INTERNATIONAL BACCALAUREATE ORGANIZATION

PHYSICS DATA BOOKLET

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To be used in the teaching and examination of
IB Diploma Programme physics

Valid for examination sessions from May 2003

Physics Data Booklet

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Fundamental Constants

Quantity	Symbol	Approximate Value
Acceleration due to gravity (Earth's surface)	g	$9.81\ \text{m s}^{-2}$
Gravitational constant	G	$6.67 \times 10^{-11}\ \text{N m}^2\ \text{kg}^{-2}$
Avogadro's constant	N_A	$6.02 \times 10^{23}\ \text{mol}^{-1}$
Gas constant	R	$8.31\ \text{J K}^{-1}\ \text{mol}^{-1}$
Boltzmann's constant	k	$1.38 \times 10^{-23}\ \text{J K}^{-1}$
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's constant	h	$6.63 \times 10^{-34}\ \text{J s}$
Charge on electron	e	$1.60 \times 10^{-19}\ \text{C}$
Electron rest mass	m_e	$9.11 \times 10^{-31}\ \text{kg} = 0.000549\ \text{u} = 0.511\ \text{MeV c}^{-2}$
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	$1.661 \times 10^{-27}\ \text{kg} = 931.5\ \text{MeV c}^{-2}$

Metric (SI) Multipliers

Prefix	Abbreviation	Value
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 light year (ly) = 9.46×10^{15} m

1 parsec (pc) = 3.26 ly

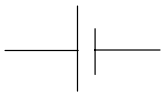
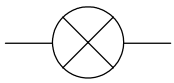
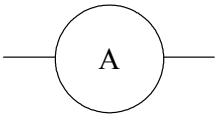
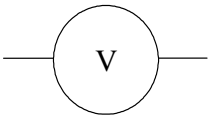
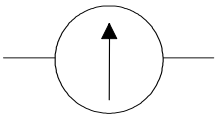
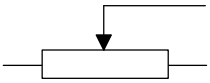
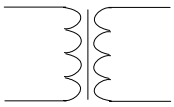
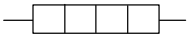
1 astronomical unit (AU) = 1.50×10^{11} m

1 radian (rad) = $180°/\pi$

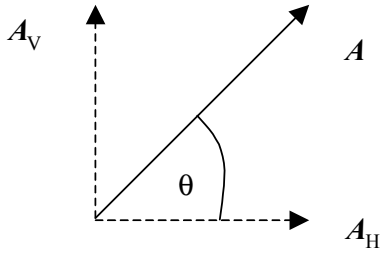
1 kilowatt-hour (kW h) = 3.60×10^{6} J

1 atm = 1.01×10^{5} N m^{-2} = 101 kPa = 760 mm Hg

Electrical Circuit Symbols

cell		battery	
lamp		ac supply	
switch		ammeter	
voltmeter		galvanometer	
resistor		potentiometer	
transformer		heating element	

Equations

Core	Additional Higher Level
Topic 1 Physics and physical measurement  $A_H = A\cos\theta$ $A_V = A\sin\theta$	
	Topic 7 Measurement and uncertainties If $y = a \pm b$ then $\Delta y = \Delta a + \Delta b$ If $y = \frac{ab}{c}$ then $\frac{\Delta y}{y} = \frac{\Delta a}{a} + \frac{\Delta b}{b} + \frac{\Delta c}{c}$
Topic 2 Mechanics $\boldsymbol{v}_{av} = \frac{\Delta \boldsymbol{s}}{\Delta t}$ $\boldsymbol{a}_{av} = \frac{\Delta \boldsymbol{v}}{\Delta t}$	**Topic 8 Mechanics** $\boldsymbol{g} = \frac{\boldsymbol{F}}{m}$ $g = G\frac{m}{r^2}$

Core	Additional Higher Level

Topic 2 Mechanics (continued)

$v = u + at$

$s = \frac{u + v}{2} t$

$s = ut + \frac{1}{2} at^2$

$v^2 = u^2 + 2as$

s : displacement

t : time

u : initial speed

v : final speed

a : acceleration

$\boldsymbol{F} = m\boldsymbol{a}$

$\boldsymbol{p} = m\boldsymbol{v}$

$\boldsymbol{F} = \frac{\Delta \boldsymbol{p}}{\Delta t}$

Impulse $= \boldsymbol{F}\Delta t = m\Delta \boldsymbol{v}$

$W = Fs\cos\theta$

$E_{\mathrm{k}} = \frac{1}{2} mv^2$

$E_{\mathrm{k}} = \frac{p^2}{2m}$

$\Delta E_{\mathrm{p}} = mg\Delta h$

$F = kx$

$E_{\mathrm{elas}} = \frac{1}{2} kx^2$

power $= \frac{\text{work}}{\text{time}} = Fv$

$a = \frac{v^2}{r} = \frac{4\pi^2 r}{T^2}$

Topic 8 Mechanics (continued)

$F = G\frac{m_1 m_2}{r^2}$

$E_p = -G\frac{m_1 m_2}{r}$

$V = -G\frac{m}{r}$

$\frac{T^2}{R^3} = \text{constant}$

$F_{\mathrm{fr}} \leq \mu_{\mathrm{s}} F_{\mathrm{N}}$

$F_{\mathrm{fr}} = \mu_{\mathrm{k}} F_{\mathrm{N}}$

$\tau = Fr\sin\theta$

Core	Additional Higher Level
Topic 3 Thermal physics $p = \frac{F}{A}$ $\Delta Q = mc\Delta T$ $\Delta Q = mL$ $pV = nRT$	**Topic 9 Thermal physics** $\Delta W = p\Delta V$ $\Delta Q = \Delta U + \Delta W$ $+\Delta Q =$ thermal energy transferred to the system $+\Delta U =$ increase in internal energy of the system $+\Delta W =$ work done by the system efficiency $= \frac{Q_h - Q_c}{Q_h}$ $\frac{Q_h}{T_h} = \frac{Q_c}{T_c}$ (Carnot cycle) efficiency $= \frac{T_h - T_c}{T_h}$ (Carnot cycle)
Topic 4 Waves $f = \frac{1}{T}$ $v = f\lambda$ $\frac{\sin\theta_1}{\sin\theta_2} = \frac{v_1}{v_2}$ $n_1 \sin\theta_1 = n_2 \sin\theta_2$ $n = \frac{c}{v}$	**Topic 10 Waves** $f' = f\left(\frac{1}{1 \pm \frac{v_s}{v}}\right)$ moving source $f' = f\left(1 \pm \frac{v_o}{v}\right)$ moving observer $f_{beat} = \lvert f_1 - f_2 \rvert$ $d \sin\theta = n\lambda$ $s = \frac{\lambda D}{d}$

Core	Additional Higher Level
Topic 5 Electricity and magnetism	**Topic 11 Electromagnetism**
$F = k\frac{q_1 q_2}{r^2} = \frac{1}{4\pi\varepsilon_0}\frac{q_1 q_2}{r^2}$	$V = k\frac{q}{r} = \frac{1}{4\pi\varepsilon_0}\frac{q}{r}$
$\boldsymbol{E} = \frac{\boldsymbol{F}}{q}$	$E = -\frac{\Delta V}{\Delta x}$
$E = k\frac{q}{r^2}$	$\Phi = BA\cos\theta$
$E = \frac{V}{d}$	$\mathcal{E} = Bvl$
$I = \frac{\Delta q}{\Delta t}$	$\mathcal{E} = -N\frac{\Delta\Phi}{\Delta t}$
$R = \frac{V}{I}$	$\frac{V_\mathrm{p}}{V_\mathrm{s}} = \frac{N_\mathrm{p}}{N_\mathrm{s}}$
$P = VI = I^2R = \frac{V^2}{R}$	$I_\mathrm{rms} = \frac{I_0}{\sqrt{2}}$
$R = R_1 + R_2$	$V_\mathrm{rms} = \frac{V_0}{\sqrt{2}}$
$\frac{1}{R} = \frac{1}{R_1} + \frac{1}{R_2}$	
$F = qvB\sin\theta$	
$F = IlB\sin\theta$	
$B = \frac{\mu_0}{2\pi}\frac{I}{r}$	
$B = \mu_0\frac{NI}{l} = \mu_0 nI$	
$\frac{F}{l} = \frac{\mu_0}{2\pi}\frac{I_1 I_2}{r}$	

Core	Additional Higher Level
Topic 6 Atomic and nuclear physics	**Topic 12 Quantum physics and nuclear physics**
$E = mc^2$	$E = hf$ $hf = \phi + E_{k_{max}}$ $hf = hf_0 + eV_s$ $p = \frac{h}{\lambda}$ $N = N_0 e^{-\lambda t}$ $T_{\frac{1}{2}} = \frac{\ln 2}{\lambda}$

Options Standard Level

Option A Mechanics extension

$$\boldsymbol{g} = \frac{\boldsymbol{F}}{m}$$

$$g = G\frac{m}{r^2}$$

$$F = G\frac{m_1 m_2}{r^2}$$

$$E_{\mathrm{p}} = -G\frac{m_1 m_2}{r}$$

$$V = -G\frac{m}{r}$$

$$\frac{T^2}{R^3} = \text{constant}$$

$$F_{\mathrm{fr}} \leq \mu_{\mathrm{s}} F_{\mathrm{N}}$$

$$F_{\mathrm{fr}} = \mu_{\mathrm{k}} F_{\mathrm{N}}$$

$$\tau = Fr\sin\theta$$

Option B Quantum physics and nuclear physics

$$E = hf$$

$$hf = \phi + E_{\mathrm{k}_{\max}}$$

$$hf = hf_0 + eV_{\mathrm{s}}$$

$$p = \frac{h}{\lambda}$$

$$N = N_0 \mathrm{e}^{-\lambda t}$$

$$T_{\frac{1}{2}} = \frac{\ln 2}{\lambda}$$

Option C Energy extension

$\Delta W = p\Delta V$

$\Delta Q = \Delta U + \Delta W$

$+\Delta Q$ = thermal energy transferred to the system

$+\Delta U$ = increase in internal energy of the system

$+\Delta W$ = work done by the system

efficiency $= \dfrac{Q_h - Q_c}{Q_h}$

$\dfrac{Q_h}{T_h} = \dfrac{Q_c}{T_c}$ (Carnot cycle)

efficiency $= \dfrac{T_h - T_c}{T_h}$ (Carnot cycle)

power $= \frac{1}{2}\rho A v^3$

Options Standard Level/Higher Level

Core (SL + HL)	Extension (HL only)
Option D Biomedical physics	
$\beta = 10 \log \frac{I}{I_0}$ where $I_0 = 10^{-12}$ W m^{-2}	Mechanical Advantage = $\frac{\text{load}}{\text{effort}}$
$I = I_0 e^{-\mu x}$	Velocity Ratio = $\frac{\text{distance moved by effort}}{\text{distance moved by load}}$
$x_{\frac{1}{2}} = \frac{\ln 2}{\mu}$	Absorbed dose = $\frac{\text{Absorbed Energy}}{\text{mass}}$
	Exposure = $\frac{\text{total charge}}{\text{mass}}$
	Dose equivalent = quality factor × Absorbed dose
	$\frac{1}{T_E} = \frac{1}{T_B} + \frac{1}{T_R}$
Option E The history and development of physics	
Any formulas required will be found in the core topics.	$\frac{1}{\lambda} = R_H \left(\frac{1}{n^2} - \frac{1}{m^2} \right)$
	$\Delta x \Delta p \geq \frac{h}{2\pi}$
	$\Delta E \Delta t \geq \frac{h}{2\pi}$
	Any other formulas required will be found in the AHL topics.

Options Standard Level/Higher Level

Core (SL + HL)	Extension (HL only)
Option F Astrophysics	
$L = \sigma A T^4$	$v = \mathrm{H}d$
$\lambda_{\max}\,(\text{metres}) = \dfrac{2.90 \times 10^{-3}}{T\,(\text{kelvin})}$	$\dfrac{\Delta\lambda}{\lambda} \cong \dfrac{v}{c}$
$d\,(\text{parsec}) = \dfrac{1}{p\,(\text{arc-second})}$	
$b = \dfrac{L}{4\pi d^2}$	
Option G Relativity	
$\gamma = \dfrac{1}{\sqrt{1 - \dfrac{v^2}{c^2}}}$	$p = \gamma m_0 u$
$\Delta t = \gamma \Delta t_0$	$E^2 = p^2c^2 + m_0^2c^4$
$L = \dfrac{L_0}{\gamma}$	$\dfrac{\Delta f}{f} = \dfrac{g\Delta h}{c^2}$
$u_x^{/} = \dfrac{u_x - v}{1 - \dfrac{u_x v}{c^2}}$	$R_{\text{Sch}} = \dfrac{2GM}{c^2}$
$m = \gamma m_0$	
$E_0 = m_0 c^2$	
$E = mc^2$	

Options Standard Level/Higher Level

Core (SL + HL)	Extension (HL only)
Option H Optics	
$n_1 \sin\theta_1 = n_2 \sin\theta_2$	$\theta = \frac{\lambda}{b}$
$n = \frac{1}{\sin\theta_c}$	$\theta = 1.22\frac{\lambda}{b}$
$\frac{1}{f} = \frac{1}{u} + \frac{1}{v}$	$d\sin\theta = n\lambda$
$m = \frac{h_i}{h_o} = \frac{v}{u}$	
$M = \frac{\theta_i}{\theta_o}$	