



INTERNATIONAL BACCALAUREATE ORGANIZATION

PHYSICS DATA BOOKLET

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

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Physics Data Booklet

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Fundamental Constants

Quantity	Symbol	Approximate Value
Acceleration due to gravity (Earth's surface)	g	9.81 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

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

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

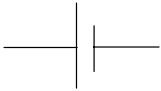

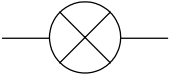


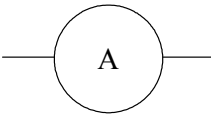
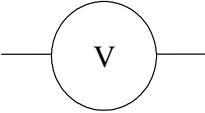
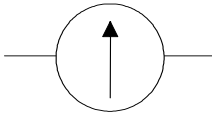

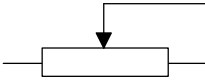
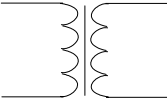

$$1 \text{ astronomical unit (AU)} = 1.50 \times 10^{11} \text{ m}$$

$$1 \text{ radian (rad)} = 180^\circ/\pi$$

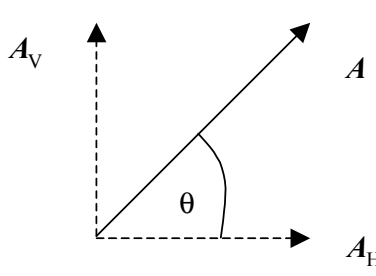
$$1 \text{ kilowatt-hour (kW h)} = 3.60 \times 10^6 \text{ J}$$

$$1 \text{ atm} = 1.01 \times 10^5 \text{ N m}^{-2} = 101 \text{ kPa} = 760 \text{ mm Hg}$$

Electrical Circuit Symbols

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

Equations

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

Core	Additional Higher Level
<p>Topic 2 Mechanics (continued)</p> $v = u + at$ $s = \frac{u + v}{2}t$ $s = ut + \frac{1}{2}at^2$ $v^2 = u^2 + 2as$ <p> s : displacement t : time u : initial speed v : final speed a : acceleration </p> $\mathbf{F} = m\mathbf{a}$ $\mathbf{p} = m\mathbf{v}$ $\mathbf{F} = \frac{\Delta \mathbf{p}}{\Delta t}$ <p>Impulse = $\mathbf{F}\Delta t = m\Delta \mathbf{v}$</p> $W = Fs \cos \theta$ $E_k = \frac{1}{2}mv^2$ $E_k = \frac{p^2}{2m}$ $\Delta E_p = mg\Delta h$ $F = kx$ $E_{\text{clas}} = \frac{1}{2}kx^2$ <p>power = $\frac{\text{work}}{\text{time}} = Fv$</p> $a = \frac{v^2}{r} = \frac{4\pi^2 r}{T^2}$	<p>Topic 8 Mechanics (continued)</p> $F = G \frac{m_1 m_2}{r^2}$ $E_p = -G \frac{m_1 m_2}{r}$ $V = -G \frac{m}{r}$ $\frac{T^2}{R^3} = \text{constant}$ $F_{\text{fr}} \leq \mu_s F_N$ $F_{\text{fr}} = \mu_k F_N$ $\tau = Fr \sin \theta$

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

Core	Additional Higher Level
<p>Topic 5 Electricity and magnetism</p> $F = k \frac{q_1 q_2}{r^2} = \frac{1}{4\pi\epsilon_0} \frac{q_1 q_2}{r^2}$ $\mathbf{E} = \frac{\mathbf{F}}{q}$ $E = k \frac{q}{r^2}$ $E = \frac{V}{d}$ $I = \frac{\Delta q}{\Delta t}$ $R = \frac{V}{I}$ $P = VI = I^2 R = \frac{V^2}{R}$ $R = R_1 + R_2$ $\frac{1}{R} = \frac{1}{R_1} + \frac{1}{R_2}$ $F = qvB \sin \theta$ $F = IlB \sin \theta$ $B = \frac{\mu_0 I}{2\pi r}$ $B = \mu_0 \frac{NI}{l} = \mu_0 nI$ $\frac{F}{l} = \frac{\mu_0}{2\pi} \frac{I_1 I_2}{r}$	<p>Topic 11 Electromagnetism</p> $V = k \frac{q}{r} = \frac{1}{4\pi\epsilon_0} \frac{q}{r}$ $E = -\frac{\Delta V}{\Delta x}$ $\Phi = BA \cos \theta$ $\mathcal{E} = Bvl$ $\mathcal{E} = -N \frac{\Delta \Phi}{\Delta t}$ $\frac{V_p}{V_s} = \frac{N_p}{N_s}$ $I_{\text{rms}} = \frac{I_0}{\sqrt{2}}$ $V_{\text{rms}} = \frac{V_0}{\sqrt{2}}$

Options Standard Level

Option A Mechanics extension

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

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

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

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

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

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

$$F_{\text{fr}} \leq \mu_s F_N$$

$$F_{\text{fr}} = \mu_k F_N$$

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

Option B Quantum physics and nuclear physics

$$E = hf$$

$$hf = \phi + E_{k_{\text{max}}}$$

$$hf = hf_0 + eV_s$$

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

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

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

Options Standard Level

Option C Energy extension

$$\Delta W = p\Delta V$$

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

+ ΔQ = thermal energy transferred to the system

+ ΔU = increase in internal energy of the system

+ ΔW = work done by the system

$$\text{efficiency} = \frac{Q_h - Q_c}{Q_h}$$

$$\frac{Q_h}{T_h} = \frac{Q_c}{T_c} \quad (\text{Carnot cycle})$$

$$\text{efficiency} = \frac{T_h - T_c}{T_h} \quad (\text{Carnot cycle})$$

$$\text{power} = \frac{1}{2}\rho Av^3$$

Options Standard Level/Higher Level

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

Options Standard Level/Higher Level

Core (SL + HL)	Extension (HL only)
<p>Option F Astrophysics</p> $L = \sigma AT^4$ $\lambda_{\text{max}} (\text{metres}) = \frac{2.90 \times 10^{-3}}{T (\text{kelvin})}$ $d (\text{parsec}) = \frac{1}{p (\text{arc-second})}$ $b = \frac{L}{4\pi d^2}$	$v = Hd$ $\frac{\Delta\lambda}{\lambda} \equiv \frac{v}{c}$
<p>Option G Relativity</p> $\gamma = \frac{1}{\sqrt{1 - \frac{v^2}{c^2}}}$ $\Delta t = \gamma \Delta t_0$ $L = \frac{L_0}{\gamma}$ $u'_x = \frac{u_x - v}{1 - \frac{u_x v}{c^2}}$ $m = \gamma m_0$ $E_0 = m_0 c^2$ $E = mc^2$	$p = \gamma m_0 u$ $E^2 = p^2 c^2 + m_0^2 c^4$ $\frac{\Delta f}{f} = \frac{g \Delta h}{c^2}$ $R_{\text{Sch}} = \frac{2GM}{c^2}$

Options Standard Level/Higher Level

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