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—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 Newtonian mechanics failed when applied to the atom and has been superseded by quantum mechanics and general relativity.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 overview

The syllabus for the Diploma Programme physics course is divided into three parts: the core, the AHL material and the options. The *Physics data booklet* is an integral part of the syllabus and should be used in conjunction with the syllabus. Students should use the data booklet during the course, and they should be issued with clean copies for papers 1, 2 and 3 in the examination.

		Teaching hours
Core		**80**
Topic 1:	Physics and physical measurement	5
Topic 2:	Mechanics	17
Topic 3:	Thermal physics	7
Topic 4:	Oscillations and waves	10
Topic 5:	Electric currents	7
Topic 6:	Fields and forces	7
Topic 7:	Atomic and nuclear physics	9
Topic 8:	Energy, power and climate change	18
AHL		**55**
Topic 9:	Motion in fields	8
Topic 10:	Thermal physics	6
Topic 11:	Wave phenomena	12
Topic 12:	Electromagnetic induction	6
Topic 13:	Quantum physics and nuclear physics	15
Topic 14:	Digital technology	8
Options		**15/22**
Options SL		
Option A:	Sight and wave phenomena	15
Option B:	Quantum physics and nuclear physics	15
Option C:	Digital technology	15
Option D:	Relativity and particle physics	15

		Teaching hours
Options SL and HL		
Option E:	Astrophysics	15/22
Option F:	Communications	15/22
Option G:	Electromagnetic waves	15/22
Options HL		
Option H:	Relativity	22
Option I:	Medical physics	22
Option J:	Particle physics	22

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.

Syllabus outline

		Teaching hours
Core		**80**
Topic 1: Physics and physical measurement		**5**
1.1	The realm of physics	1
1.2	Measurement and uncertainties	2
1.3	Vectors and scalars	2
Topic 2 : Mechanics		**17**
2.1	Kinematics	6
2.2	Forces and dynamics	6
2.3	Work, energy and power	3
2.4	Uniform circular motion	2
Topic 3 : Thermal physics		**7**
3.1	Thermal concepts	2
3.2	Thermal properties of matter	5
Topic 4: Oscillations and waves		**10**
4.1	Kinematics of simple harmonic motion (SHM)	2
4.2	Energy changes during simple harmonic motion (SHM)	1
4.3	Forced oscillations and resonance	3
4.4	Wave characteristics	2
4.5	Wave properties	2
Topic 5: Electric currents		**7**
5.1	Electric potential difference, current and resistance	4
5.2	Electric circuits	3
Topic 6: Fields and forces		**7**
6.1	Gravitational force and field	2
6.2	Electric force and field	3
6.3	Magnetic force and field	2
Topic 7: Atomic and nuclear physics		**9**
7.1	The atom	2
7.2	Radioactive decay	3
7.3	Nuclear reactions, fission and fusion	4

		Teaching hours
Topic 8: Energy, power and climate change		**18**
8.1	Energy degradation and power generation	2
8.2	World energy sources	2
8.3	Fossil fuel power production	1
8.4	Non-fossil fuel power production	7
8.5	Greenhouse effect	3
8.6	Global warming	3

AHL — 55

Topic 9: Motion in fields		**8**
9.1	Projectile motion	2
9.2	Gravitational field, potential and energy	2
9.3	Electric field, potential and energy	2
9.4	Orbital motion	2
Topic 10: Thermal physics		**6**
10.1	Thermodynamics	2
10.2	Processes	3
10.3	Second law of thermodynamics and entropy	1
Topic 11: Wave phenomena		**12**
11.1	Standing (stationary) waves	2
11.2	Doppler effect	2
11.3	Diffraction	1
11.4	Resolution	4
11.5	Polarization	3
Topic 12: Electromagnetic induction		**6**
12.1	Induced electromotive force (emf)	3
12.2	Alternating current	2
12.3	Transmission of electrical power	1
Topic 13: Quantum physics and nuclear physics		**15**
13.1	Quantum physics	10
13.2	Nuclear physics	5
Topic 14: Digital technology		**8**
14.1	Analogue and digital signals	4
14.2	Data capture; digital imaging using charge-coupled devices (CCDs)	4

		Teaching hours
Options SL		**15**

Options SL

These options are available at SL only.

		15
Option A: Sight and wave phenomena		**15**
A1	The eye and sight	3
A2	Standing (stationary) waves	2
A3	Doppler effect	2
A4	Diffraction	1
A5	Resolution	4
A6	Polarization	3
Option B: Quantum physics and nuclear physics		**15**
B1	Quantum physics	10
B2	Nuclear physics	5
Option C: Digital technology		**15**
C1	Analogue and digital signals	4
C2	Data capture; digital imaging using charge-coupled devices (CCDs)	4
C3	Electronics	5
C4	The mobile phone system	2
Option D: Relativity and particle physics		**15**
D1	Introduction to relativity	1
D2	Concepts and postulates of special relativity	2
D3	Relativistic kinematics	5
D4	Particles and interactions	5
D5	Quarks	2

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).

		15/22
Option E: Astrophysics		**15/22**
Core (SL and HL)		**15**
E1	Introduction to the universe	2
E2	Stellar radiation and stellar types	4
E3	Stellar distances	5
E4	Cosmology	4
Extension (HL only)		**7**
E5	Stellar processes and stellar evolution	4
E6	Galaxies and the expanding universe	3

		Teaching hours
Option F: Communications		**15/22**
Core (SL and HL)		**15**
F1	Radio communication	5
F2	Digital signals	4
F3	Optic fibre transmission	3
F4	Channels of communication	3
Extension (HL only)		**7**
F5	Electronics	5
F6	The mobile phone system	2
Option G: Electromagnetic waves		**15/22**
Core (SL and HL)		**15**
G1	Nature of EM waves and light sources	4
G2	Optical instruments	6
G3	Two-source interference of waves	3
G4	Diffraction grating	2
Extension (HL only)		**7**
G5	X-rays	4
G6	Thin-film interference	3

Options HL — 22

These options are available at HL only.

Option H: Relativity		**22**
H1	Introduction to relativity	1
H2	Concepts and postulates of special relativity	2
H3	Relativistic kinematics	5
H4	Some consequences of special relativity	4
H5	Evidence to support special relativity	3
H6	Relativistic momentum and energy	2
H7	General relativity	4
H8	Evidence to support general relativity	1
Option I: Medical physics		**22**
I1	The ear and hearing	6
I2	Medical imaging	10
I3	Radiation in medicine	6
Option J: Particle physics		**22**
J1	Particles and interactions	5
J2	Particle accelerators and detectors	6
J3	Quarks	2
J4	Leptons and the standard model	2
J5	Experimental evidence for the quark and standard models	5
J6	Cosmology and strings	2

Syllabus details—Core

Topic 1: Physics and physical measurement (5 hours)

1.1 The realm of physics

1 hour

	Assessment statement	Obj	Teacher's notes
Range of magnitudes of quantities in our universe			
1.1.1	State and compare quantities to the nearest order of magnitude.	3	
1.1.2	State the ranges of magnitude of distances, masses and times that occur in the universe, from smallest to greatest.	1	Distances: from 10^{-15} m to 10^{+25} m (sub-nuclear particles to extent of the visible universe). Masses: from 10^{-30} kg to 10^{+50} kg (electron to mass of the universe). Times: from 10^{-23} s to 10^{+18} s (passage of light across a nucleus to the age of the universe). **Aim 7:** There are some excellent simulations to illustrate this. **TOK:** This is a very stimulating area for a discussion of ways of knowing.
1.1.3	State ratios of quantities as differences of orders of magnitude.	1	For example, the ratio of the diameter of the hydrogen atom to its nucleus is about 10^5, or a difference of five orders of magnitude.
1.1.4	Estimate approximate values of everyday quantities to one or two significant figures and/or to the nearest order of magnitude.	2	

1.2 Measurement and uncertainties

2 hours

TOK: Data and its limitations is a fruitful area for discussion.

	Assessment statement	Obj	Teacher's notes
The SI system of fundamental and derived units			
1.2.1	State the fundamental units in the SI system.	1	Students need to know the following: kilogram, metre, second, ampere, mole and kelvin.
1.2.2	Distinguish between fundamental and derived units and give examples of derived units.	2	

