Diploma Programme

Physics data booklet

For use during the course and in the examinations

First assessment 2025

Version 1.2

International Baccalaureate®
Baccalauréat International
Bachillerato Internacional

Diploma Programme
Physics data booklet

Published February 2023
Updated May 2023, November 2023

Published on behalf of the International Baccalaureate Organization, a not-for-profit educational foundation of 15 Route des Morillons, 1218 Le Grand-Saconnex, Geneva, Switzerland by the

International Baccalaureate Organization (UK) Ltd
Peterson House, Malthouse Avenue, Cardiff Gate
Cardiff, Wales CF23 8GL
United Kingdom
Website: ibo.org

4082

Contents

This page is intentionally blank.

Introduction

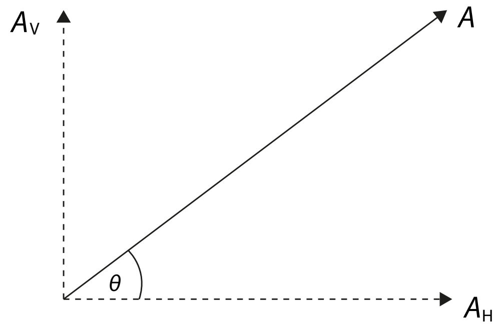
This Diploma Programme (DP) *Physics data booklet* accompanies the DP *Physics guide* and DP *Physics teacher support material*. It contains electrical symbols, mathematics equations, constants, and physics equations relevant to the course.

Students must have access to a copy of this booklet for the duration of the course so that they can become familiar with its contents. Direct reference is made to relevant equations in the "Understandings" sections of the guide. This helps to maintain the emphasis on interpretation and application rather than memorization of symbols, constants and equations.

The *Physics data booklet* is split into two sections. The first includes information which is used throughout the teaching of DP physics and the second contains equations relevant to specific themes and topics. Note that all equations relate to the magnitude of the quantities only. Vector notation has not been used.

Each student must have access to a clean copy of the *Physics data booklet* during examinations. It is the responsibility of the school to download a copy of this booklet from IBIS or the Programme Resource Centre and to ensure that there are sufficient copies available for all students.

Mathematical equations

Area of a triangle	$A = \frac{1}{2}(bh)$ where b is the base, h is the height
Area of a circle	$A = \pi r^2$ where r is the radius
Circumference of a circle	$C = 2\pi r$
Volume of a cuboid	$V = lwh$ where l is the length, w is the width, h is the height
Volume of a cylinder	$V = \pi r^2 h$
Volume of a prism	$V = Ah$ where A is the area of cross-section
Volume of a sphere	$V = \frac{4}{3}\pi r^3$
Area of the curved surface of a cylinder	$A = 2\pi rh$
Vectors	 $A_H = A\cos\theta$ $A_V = A\sin\theta$
Trigonometric relationships	$\tan\theta = \frac{\sin\theta}{\cos\theta}$ $\sin^2\theta + \cos^2\theta = 1$

Uncertainties

If: $y = a \pm b$	then: $\Delta y = \Delta a + \Delta b$
If: $y = \frac{ab}{c}$	then: $\frac{\Delta y}{y} = \frac{\Delta a}{a} + \frac{\Delta b}{b} + \frac{\Delta c}{c}$
If: $y = a^n$	then: $\frac{\Delta y}{y} = \left\lvert n \frac{\Delta a}{a} \right\rvert$

Fundamental constants

Quantity	**Symbol**	**Approximate value**
Acceleration of free fall	g	$9.8\,\text{m s}^{-2}$ (Earth's surface)
Gravitational constant	G	$6.67 \times 10^{-11}\,\text{N m}^2\,\text{kg}^{-2}$
Avogadro constant	N_A	$6.02 \times 10^{23}\,\text{mol}^{-1}$
Gas constant	R	$8.31\,\text{J K}^{-1}\,\text{mol}^{-1}$
Boltzmann constant	k_B	$1.38 \times 10^{-23}\,\text{J K}^{-1}$
Stefan–Boltzmann constant	σ	$5.67 \times 10^{-8}\,\text{W m}^{-2}\,\text{K}^{-4}$
Coulomb constant	k	$8.99 \times 10^{9}\,\text{N m}^2\,\text{C}^{-2}$
Permittivity of free space	ε_0	$8.85 \times 10^{-12}\,\text{C}^2\,\text{N}^{-1}\,\text{m}^{-2}$
Permeability of free space	μ_0	$4\pi \times 10^{-7}\,\text{T m A}^{-1}$
Speed of light in vacuum	c	$3.00 \times 10^{8}\,\text{m s}^{-1}$
Planck constant	h	$6.63 \times 10^{-34}\,\text{J s}$
Elementary charge	e	$1.60 \times 10^{-19}\,\text{C}$
Electron rest mass	m_e	$9.110 \times 10^{-31}\,\text{kg} = 0.000549\,\text{u} = 0.511\,\text{MeV c}^{-2}$
Proton rest mass	m_p	$1.673 \times 10^{-27}\,\text{kg} = 1.007276\,\text{u} = 938\,\text{MeV c}^{-2}$
Neutron rest mass	m_n	$1.675 \times 10^{-27}\,\text{kg} = 1.008665\,\text{u} = 940\,\text{MeV c}^{-2}$
(Unified) atomic mass unit	u	$1.661 \times 10^{-27}\,\text{kg} = 931.5\,\text{MeV c}^{-2}$
Solar constant	S	$1.36 \times 10^{3}\,\text{W m}^{-2}$
Fermi radius	R_0	$1.20 \times 10^{-15}\,\text{m}$

Metric (SI) multipliers

Prefix	Abbreviation	Value
peta	P	10^{15}
tera	T	10^{12}
giga	G	10^{9}
mega	M	10^{6}
kilo	k	10^{3}
hecto	h	10^{2}
deca	da	10^{1}
deci	d	10^{-1}
centi	c	10^{-2}
milli	m	10^{-3}
micro	μ	10^{-6}
nano	n	10^{-9}
pico	p	10^{-12}
femto	f	10^{-15}

Unit conversions

$$1 \text{ radian (rad)} \equiv \frac{180°}{\pi}$$

$$\text{Temperature}(\text{K}) = \text{temperature}(°\text{C}) + 273$$

$$1 \text{ light year}(\text{ly}) = 9.46 \times 10^{15} \text{ m}$$

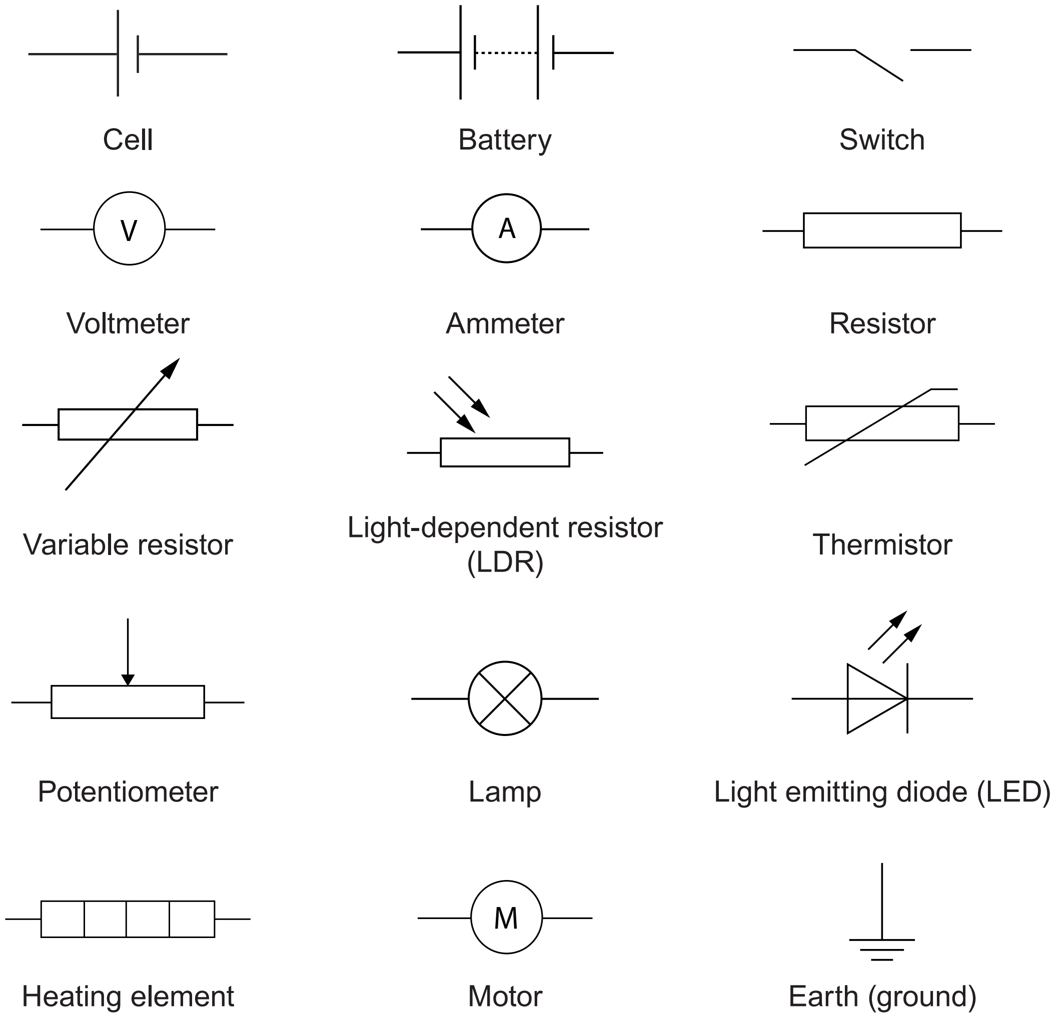
$$1 \text{ parsec}(\text{pc}) = 3.26 \text{ ly}$$

$$1 \text{ astronomical unit } (\text{AU}) = 1.50 \times 10^{11} \text{ m}$$

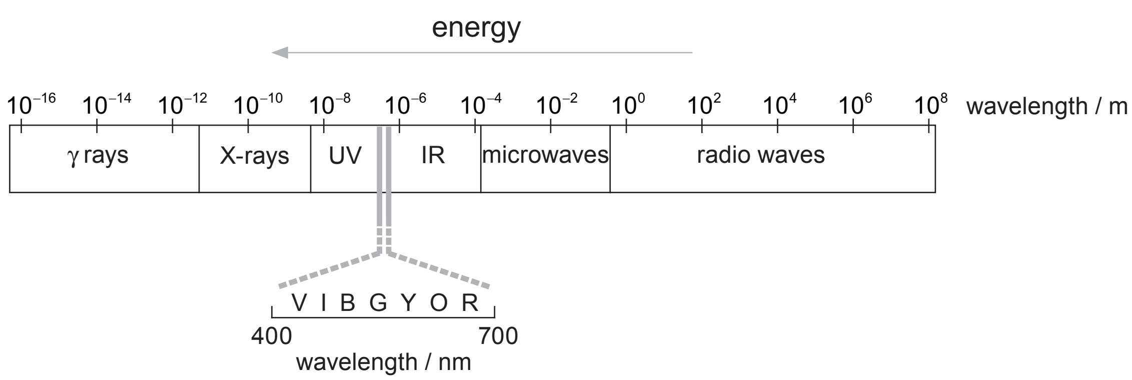
$$1 \text{ kilowatt-hour}(\text{kWh}) = 3.60 \times 10^{6} \text{ J}$$

$$hc = 1.99 \times 10^{-25} \text{ J m} = 1.24 \times 10^{-6} \text{ eV m}$$

Electrical circuit symbols



Electromagnetic spectrum



A. Space, time and motion

Standard level and higher level	
A.1 Kinematics	$s = \frac{u+v}{2}t$ $v = u + at$ $s = ut + \frac{1}{2}at^2$ $v^2 = u^2 + 2as$
A.2 Forces and momentum	$F_f \le \mu_s F_N$ $F_f = \mu_d F_N$ $F_H = -kx$ $F_d = 6\pi\eta rv$ $F_b = \rho Vg$ $F_g = mg$ $p = mv$ $J = F\Delta t$ $F = ma = \frac{\Delta p}{\Delta t}$ $a = \frac{v^2}{r} = \omega^2 r = \frac{4\pi^2 r}{T^2}$ $v = \frac{2\pi r}{T} = \omega r$
A.3 Work, energy and power	$W = Fs\cos\theta$ $E_k = \frac{1}{2}mv^2 = \frac{p^2}{2m}$ $\Delta E_p = mg\Delta h$ $E_H = \frac{1}{2}k\Delta x^2$ $P = \frac{\Delta W}{\Delta t} = Fv$ $\eta = \frac{\text{useful work out}}{\text{total work in}} = \frac{\text{useful power out}}{\text{total power in}}$

Additional higher level	
A.4 Rigid body mechanics	$\tau = Fr\sin\theta$ $\Delta\theta = \frac{\omega_f + \omega_i}{2}t$ $\omega_f = \omega_i + \alpha t$ $\Delta\theta = \omega_i t + \frac{1}{2}\alpha t^2$ $\omega_f^2 = \omega_i^2 + 2\alpha\Delta\theta$ $I = \Sigma mr^2$ $\tau = I\alpha$ $L = I\omega$ $\Delta L = \tau\Delta t$ $\Delta L = \Delta(I\omega)$ $E_k = \frac{1}{2}I\omega^2 = \frac{L^2}{2I}$
A.5 Galilean and special relativity	$x' = x - vt$ $t' = t$ $u' = u - v$ $x' = \gamma(x - vt)$ where $\gamma = \frac{1}{\sqrt{1 - \frac{v^2}{c^2}}}$ $t' = \gamma\left(t - \frac{vx}{c^2}\right)$ $u' = \frac{u - v}{1 - \frac{uv}{c^2}}$ $(\Delta s)^2 = (c\Delta t)^2 - \Delta x^2$ $\Delta t = \gamma\Delta t_0$ $L = \frac{L_0}{\gamma}$ $\tan\theta = \frac{v}{c}$

B. The particulate nature of matter

Standard level and higher level	
B.1 Thermal energy transfers	$\rho = \frac{m}{V}$ $\overline{E_k} = \frac{3}{2} k_B T$ $Q = mc\Delta T$ $Q = mL$ $\frac{\Delta Q}{\Delta t} = -kA \frac{\Delta T}{\Delta x}$ $L = \sigma A T^4$ $b = \frac{L}{4\pi d^2}$ $\lambda_{max} T = 2.9 \times 10^{-3}\,\text{mK}$
B.2 Greenhouse effect	$\text{emissivity} = \frac{\text{power radiated per unit area}}{\sigma T^4}$ $\text{albedo} = \frac{\text{total scattered power}}{\text{total incident power}}$
B.3 Gas laws	$P = \frac{F}{A}$ $n = \frac{N}{N_A}$ $\frac{PV}{T} = \text{constant}$ $PV = nRT = Nk_B T$ $P = \frac{1}{3}\rho v^2$ $U = \frac{3}{2} nRT = \frac{3}{2} Nk_B T$

B.5 Current and circuits	$I = \frac{\Delta q}{\Delta t}$ $V = \frac{W}{q}$ $R = \frac{V}{I}$ $\rho = \frac{RA}{L}$ $P = IV = I^2R = \frac{V^2}{R}$ <table><tr><th>Series circuits</th><th>Parallel circuits</th></tr><tr><td>$I = I_1 = I_2 = \ldots$ $V = V_1 + V_2 + \ldots$ $R_s = R_1 + R_2 + \ldots$</td><td>$I = I_1 + I_2 + \ldots$ $V = V_1 = V_2 = \ldots$ $\frac{1}{R_p} = \frac{1}{R_1} + \frac{1}{R_2} + \ldots$</td></tr></table>$\varepsilon = I(R + r)$
Additional higher level	
B.4 Thermodynamics	$Q = \Delta U + W$ $W = P\Delta V$ $\Delta U = \frac{3}{2}nR\Delta T = \frac{3}{2}Nk_B\Delta T$ $\Delta S = \frac{\Delta Q}{T}$ $S = k_B \ln \Omega$ $PV^{\frac{5}{3}} = \text{constant}$ $\eta = \frac{\text{useful work}}{\text{input energy}}$ $\eta_{\text{Carnot}} = 1 - \frac{T_c}{T_h}$

C. Wave behaviour

Standard level and higher level	
C.1 Simple harmonic motion	$a = -\omega^2 x$ $T = \frac{1}{f} = \frac{2\pi}{\omega}$ $T = 2\pi\sqrt{\frac{m}{k}}$ $T = 2\pi\sqrt{\frac{l}{g}}$
C.2 Wave model	$v = f\lambda = \frac{\lambda}{T}$
C.3 Wave phenomena	$\frac{n_1}{n_2} = \frac{\sin\theta_2}{\sin\theta_1} = \frac{v_2}{v_1}$ Constructive interference: path difference $= n\lambda$ Destructive interference: path difference $= (n + \frac{1}{2})\lambda$ $s = \frac{\lambda D}{d}$
C.5 Doppler effect	$\frac{\Delta f}{f} = \frac{\Delta\lambda}{\lambda} \approx \frac{v}{c}$
Additional higher level	
C.1 Simple harmonic motion	$x = x_0 \sin(\omega t + \phi)$ $v = \omega x_0 \cos(\omega t + \phi)$ $v = \pm\omega\sqrt{x_0^2 - x^2}$ $E_T = \frac{1}{2} m\omega^2 x_0^2$ $E_p = \frac{1}{2} m\omega^2 x^2$

C.3 Wave phenomena	$\theta = \frac{\lambda}{b}$ $n\lambda = d \sin\theta$
C.5 Doppler effect	Moving source: $f' = f\left(\frac{v}{v \pm u_s}\right)$ Moving observer: $f' = f\left(\frac{v \pm u_o}{v}\right)$

D. Fields

Standard level and higher level	
D.1 Gravitational fields	$F = G\frac{m_1m_2}{r^2}$ $g = \frac{F}{m} = G\frac{M}{r^2}$
D.2 Electric and magnetic fields	$F = k\frac{q_1q_2}{r^2}$ where $k = \frac{1}{4\pi\varepsilon_0}$ $E = \frac{F}{q}$ $E = \frac{V}{d}$
D.3 Motion in electromagnetic fields	$F = qvB\sin\theta$ $F = BIL\sin\theta$ $\frac{F}{L} = \mu_0\frac{I_1I_2}{2\pi r}$
Additional higher level	
D.1 Gravitational fields	$E_\text{p} = -G\frac{m_1m_2}{r}$ $V_\text{g} = -G\frac{M}{r}$ $g = -\frac{\Delta V_\text{g}}{\Delta r}$ $W = m\Delta V_\text{g}$ $v_\text{esc} = \sqrt{\frac{2GM}{r}}$ $v_\text{orbital} = \sqrt{\frac{GM}{r}}$
D.2 Electric and magnetic fields	$E_\text{p} = k\frac{q_1q_2}{r}$ $V_\text{e} = \frac{kQ}{r}$ $E = -\frac{\Delta V_\text{e}}{\Delta r}$ $W = q\Delta V_\text{e}$

D.4 Induction	$\Phi = BA\cos\theta$ $\varepsilon = -N\frac{\Delta\Phi}{\Delta t}$ $\varepsilon = BvL$

E. Nuclear and quantum physics

Standard level and higher level	
E.1 Structure of the atom	$E = hf$
E.3 Radioactive decay	$E = mc^2$
E.5 Fusion and stars	$\text{d(parsec)} = \frac{1}{\text{p(arc-second)}}$
Additional higher level	
E.1 Structure of the atom	$R = R_0 A^{\frac{1}{3}}$ $E = -\frac{13.6}{n^2}\text{eV}$ $mvr = \frac{nh}{2\pi}$
E.2 Quantum physics	$E_{\text{max}} = hf - \Phi$ $\lambda = \frac{h}{p}$ $\lambda_f - \lambda_i = \Delta\lambda = \frac{h}{m_e c}(1-\cos\theta)$
E.3 Radioactive decay	$N = N_0 e^{-\lambda t}$ $A = \lambda N = \lambda N_0 e^{-\lambda t}$ $T_{\frac{1}{2}} = \frac{\ln 2}{\lambda}$