Physics in International Baccalaureate Diploma Progarmme

Physics is the most fundamental of the experimental sciences, as it seeks to explain the universe itself, from the very smallest particles—quarks (perhaps 10^{-17} m in size), which may be truly fundamental—to the vast distances between galaxies (10^{24} m).

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 behaviour of electric charge and unified light and electricity, while thermodynamics described the relation between heat 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 Newtonian mechanics failed when applied to the atom and has been superseded by quantum mechanics and general relativity.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 things have remained unchanged. Observations remain essential at the very core of physics, and this sometimes requires a leap of imagination to decide what to look for. Models are developed to try to understand the observations, and these themselves can become theories that attempt to explain the observations. Theories are not directly derived from the observations but need to be created. These acts of creation can sometimes compare 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 is useless. 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 to increase facility in the use of mathematics, which is the language of physics. It also allows students to develop interpersonal skills, and information and communication technology 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—for good or bad. 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; and their challenges, disappointments and triumphs.

Syllabus outline

Core

Topic 1: Physics and physical measurement
1.1 The realm of physics
1.2 Measurement and uncertainties
1.3 Vectors and scalars

Topic 2 : Mechanics
2.1 Kinematics
2.2 Forces and dynamics
2.3 Work, energy and power
2.4 Uniform circular motion

Topic 3 : Thermal physics
3.1 Thermal concepts
3.2 Thermal properties of matter

Topic 4: Oscillations and waves
4.1 Kinematics of simple harmonic motion (SHM)
4.2 Energy changes during simple harmonic motion (SHM)
4.3 Forced oscillations and resonance
4.4 Wave characteristics
4.5 Wave properties

Topic 5: Electric currents
5.1 Electric potential difference, current and resistance
5.2 Electric circuits

Topic 6: Fields and forces
6.1 Gravitational force and field
6.2 Electric force and field
6.3 Magnetic force and field

Topic 7: Atomic and nuclear physics
7.1 The atom
7.2 Radioactive decay
7.3 Nuclear reactions, fission and fusion

Topic 8: Energy, power and climate change
8.1 Energy degradation and power generation
8.2 World energy sources
8.3 Fossil fuel power production
8.4 Non-fossil fuel power production
8.5 Greenhouse effect
8.6 Global warming

AHL

Topic 9: Motion in fields
9.1 Projectile motion
9.2 Gravitational field, potential and energy
9.3 Electric field, potential and energy
9.4 Orbital motion

Topic 10: Thermal physics
10.1 Thermodynamics
10.2 Processes
10.3 Second law of thermodynamics and entropy

Topic 11: Wave phenomena
11.1 Standing (stationary) waves
11.2 Doppler effect
11.3 Diffraction
11.4 Resolution
11.5 Polarization

Topic 12: Electromagnetic induction
12.1 Induced electromotive force (emf)
12.2 Alternating current
12.3 Transmission of electrical power

Topic 13: Quantum physics and nuclear physics
13.1 Quantum physics
13.2 Nuclear physics

Topic 14: Digital technology
14.1 Analogue and digital signals
14.2 Data capture; digital imaging using charge-coupled devices (CCDs)

Options SL

These options are available at SL only.

Option A: Sight and wave phenomena

A1 The eye and sight
A2 Standing (stationary) waves
A3 Doppler effect
A4 Diffraction
A5 Resolution
A6 Polarization

Option B: Quantum physics and nuclear physics

B1 Quantum physics
B2 Nuclear physics

Option C: Digital technology

C1 Analogue and digital signals
C2 Data capture; digital imaging using charge-coupled devices (CCDs)
C3 Electronics
C4 The mobile phone system

Option D: Relativity and particle physics

D1 Introduction to relativity
D2 Concepts and postulates of special relativity
D3 Relativistic kinematics
D4 Particles and interactions
D5 Quarks

Options SL and HL

SL students study the core of these options, and HL students study the whole option (that is, the core and the extension material).

Option E: Astrophysics
Core (SL and HL)
E1 Introduction to the universe
E2 Stellar radiation and stellar types
E3 Stellar distances
E4 Cosmology
Extension (HL only)
E5 Stellar processes and stellar evolution
E6 Galaxies and the expanding universe

Option F: Communications
Core (SL and HL)
F1 Radio communication
F2 Digital signals
F3 Optic fibre transmission
F4 Channels of communication
Extension (HL only)
F5 Electronics
F6 The mobile phone system

Option G: Electromagnetic waves
Core (SL and HL)
G1 Nature of EM waves and light sources
G2 Optical instruments
G3 Two-source interference of waves
G4 Diffraction grating
Extension (HL only)
G5 X-rays
G6 Thin-film interference

Options HL

These options are available at HL only.

Option H: Relativity
H1 Introduction to relativity
H2 Concepts and postulates of special relativity
H3 Relativistic kinematics
H4 Some consequences of special relativity
H5 Evidence to support special relativity
H6 Relativistic momentum and energy
H7 General relativity
H8 Evidence to support general relativity

Option I: Medical physics
I1 The ear and hearing
I2 Medical imaging
I3 Radiation in medicine

Option J: Particle physics
J1 Particles and interactions
J2 Particle accelerators and detectors
J3 Quarks
J4 Leptons and the standard model
J5 Experimental evidence for the quark and standard models
J6 Cosmology and strings

Students at SL are required to study any **two** options from A–G.
The duration of each option is 15 hours.

Students at HL are required to study any **two** options from E–J.
The duration of each option is 22 hours.