IB Physics Data Booklet Reference

IB SL Study Guide

Contents

How to Use This Guide

The IB Physics Data Booklet is your official formula sheet for all exams — Paper 1, Paper 2, and Paper 3. This guide helps you:

- **Understand what's given** — constants, equations, and tables you can reference during exams
- **Know what to memorize** — core concepts and relationships NOT in the booklet
- **Navigate efficiently** — find formulas quickly under exam pressure
- **Avoid common mistakes** — unit errors, sign conventions, and factor-of-2 pitfalls

⚠ **EXAM ALERT**

Critical Exam Rule: You receive the Data Booklet with every physics exam. Do NOT waste time memorizing every formula — instead, know WHERE to find each equation and WHEN to use it.

This guide is based on the IB Physics Data Booklet for first assessment 2025+. Always verify with your teacher that you have the current version.

Jump to section: Fundamental Constants · Unit Prefixes & Conversions · Theme A: Motion · Theme B: Particulate Nature · Theme C: Waves · Theme D: Fields · Theme E: Nuclear & Quantum · Exam Strategies

Section 1: Fundamental Constants

These constants appear throughout physics calculations. The Data Booklet provides precise values — you don't need to memorize them.

Universal Constants

Symbol	Constant	Value (from booklet)	Units
c	Speed of light in vacuum	3.00×10^{8}	$\mathrm{m\ s^{-1}}$
G	Gravitational constant	6.67×10^{-11}	$\mathrm{N\ m^{2}\ kg^{-2}}$
N_A	Avogadro constant	6.02×10^{23}	$\mathrm{mol^{-1}}$
R	Molar gas constant	8.31	$\mathrm{J\ K^{-1}\ mol^{-1}}$
k_B	Boltzmann constant	1.38×10^{-23}	$\mathrm{J\ K^{-1}}$
σ	Stefan-Boltzmann constant	5.67×10^{-8}	$\mathrm{W\ m^{-2}\ K^{-4}}$

Electromagnetic Constants

Symbol	Constant	Value (from booklet)	Units
e	Elementary charge	1.60×10^{-19}	C
ϵ_0	Permittivity of free space	8.85×10^{-12}	$\mathrm{F\ m^{-1}}$
μ_0	Permeability of free space	$4\pi \times 10^{-7}$	$\mathrm{H\ m^{-1}}$
h	Planck constant	6.63×10^{-34}	J s

Particle Masses

Particle	Symbol	Mass (from booklet)	Units
Electron	m_e	9.11×10^{-31}	kg
Proton	m_p	1.673×10^{-27}	kg
Neutron	m_n	1.675×10^{-27}	kg
Unified atomic mass unit	u	1.661×10^{-27}	kg

IB TIP

Relationship to memorize: Note that $k_B = R/N_A$ and $c^2 = 1/(\epsilon_0\mu_0)$. These aren't stated explicitly in the booklet but follow from the constants given.

Earth and Astronomical Data

The booklet includes:

- Mass of Earth: $M_E = 5.97 \times 10^{24}$ kg
- Mean radius of Earth: $R_E = 6.37 \times 10^{6}$ m
- Gravitational field strength at Earth's surface: $g = 9.81\ \mathrm{m\ s^{-2}}$
- Mass of Sun: $M_S = 1.99 \times 10^{30}$ kg
- Mean Earth-Sun distance: 1.50×10^{11} m (1 AU)

EXAM ALERT

Common Mistake: The booklet provides $g = 9.81\ \mathrm{m\ s^{-2}}$ for Earth's surface. Do NOT use $g = 10\ \mathrm{m\ s^{-2}}$ in exam calculations unless the question explicitly rounds it.

Section 2: Unit Prefixes and Conversions

Metric Prefixes (Given in Booklet)

Prefix	Symbol	Factor	Example
tera	T	10^{12}	1 TW = 10^{12} W
giga	G	10^{9}	1 GHz = 10^{9} Hz
mega	M	10^{6}	1 MeV = 10^{6} eV
kilo	k	10^{3}	1 km = 10^{3} m
centi	c	10^{-2}	1 cm = 10^{-2} m
milli	m	10^{-3}	1 ms = 10^{-3} s
micro	μ	10^{-6}	1 μF = 10^{-6} F
nano	n	10^{-9}	1 nm = 10^{-9} m
pico	p	10^{-12}	1 pF = 10^{-12} F
femto	f	10^{-15}	1 fm = 10^{-15} m

Common Unit Conversions

The booklet provides:

- 1 electronvolt (eV) = 1.60×10^{-19} J
- 1 day = 8.64×10^{4} s
- 1 year = 3.16×10^{7} s
- 1 light year (ly) = 9.46×10^{15} m
- 1 parsec (pc) = 3.08×10^{16} m

MEMORISE THIS

Know by heart: The relationship $1\text{ eV} = 1.60 \times 10^{-19}$ J is critical for nuclear and quantum physics. While it's in the booklet, you should recognize it instantly.

Section 3: Theme A — Space, Time and Motion

Given in the Booklet (All Levels)

Kinematics:

- $v = u + at$ (constant acceleration)
- $s = ut + \frac{1}{2}at^2$
- $v^2 = u^2 + 2as$
- $s = \frac{1}{2}(u + v)t$

Projectile motion:

- Horizontal: $x = v_x t$
- Vertical: $y = v_y t - \frac{1}{2}gt^2$

Momentum and collisions:

- $p = mv$ (momentum)
- $F = \frac{\Delta p}{\Delta t}$ (Newton's second law, impulse form)

Energy and work:

- $E_k = \frac{1}{2}mv^2$ (kinetic energy)
- $E_p = mgh$ (gravitational potential energy near Earth's surface)
- $W = Fs\cos\theta$ (work done)
- $P = \frac{W}{t}$ (power)
- Efficiency: $\eta = \frac{\text{useful energy output}}{\text{total energy input}}$

Circular motion:

- $v = \frac{2\pi r}{T}$ (tangential speed)
- $a_c = \frac{v^2}{r}$ (centripetal acceleration)
- $F_c = \frac{mv^2}{r}$ (centripetal force)

NOT Given (Must Memorize)

MEMORISE THIS

Core definitions:

- Velocity is rate of change of displacement: $v = \Delta s/\Delta t$
- Acceleration is rate of change of velocity: $a = \Delta v/\Delta t$
- Newton's first law: object continues in uniform motion unless acted on by resultant force
- Newton's second law: $F = ma$ (standard form)
- Newton's third law: action-reaction pairs are equal and opposite

Conservation laws:

- **Conservation of momentum:** Total momentum before = total momentum after (in isolated system)
- **Conservation of energy:** Total energy is constant in isolated system

EXAM ALERT

Exam Trap: The booklet gives $F = \Delta p/\Delta t$ but NOT $F = ma$. However, for constant mass, they are equivalent. Show your working when deriving one from the other.

Section 4: Theme B — The Particulate Nature of Matter

Given in the Booklet (All Levels)

Thermal physics:

- $pV = nRT$ (ideal gas law)
- $E_k = \frac{3}{2}kT$ (mean kinetic energy of ideal gas molecule)
- $Q = mc\Delta T$ (heat energy transfer, specific heat)
- $Q = mL$ (latent heat)

Internal energy and thermodynamics:

- First law: $\Delta U = Q - W$
- $W = p\Delta V$ (work done by gas at constant pressure)

Density and pressure:

- $\rho = \frac{m}{V}$ (density)
- $p = \frac{F}{A}$ (pressure)

Given in the Booklet (HL Only) HL

- $pV^\gamma = \text{constant}$ (adiabatic process)
- Carnot efficiency: $\eta = 1 - \frac{T_C}{T_H}$
- Entropy change: $\Delta S = \frac{Q}{T}$ (reversible process)

NOT Given (Must Memorize)

MEMORISE THIS

Key concepts:

- **Absolute zero:** 0 K = -273.15°C (lowest possible temperature)
- **Internal energy** is the sum of random kinetic and potential energies of particles
- **Isothermal process:** constant temperature ($\Delta T = 0$, so $\Delta U = 0$ for ideal gas)
- **Isobaric process:** constant pressure
- **Isochoric process:** constant volume ($\Delta V = 0$, so $W = 0$)

IB TIP

Quick Check: For ideal gas at constant temperature, $pV = \text{constant}$ (Boyle's law). This follows from $pV = nRT$ when T and n are fixed.

Section 5: Theme C — Wave Behaviour

Given in the Booklet (All Levels)

Wave properties:

- $v = f\lambda$ (wave equation)
- $f = \frac{1}{T}$ (frequency and period)

Electromagnetic spectrum:

- The booklet includes a table showing wavelength ranges for radio, microwave, infrared, visible, UV, X-ray, gamma

Optics:

- $n = \frac{c}{v}$ (refractive index)
- Snell's law: $n_1 \sin\theta_1 = n_2 \sin\theta_2$
- Critical angle: $\sin\theta_c = \frac{n_2}{n_1}$ (for $n_1 > n_2$)
- Lens equation: $\frac{1}{f} = \frac{1}{u} + \frac{1}{v}$
- Magnification: $m = \frac{v}{u}$

Interference:

- Double-slit: $d\sin\theta = n\lambda$ (maxima)
- Single-slit diffraction: $b\sin\theta = n\lambda$ (minima)

Doppler effect:

- For sound: $f' = f\frac{v \pm v_o}{v \mp v_s}$
- For light (non-relativistic): $\frac{\Delta f}{f} = \frac{v}{c}$ (approaching source)

Given in the Booklet (HL Only) HL

- Diffraction grating: $d\sin\theta = n\lambda$
- Rayleigh criterion: $\theta \approx 1.22\frac{\lambda}{b}$
- Relativistic Doppler: $f' = f\sqrt{\frac{1+v/c}{1-v/c}}$

NOT Given (Must Memorize)

MEMORISE THIS

Definitions:

- **Wavelength** λ: distance between successive crests
- **Frequency** f: number of oscillations per second
- **Amplitude** A: maximum displacement from equilibrium
- **Transverse wave:** oscillations perpendicular to energy transfer (e.g., EM waves, water waves)

- **Longitudinal wave:** oscillations parallel to energy transfer (e.g., sound)

Key concepts:

- Constructive interference: waves in phase, amplitudes add
- Destructive interference: waves out of phase, amplitudes subtract
- Polarization applies only to transverse waves

⚠ EXAM ALERT

Common Error: The double-slit formula $d \sin\theta = n\lambda$ gives maxima positions. For small angles, $\sin\theta \approx \tan\theta = x/D$, so $x = \frac{n\lambda D}{d}$ (fringe separation is $\Delta x = \frac{\lambda D}{d}$).

Section 6: Theme D — Fields

Given in the Booklet (All Levels)

Gravitational fields:

- $g = \frac{F}{m}$ (field strength)
- $F = \frac{Gm_1m_2}{r^2}$ (Newton's law of gravitation)
- $g = \frac{GM}{r^2}$ (field strength at distance r)
- $V = -\frac{GM}{r}$ (gravitational potential)
- $E_p = -\frac{GMm}{r}$ (gravitational potential energy)

Orbital motion:

- $v = \sqrt{\frac{GM}{r}}$ (orbital speed)
- $T^2 = \frac{4\pi^2}{GM}r^3$ (Kepler's third law)

Electric fields:

- $F = \frac{1}{4\pi\epsilon_0}\frac{q_1q_2}{r^2}$ (Coulomb's law, also written as $F = k\frac{q_1q_2}{r^2}$ where $k = \frac{1}{4\pi\epsilon_0}$)
- $E = \frac{F}{q}$ (electric field strength)
- $E = \frac{V}{d}$ (uniform field between plates)
- $V = \frac{Q}{4\pi\epsilon_0 r}$ (electric potential, point charge)
- $C = \frac{Q}{V}$ (capacitance)
- $E = \frac{1}{2}QV = \frac{1}{2}CV^2 = \frac{1}{2}\frac{Q^2}{C}$ (energy stored in capacitor)

Magnetic fields:

- $F = BIl\sin\theta$ (force on current-carrying wire)
- $F = Bqv\sin\theta$ (force on moving charge)

Given in the Booklet (HL Only) HL

- $r = \frac{mv}{Bq}$ (radius of circular path in magnetic field)
- Faraday's law: $\mathcal{E} = -N\frac{\Delta\Phi}{\Delta t}$

- Magnetic flux: $\Phi = BA\cos\theta$
- $\mathcal{E} = Blv$ (motional EMF)

NOT Given (Must Memorize)

MEMORISE THIS

Core principles:

- **Gravitational fields are always attractive**
- **Electric fields can be attractive or repulsive** (like charges repel, unlike attract)
- Gravitational potential energy is zero at infinity and becomes more negative closer to mass
- Electric potential is zero at infinity for point charges

Escape velocity concept: Minimum speed to escape gravitational field. Derivation uses $E_k + E_p = 0$ at infinity.

IB TIP

Sign conventions: The negative signs in $V = -GM/r$ and $E_p = -GMm/r$ are critical. Gravitational potential is always negative (field is attractive). Don't drop the sign in calculations.

Section 7: Theme E — Nuclear and Quantum Physics

Given in the Booklet (All Levels)

Photon energy and quantum theory:

- $E = hf$ (photon energy)
- $E = \frac{hc}{\lambda}$ (alternative form)
- $E_k = hf - \phi$ (photoelectric effect)
- $\lambda = \frac{h}{p}$ (de Broglie wavelength)

Nuclear physics:

- $E = mc^2$ (mass-energy equivalence)
- $A = \lambda N$ (radioactive decay activity)
- $N = N_0 e^{-\lambda t}$ (exponential decay law)
- $T_{1/2} = \frac{\ln 2}{\lambda}$ (half-life)

Atomic structure:

- $\frac{1}{\lambda} = R\left(\frac{1}{n_f^2} - \frac{1}{n_i^2}\right)$ (Rydberg formula for hydrogen spectrum)
- Rydberg constant: $R = 1.097 \times 10^7\ \mathrm{m}^{-1}$

Given in the Booklet (HL Only) HL

- Schrödinger equation (time-independent): $-\frac{\hbar^2}{2m}\frac{d^2\psi}{dx^2} + V\psi = E\psi$
- Heisenberg uncertainty principle: $\Delta x \Delta p \geq \frac{\hbar}{2}$ (where $\hbar = h/2\pi$)
- Tunneling probability expressions

NOT Given (Must Memorize)

MEMORISE THIS

Key concepts:

- **Work function** ϕ: minimum energy to remove electron from metal surface
- **Threshold frequency** f_0: minimum photon frequency for photoelectric effect ($hf_0 = \phi$)
- **Nuclear notation:** ${}^A_Z X$ where A is mass number (nucleons), Z is atomic number (protons)
- **Alpha decay:** ${}^A_Z X \to {}^{A-4}_{Z-2} Y + {}^4_2\text{He}$
- **Beta-minus decay:** ${}^A_Z X \to {}^A_{Z+1} Y + e^- + \bar{\nu}_e$
- **Beta-plus decay:** ${}^A_Z X \to {}^A_{Z-1} Y + e^+ + \nu_e$
- **Gamma decay:** excited nucleus releases photon, A and Z unchanged

Decay constant λ: probability of decay per unit time. Related to half-life by $T_{1/2} = \ln 2/\lambda \approx 0.693/\lambda$.

EXAM ALERT

Critical Distinction: In photoelectric effect, $E_k = hf - \phi$ gives the **maximum** kinetic energy of emitted electrons. Some electrons lose energy escaping the metal, so their kinetic energy is less than this maximum.

IB TIP

Energy units: Nuclear physics often uses electronvolts (eV) or mega-electronvolts (MeV). Remember 1 eV $= 1.60 \times 10^{-19}$ J. For example, rest mass energy of electron is $m_e c^2 = 0.511$ MeV.

Section 8: Exam Strategies for Using the Data Booklet

1. Know the Layout

The Data Booklet is organized by theme (A, B, C, D, E). Spend 5 minutes at the start of your course familiarizing yourself with the booklet's structure:

- **Page 1:** Constants and conversion factors
- **Pages 2-6:** Formulae organized by theme (A through E)
- **Page 7:** Standard model of particle physics (HL)
- **Page 8:** Electromagnetic spectrum, units, SI prefixes

IB TIP

Pre-exam drill: Before each mock exam, practice finding 10 random formulas in the booklet. Time yourself — you should locate any equation within 10 seconds.

2. Understand vs. Locate

Don't treat the Data Booklet as a crutch. You still need to:

- **Understand when to use each formula** (the booklet doesn't tell you which equation applies to which problem)
- **Know variable meanings** (is r radius, distance, or separation?)
- **Recognize units** (does your answer need to be in eV or Joules?)

EXAM ALERT

Examiner Tip: The most common error is using the correct formula with the wrong variables. For example, using r as Earth's radius when the problem requires orbital radius. Always sketch a diagram and label variables clearly.

3. Memorize Strategic Shortcuts

While most formulas are given, memorizing a few relationships saves time:

MEMORISE THIS

High-frequency formulas to know by heart:

- $v = f\lambda$ (wave equation)
- $F = ma$ (Newton's second law, standard form)
- $E_k = \frac{1}{2}mv^2$
- $p = mv$
- $E = hf$
- $E = mc^2$
- Conservation of momentum and energy (concepts, not just formulas)

4. Check Units and Factors

Many formulas have factors like $\frac{1}{2}$, 2π, or 4π. Common mistakes:

Formula	Common Error	Correct Form
$E_k = \frac{1}{2}mv^2$	Forgetting $\frac{1}{2}$	Always include the half
$v = \frac{2\pi r}{T}$	Writing $v = \frac{r}{T}$	Don't drop 2π
Coulomb's law	Forgetting $4\pi\epsilon_0$	$F = \frac{1}{4\pi\epsilon_0}\frac{q_1 q_2}{r^2}$
Half-life	Using λ instead of $\ln 2$	$T_{1/2} = \frac{\ln 2}{\lambda} = \frac{0.693}{\lambda}$

EXAM ALERT

Units Check: After calculating, verify your answer has the correct SI unit. For example, energy must be in joules (J), not kg m^2 s^{-2} (even though they're equivalent, the markscheme expects J).

5. Cross-Reference Related Formulas

Some physics problems require combining multiple equations. The Data Booklet doesn't show derivations, so practice connecting formulas:

Example: To find escape velocity from a planet, you combine:

- Gravitational potential energy: $E_p = -\frac{GMm}{r}$
- Kinetic energy: $E_k = \frac{1}{2}mv^2$
- Conservation of energy: $E_k + E_p = 0$ at infinity

Result (NOT in booklet): $v_{\text{esc}} = \sqrt{\frac{2GM}{r}}$

IB TIP

Derivation Practice: For each major topic, identify 2-3 formulas that aren't directly in the booklet but can be derived from those that are. Practice these derivations — they frequently appear in Paper 2.

6. Flag HL-Only Content

If you're taking SL, ignore formulas marked "HL only" in the booklet (they appear in a separate section or are marked explicitly). Spending time on irrelevant equations wastes exam minutes.

MEMORISE THIS

SL students ignore:

- Adiabatic processes ($pV^\gamma = \text{constant}$)
- Carnot cycle and entropy formulas
- Rayleigh criterion and diffraction grating details
- Relativistic Doppler
- Schrödinger equation
- Detailed particle physics (HL covers quarks, leptons, Feynman diagrams)

7. Practice Under Exam Conditions

In mock exams:

1. **Time yourself** — can you find a formula in under 10 seconds?
2. **Mark up the booklet** — you're allowed to write in it during the exam (though it's discarded after). Use it to track which page has which theme.

3. **Check the version** — ensure you're practicing with the 2025+ booklet, not an outdated version.

⚠ EXAM ALERT

Do NOT bring your own formula sheet. Only the official IB-provided Data Booklet is allowed. Any notes or annotations from home are prohibited.

Exam-Style Practice Questions

▶ **Question 1:** A student claims they don't need to memorize any physics formulas because "it's all in the Data Booklet." Evaluate this claim. [4 marks]

▶ **Question 2:** The Data Booklet gives gravitational potential energy as $E_p = -\frac{GMm}{r}$ but many textbooks use $E_p = mgh$ near Earth's surface. Explain why both are correct and state when each should be used. [3 marks]

▶ **Question 3:** A student finds three different formulas for capacitor energy in the Data Booklet: $E = \frac{1}{2}QV$, $E = \frac{1}{2}CV^2$, and $E = \frac{1}{2}\frac{Q^2}{C}$. Show that these are equivalent starting from $C = Q/V$. [3 marks]

▶ **Question 4:** The Data Booklet provides the formula $\lambda = h/p$ for de Broglie wavelength. A proton is accelerated through a potential difference of 100 V. Calculate its de Broglie wavelength. (Mass of proton $m_p = 1.673 \times 10^{-27}$ kg, $h = 6.63 \times 10^{-34}$ J s, $e = 1.60 \times 10^{-19}$ C) [4 marks]

Final Checklist for Data Booklet Mastery

Before your IB Physics exam, ensure you can:

- ☐ Locate any formula in the booklet within 10 seconds
- ☐ State from memory which formulas are NOT in the booklet (e.g., $F = ma$ standard form, conservation laws as concepts)
- ☐ Explain when to use general formulas vs. special cases (e.g., $E_p = -GMm/r$ vs. $E_p = mgh$)
- ☐ Identify all variables in context (e.g., distinguish orbital radius from planetary radius)
- ☐ Derive 5+ important relationships not directly given (escape velocity, Kepler's third law proof, capacitor energy forms)
- ☐ Check units after every calculation
- ☐ Recognize common factor errors ($\frac{1}{2}$, 2π, $4\pi\epsilon_0$)

IB TIP

Final Advice: The Data Booklet is a tool, not a crutch. Students who score 7s in IB Physics rarely look up formulas — they've internalized when to use each equation and only reference the booklet for exact constant values or rarely-used formulas. Aim for that level of mastery.

Related Guides:

- Space, Time and Motion — Theme A formulas in context
- Fields — Theme D formulas in context
- Nuclear and Quantum Physics — Theme E formulas in context
- Wave Behaviour — Theme C formulas in context
- Particulate Nature of Matter — Theme B formulas in context