Physics

First examinations 2009
Last examinations 2015

Diploma Programme

Data booklet

IBO

Diploma Programme

Physics
Data booklet

First examinations 2009
Last examinations 2015

International Baccalaureate Organization

Buenos Aires Cardiff Geneva New York Singapore

Diploma Programme
Physics—data booklet

Published September 2007
Revised edition published January 2015

International Baccalaureate Organization
Peterson House, Malthouse Avenue, Cardiff Gate
Cardiff, Wales GB CF23 8GL
United Kingdom
Phone: +44 29 2054 7777
Fax: +44 29 2054 7778
Web site: http://www.ibo.org

The International Baccalaureate Organization (IBO) was established in 1968 and is a non-profit, international educational foundation registered in Switzerland.

The IBO is grateful for permission to reproduce and/or translate any copyright material used in this publication. Acknowledgments are included, where appropriate, and, if notified, the IBO will be pleased to rectify any errors or omissions at the earliest opportunity.

IBO merchandise and publications in its official and working languages can be purchased through the IB store at http://store.ibo.org. General ordering queries should be directed to the sales and marketing department in Cardiff.

Phone: +44 29 2054 7746
Fax: +44 29 2054 7779
E-mail: sales@ibo.org

Contents

Fundamental constants

Quantity	Symbol	Approximate value
Acceleration of free fall (Earth's surface)	g	$9.81\,\text{m}\,\text{s}^{-2}$
Gravitational constant	G	$6.67\times10^{-11}\,\text{N m}^2\,\text{kg}^{-2}$
Avogadro's constant	N_A	$6.02\times10^{23}\,\text{mol}^{-1}$
Gas constant	R	$8.31\,\text{J K}^{-1}\,\text{mol}^{-1}$
Boltzmann's constant	k	$1.38\times10^{-23}\,\text{J K}^{-1}$
Stefan–Boltzmann constant	σ	$5.67\times10^{-8}\,\text{W m}^{-2}\,\text{K}^{-4}$
Coulomb constant	k	$8.99\times10^{9}\,\text{N m}^2\,\text{C}^{-2}$
Permittivity of free space	ε_0	$8.85\times10^{-12}\,\text{C}^2\,\text{N}^{-1}\,\text{m}^{-2}$
Permeability of free space	μ_0	$4\pi\times10^{-7}\,\text{T m A}^{-1}$
Speed of light in vacuum	c	$3.00\times10^{8}\,\text{m s}^{-1}$
Planck's constant	h	$6.63\times10^{-34}\,\text{J s}$
Elementary charge	e	$1.60\times10^{-19}\,\text{C}$
Electron rest mass	m_e	$9.110\times10^{-31}\,\text{kg} = 0.000549\,\text{u} = 0.511\,\text{MeV c}^{-2}$
Proton rest mass	m_p	$1.673\times10^{-27}\,\text{kg} = 1.007276\,\text{u} = 938\,\text{MeV c}^{-2}$
Neutron rest mass	m_n	$1.675\times10^{-27}\,\text{kg} = 1.008665\,\text{u} = 940\,\text{MeV c}^{-2}$
Unified atomic mass unit	u	$1.661\times10^{-27}\,\text{kg} = 931.5\,\text{MeV c}^{-2}$

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) $= 9.46 \times 10^{15}$ m

1 parsec (pc) $= 3.26$ ly

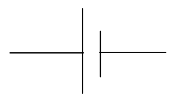
1 astronomical unit (AU) $= 1.50 \times 10^{11}$ m

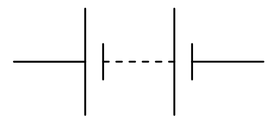
1 radian (rad) $= \dfrac{180^\circ}{\pi}$

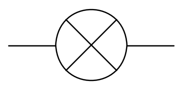
1 kilowatt-hour (kW h) $= 3.60 \times 10^{6}$ J

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

Electrical circuit symbols

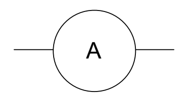
cell 

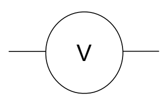
battery 

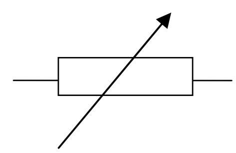
lamp 

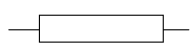
ac supply 

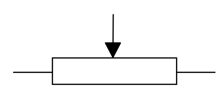
switch 

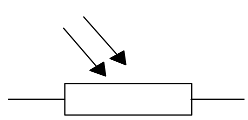
ammeter 

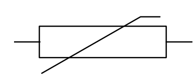
voltmeter 

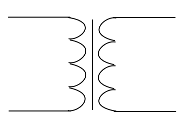
variable resistor 

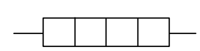
resistor 

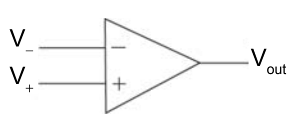
potentiometer 

light-dependent resistor (LDR) 

thermistor 

transformer 

heating element 

operational amplifier (op-amp) 

Equations—Core and AHL

Note: All equations relate to the magnitude of the quantities only. Vector notation has not been used.

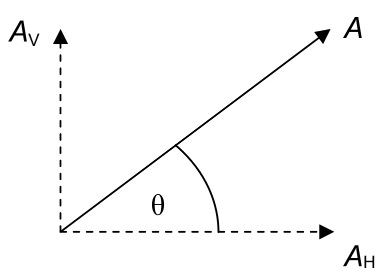
Core	AHL
Topic 1: Physics and physical measurement	

If $y = a \pm b$

then $\Delta y = \Delta a + \Delta b$

If $y = \dfrac{ab}{c}$

then $\dfrac{\Delta y}{y} = \dfrac{\Delta a}{a} + \dfrac{\Delta b}{b} + \dfrac{\Delta c}{c}$



$A_H = A\cos\theta$

$A_V = A\sin\theta$

Core	AHL
Topic 2: Mechanics $s=\frac{u+v}{2}t$ $s=ut+\frac{1}{2}at^2$ $v^2=u^2+2as$ $F=ma$ $p=mv$ $F=\frac{\Delta p}{\Delta t}$ Impulse $=F\Delta t=m\Delta v$ $W=Fs\cos\theta$ $E_K=\frac{1}{2}mv^2$ $E_K=\frac{p^2}{2m}$ $\Delta E_P=mg\Delta h$ power $=Fv$ $a=\frac{v^2}{r}=\frac{4\pi^2 r}{T^2}$	
Topic 3: Thermal physics $P=\frac{F}{A}$ $Q=mc\Delta T$ $Q=mL$	**Topic 10: Thermal physics** $PV=nRT$ $W=P\Delta V$ $Q=\Delta U+W$

Core	AHL
Topic 4: Oscillations and waves	**Topic 11: Wave phenomena**
$\omega = \frac{2\pi}{T}$	$f' = f\left(\frac{v}{v \pm u_s}\right)$ moving source
$x = x_0 \sin \omega t$; $x = x_0 \cos \omega t$	$f' = f\left(\frac{v \pm u_o}{v}\right)$ moving observer
$v = v_0 \cos \omega t$; $v = -v_0 \sin \omega t$	$\Delta f = \frac{v}{c} f$
$v = \pm\omega\sqrt{(x_0{}^2 - x^2)}$	$\theta = \frac{\lambda}{b}$
$E_K = \frac{1}{2} m\omega^2 (x_0{}^2 - x^2)$	$\theta = 1.22 \frac{\lambda}{b}$
$E_{K(max)} = \frac{1}{2} m\omega^2 x_0^2$	$I = I_0 \cos^2 \theta$
$E_T = \frac{1}{2} m\omega^2 x_0^2$	$n = \tan \phi$
$v = f\lambda$	
$\frac{n_1}{n_2} = \frac{\sin\theta_2}{\sin\theta_1} = \frac{v_2}{v_1}$	
path difference $= n\lambda$	
path difference $= \left(n + \frac{1}{2}\right)\lambda$	

Core	AHL
Topic 5: Electric currents $Ve = \frac{1}{2}mv^2$ $I = \frac{\Delta q}{\Delta t}$ $R = \frac{V}{I}$ $R = \frac{\rho L}{A}$ $P = VI = I^2 R = \frac{V^2}{R}$ $\varepsilon = I(R + r)$ $R = R_1 + R_2 + \cdots$ $\frac{1}{R} = \frac{1}{R_1} + \frac{1}{R_2} + \cdots$	**Topic 12: Electromagnetic induction** $\Phi = BA\cos\theta$ $\varepsilon = Bvl$ $\varepsilon = -N\frac{\Delta\Phi}{\Delta t}$ $\frac{I_s}{I_p} = \frac{V_p}{V_s} = \frac{N_p}{N_s}$ $I_{rms} = \frac{I_0}{\sqrt{2}}$ $V_{rms} = \frac{V_0}{\sqrt{2}}$ $R = \frac{V_0}{I_0} = \frac{V_{rms}}{I_{rms}}$ $P_{max} = I_0 V_0$ $P_{av} = \frac{1}{2}I_0 V_0$
Topic 6: Fields and forces	**Topic 9: Motion in fields**

Topic 6: Fields and forces

$F = G\frac{m_1 m_2}{r^2}$	$F = k\frac{q_1 q_2}{r^2}$
$g = \frac{F}{m}$	$E = \frac{F}{q}$

$F = \frac{q_1 q_2}{4\pi\varepsilon_0 r^2}$

$F = qvB\sin\theta$

$F = BIL\sin\theta$

Topic 9: Motion in fields

$\Delta V = \frac{\Delta E_p}{m}$	$\Delta V = \frac{\Delta E_p}{q}$
$V = -\frac{Gm}{r}$	$V = \frac{kq}{r} = \frac{q}{4\pi\varepsilon_0 r}$
$g = -\frac{\Delta V}{\Delta r}$	$E = -\frac{\Delta V}{\Delta x}$

Core	AHL
Topic 7: Atomic and nuclear physics $E = mc^2$	**Topic 13: Quantum physics and nuclear physics** $E = hf$ $hf = \phi + E_{max}$ $hf = hf_0 + eV$ $p = \frac{h}{\lambda}$ $E_K = \frac{n^2 h^2}{8 m_e L^2}$ $\Delta x \Delta p \geq \frac{h}{4\pi}$ $\Delta E \Delta t \geq \frac{h}{4\pi}$ $N = N_0 e^{-\lambda t}$ $A = -\frac{\Delta N}{\Delta t}$ $A = \lambda N = \lambda N_0 e^{-\lambda t}$ $T_{\frac{1}{2}} = \frac{\ln 2}{\lambda}$

Core	AHL
Topic 8: Energy, power and climate change $\text{power} = \frac{1}{2} A\rho v^3$ $\text{power per unit length} = \frac{1}{2} A^2 \rho g v$ $I = \frac{\text{power}}{A}$ $\text{albedo} = \frac{\text{total scattered power}}{\text{total incident power}}$ $C_s = \frac{Q}{A\Delta T}$ $\text{power} = \sigma A T^4$ $\text{power} = e\sigma A T^4$ $\Delta T = \frac{(I_{in} - I_{out})\Delta t}{C_s}$	

Equations—Options SL

Option A: Sight and wave phenomena

$f' = f\left(\dfrac{v}{v \pm u_s}\right)$ moving source

$f' = f\left(\dfrac{v \pm u_o}{v}\right)$ moving observer

$\Delta f = \dfrac{v}{c} f$

$\theta = \dfrac{\lambda}{b}$

$\theta = 1.22\dfrac{\lambda}{b}$

$I = I_0 \cos^2 \theta$

$n = \tan \phi$

Option B: Quantum physics and nuclear physics

$E = hf$

$hf = \phi + E_{max}$

$hf = hf_0 + eV$

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

$E_K = \dfrac{n^2 h^2}{8 m_e L^2}$

$\Delta x \Delta p \geq \dfrac{h}{4\pi}$

$\Delta E \Delta t \geq \dfrac{h}{4\pi}$

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

$A = -\dfrac{\Delta N}{\Delta t}$

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

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

Option C: Digital technology

$G = -\dfrac{R_F}{R}$

$G = 1 + \dfrac{R_F}{R}$

Option D: Relativity and particle physics

$$\gamma = \frac{1}{\sqrt{1 - \frac{v^2}{c^2}}}$$

$$\Delta t = \gamma \Delta t_0$$

$$L = \frac{L_0}{\gamma}$$

$$\Delta E \, \Delta t \geq \frac{h}{4\pi}$$

$$R \approx \frac{h}{4\pi mc}$$

$$E = hf$$

Equations—Options SL and HL

Core (SL and HL)	Extension (HL only)
Option E: Astrophysics	
$L = \sigma A T^4$	$L \propto m^n$ where $3 < n < 4$
$\lambda_{\text{max}}\,(\text{metres}) = \dfrac{2.90 \times 10^{-3}}{T\,(\text{kelvin})}$	$\dfrac{\Delta\lambda}{\lambda} \cong \dfrac{v}{c}$
$d\,(\text{parsec}) = \dfrac{1}{p\,(\text{arc-second})}$	$v = H_0 d$
$b = \dfrac{L}{4\pi d^2}$	
$m - M = 5 \lg \left(\dfrac{d}{10}\right)$	
Option F: Communications	
$n = \dfrac{1}{\sin C}$	$G = -\dfrac{R_F}{R}$
attenuation / dB $= 10 \lg \dfrac{I_1}{I_2}$	$G = 1 + \dfrac{R_F}{R}$

Core (SL and HL)	Extension (HL only)
Option G: Electromagnetic waves	
$\frac{1}{f}=\frac{1}{v}+\frac{1}{u}$	$\lambda_{\text{min}}=\frac{hc}{eV}$
$P=\frac{1}{f}$	$2d\sin\theta=n\lambda$
$\text{m}=\frac{h_{\text{i}}}{h_{\text{o}}}=-\frac{v}{u}$ $\quad M=\frac{\theta_{\text{i}}}{\theta_{\text{o}}}$	$2nt=m\lambda$
$M=\frac{f_{\text{o}}}{f_{\text{e}}}$	$2nt=\left(m+\frac{1}{2}\right)\lambda$
$m=\frac{D}{f}+1$ $\quad m=\frac{D}{f}$	$2nt\cos\phi=m\lambda$
$s=\frac{\lambda D}{d}$	$2nt\cos\phi=\left(m+\frac{1}{2}\right)\lambda$
$\sin\theta=\frac{n\lambda}{d}$	
$\frac{x}{D}=\frac{n\lambda}{d}$	
$\frac{x}{D}=(n+\frac{1}{2})\frac{\lambda}{d}$	
$d\sin\theta=n\lambda$	

Equations—Options HL

Option H: Relativity

$$\gamma = \frac{1}{\sqrt{1-\frac{v^2}{c^2}}}$$

$$\Delta t = \gamma \Delta t_0$$

$$L = \frac{L_0}{\gamma}$$

$$u_x' = \frac{u_x - v}{1-\frac{u_x v}{c^2}}$$

$$E_0 = m_0 c^2$$

$$E = \gamma m_0 c^2$$

$$p = \gamma m_0 u$$

$$E_K = (\gamma - 1) m_0 c^2$$

$$E^2 = p^2 c^2 + m_0^2 c^4$$

$$\frac{\Delta f}{f} = \frac{g \Delta h}{c^2}$$

$$R_s = \frac{2GM}{c^2}$$

$$\Delta t = \frac{\Delta t_0}{\sqrt{1-\frac{R_s}{r}}}$$

Option I: Medical physics

$$IL = 10 \lg \frac{I}{I_0} \quad \text{where} \quad I_0 = 1.0 \times 10^{-12}\ \text{W m}^{-2}$$

$$I = I_0 e^{-\mu x}$$

$$\mu x_{\frac{1}{2}} = \ln 2$$

dose equivalent = absorbed dose × quality factor

$$Z = \rho c$$

$$\frac{1}{T_E} = \frac{1}{T_P} + \frac{1}{T_B}$$

Option J: Particle physics

$$\Delta E \Delta t \geq \frac{h}{4\pi}$$

$$R \approx \frac{h}{4\pi mc}$$

$$E = hf$$

$$E = mc^2 + E_K$$

$$E_a^2 = 2Mc^2E + (Mc^2)^2 + (mc^2)^2$$

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

$$E_K = \tfrac{3}{2}kT$$