and power

2.4 – Momentum and impulse

Topic 3: Thermal physics

3.1 – Thermal concepts

3.2 – Modeling a gas

Topic 4: Waves

4.1 – Oscillations

4.2 – Travelling waves

4.3 – Wave characteristics

4.4 – Wave behaviour

4.5 – Standing waves

Topic 5: Electricity and magnetism

5.1 – Electric fields

5.2 – Heating effect of electric currents

5.3 – Electric cells

5.4 – Magnetic effects of electric currents

Topic 6: Circular motion and gravitation

6.1 – Circular motion

6.2 – Newton's law of gravitation

Topic 7: Atomic, nuclear and particle physics

7.1 – Discrete energy and radioactivity

7.2 – Nuclear reactions

7.3 – The structure of matter

Topic 8: Energy production

8.1 – Energy sources

8.2 – Thermal energy transfer

Additional higher level (AHL)

Topic 9: Wave phenomena

9.1 – Simple harmonic motion

9.2 – Single-slit diffraction

9.3 – Interference

9.4 – Resolution

9.5 – Doppler effect

Topic 10: Fields

10.1 – Describing fields

10.2 – Fields at work

Topic 11: Electromagnetic induction

11.1 – Electromagnetic induction

11.2 – Power generation and transmission

11.3 – Capacitance

Topic 12: Quantum and nuclear physics

12.1 – The interaction of matter with radiation

12.2 – Nuclear physics

Option D: Astrophysics Core topics

D.1 – Stellar quantities

D.2 – Stellar characteristics and stellar evolution

D.3 – Cosmology

Additional higher level topics

D.4 – Stellar processes (HL only)

D.5 – Further cosmology (HL only)

Appendix 2: Assessment details

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 assessments 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). Additional publications such as specimen papers and markschemes, teacher support materials, subject reports and grade descriptors can also be found on the OCC. Past examination papers as well as markschemes can be purchased from the IB store.

Methods of assessment

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.

Analytic markschemes

Analytic markschemes are prepared for those examination questions that expect a particular kind of response and/or a given final answer from students. They give detailed instructions to examiners on how to break down the total mark for each question for different parts of the response.

Marking notes

For some assessment components marked using assessment criteria, marking notes are provided. Marking notes give guidance on how to apply assessment criteria to the particular requirements of a question.

Inclusive assessment arrangements

Inclusive assessment arrangements are available for candidates with assessment access requirements. These arrangements enable candidates with diverse needs to access the examinations and demonstrate their knowledge and understanding of the constructs being assessed.

The IB document *Candidates with assessment access requirements* provides details on all the inclusive assessment arrangements available to candidates with learning support requirements. The IB document *Learning diversity within the International Baccalaureate programmes/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 for the Diploma Programme* provide details on special consideration.

Responsibilities of the school

The school is required to ensure that equal access arrangements and reasonable adjustments are provided to candidates with special educational needs that are in line with the IB documents *Candidates with assessment access requirements* and *Learning diversity within the International Baccalaureate programmes/ Special educational needs within the International Baccalaureate programmes.*