IB Physics

SL formula booklet

The complete IB Physics data booklet, SL content only

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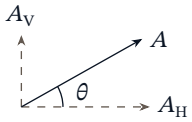
Mathematical equations

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

Uncertainties

Sum or difference: add absolute uncertainties	If $y = a \pm b$, then $\Delta y = \Delta a + \Delta b$
Product or quotient: add fractional uncertainties	If $y = \frac{ab}{c}$, then $\frac{\Delta y}{y} = \frac{\Delta a}{a} + \frac{\Delta b}{b} + \frac{\Delta c}{c}$
Power: multiply the fractional uncertainty by the power	If $y = a^n$, then $\frac{\Delta y}{y} = \left\lvert n\frac{\Delta a}{a}\right\rvert$

Metric (SI) multipliers

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

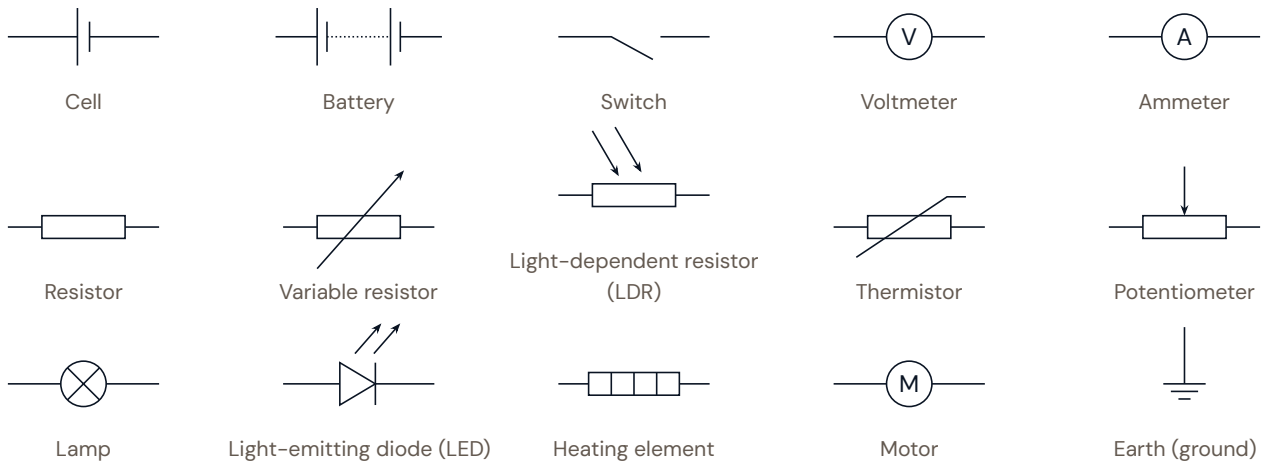
Unit conversions

Radian in degrees	1 radian (rad) $\equiv \frac{180°}{\pi}$
Kelvin from degrees Celsius	Temperature (K) = temperature (°C) + 273
Light year	1 light year (ly) = 9.46×10^{15} m
Parsec	1 parsec (pc) = 3.26 ly
Astronomical unit	1 astronomical unit (AU) = 1.50×10^{11} m
Kilowatt-hour	1 kilowatt-hour (kWh) = 3.60×10^{6} J
Planck constant times speed of light	$hc = 1.99 \times 10^{-25}$ J m = 1.24×10^{-6} eV m

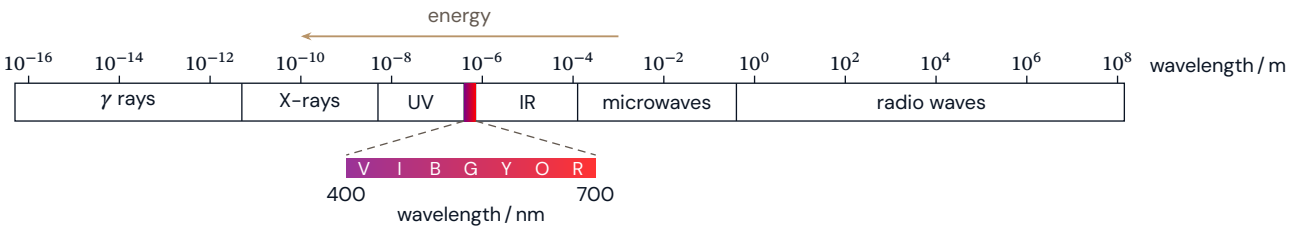
Fundamental constants

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

Electrical circuit symbols



Electromagnetic spectrum



A. Space, time and motion

All equations give magnitudes only: vector notation is not used.

A.1 KINEMATICS

SUVAT: displacement from average velocity	$s = \frac{u+v}{2}t$
SUVAT: final velocity	$v = u + at$
SUVAT: displacement from initial velocity	$s = ut + \frac{1}{2}at^2$
SUVAT: velocity and displacement (no time)	$v^2 = u^2 + 2as$

A.2 FORCES AND MOMENTUM

Static friction (up to a maximum)	$F_\mathrm{f} \leq \mu_\mathrm{s} F_\mathrm{N}$
Dynamic (kinetic) friction	$F_\mathrm{f} = \mu_\mathrm{d} F_\mathrm{N}$
Hooke's law	$F_\mathrm{H} = -kx$
Stokes' drag on a sphere	$F_\mathrm{d} = 6\pi\eta r v$
Buoyancy force (Archimedes' principle)	$F_\mathrm{b} = \rho V g$
Weight	$F_\mathrm{g} = mg$
Linear momentum	$p = mv$
Impulse	$J = F\Delta t$
Newton's second law	$F = ma = \frac{\Delta p}{\Delta t}$
Centripetal acceleration	$a = \frac{v^2}{r} = \omega^2 r = \frac{4\pi^2 r}{T^2}$
Speed in circular motion	$v = \frac{2\pi r}{T} = \omega r$

A.3 WORK, ENERGY AND POWER

Work done by a constant force	$W = Fs\cos\theta$
Kinetic energy	$E_\mathrm{k} = \frac{1}{2}mv^2 = \frac{p^2}{2m}$
Change in gravitational potential energy	$\Delta E_\mathrm{p} = mg\Delta h$
Elastic potential energy	$E_\mathrm{H} = \frac{1}{2}k\Delta x^2$
Power	$P = \frac{\Delta W}{\Delta t} = Fv$
Efficiency	$\eta = \frac{\text{useful work out}}{\text{total work in}} = \frac{\text{useful power out}}{\text{total power in}}$

B. The particulate nature of matter

B.1 THERMAL ENERGY TRANSFERS

Density	$\rho = \frac{m}{V}$
Mean kinetic energy of a gas particle	$\overline{E_\mathrm{k}} = \frac{3}{2}k_\mathrm{B}T$
Specific heat capacity	$Q = mc\Delta T$
Specific latent heat	$Q = mL$
Rate of thermal conduction	$\frac{\Delta Q}{\Delta t} = -kA\frac{\Delta T}{\Delta x}$

Stefan–Boltzmann law (luminosity)	$L = \sigma A T^4$
Apparent brightness	$b = \frac{L}{4\pi d^2}$
Wien's displacement law	$\lambda_{\max} T = 2.9 \times 10^{-3}\ \mathrm{m\,K}$

B.2 GREENHOUSE EFFECT

Emissivity	$\text{emissivity} = \frac{\text{power radiated per unit area}}{\sigma T^4}$
Albedo	$\text{albedo} = \frac{\text{total scattered power}}{\text{total incident power}}$

B.3 GAS LAWS

Pressure	$P = \frac{F}{A}$
Amount of substance (moles)	$n = \frac{N}{N_\mathrm{A}}$
Combined gas law (fixed amount of gas)	$\frac{PV}{T} = \text{constant}$
Ideal gas equation	$PV = nRT = Nk_\mathrm{B}T$
Kinetic theory: pressure of an ideal gas	$P = \frac{1}{3}\rho v^2$
Internal energy of an ideal monatomic gas	$U = \frac{3}{2}nRT = \frac{3}{2}Nk_\mathrm{B}T$

B.5 CURRENT AND CIRCUITS

Electric current	$I = \frac{\Delta q}{\Delta t}$
Potential difference	$V = \frac{W}{q}$
Resistance	$R = \frac{V}{I}$
Resistivity	$\rho = \frac{RA}{L}$
Electrical power	$P = IV = I^2R = \frac{V^2}{R}$

Series and parallel circuits: current, potential difference, resistance	SERIES CIRCUITS	PARALLEL CIRCUITS
	$I = I_1 = I_2 = \ldots$	$I = I_1 + I_2 + \ldots$
	$V = V_1 + V_2 + \ldots$	$V = V_1 = V_2 = \ldots$
	$R_\mathrm{s} = R_1 + R_2 + \ldots$	$\frac{1}{R_\mathrm{p}} = \frac{1}{R_1} + \frac{1}{R_2} + \ldots$

EMF and internal resistance	$\varepsilon = I(R + r)$

C. Wave behaviour

C.1 SIMPLE HARMONIC MOTION

Defining equation of SHM	$a = -\omega^2 x$
Period, frequency and angular frequency	$T = \frac{1}{f} = \frac{2\pi}{\omega}$
Period of a mass on a spring	$T = 2\pi\sqrt{\frac{m}{k}}$
Period of a simple pendulum	$T = 2\pi\sqrt{\frac{l}{g}}$

C.2 WAVE MODEL

Wave equation	$v = f\lambda = \frac{\lambda}{T}$

C.3 WAVE PHENOMENA

Snell's law (refraction)	$\frac{n_1}{n_2} = \frac{\sin\theta_2}{\sin\theta_1} = \frac{v_2}{v_1}$
Constructive interference	$\text{path difference} = n\lambda$
Destructive interference	$\text{path difference} = \left(n + \frac{1}{2}\right)\lambda$
Double-slit fringe spacing	$s = \frac{\lambda D}{d}$

C.5 DOPPLER EFFECT

Doppler effect for light ($v \ll c$)	$\frac{\Delta f}{f} = \frac{\Delta\lambda}{\lambda} \approx \frac{v}{c}$

D. Fields

D.1 GRAVITATIONAL FIELDS

Newton's law of gravitation	$F = G\frac{m_1 m_2}{r^2}$
Gravitational field strength	$g = \frac{F}{m} = G\frac{M}{r^2}$

D.2 ELECTRIC AND MAGNETIC FIELDS

Coulomb's law	$F = k\frac{q_1 q_2}{r^2} \quad \text{where } k = \frac{1}{4\pi\varepsilon_0}$
Electric field strength	$E = \frac{F}{q}$
Uniform field between parallel plates	$E = \frac{V}{d}$

D.3 MOTION IN ELECTROMAGNETIC FIELDS

Magnetic force on a moving charge	$F = qvB\sin\theta$
Magnetic force on a current-carrying wire	$F = BIL\sin\theta$
Force per unit length between parallel wires	$\frac{F}{L} = \mu_0\frac{I_1 I_2}{2\pi r}$

E. Nuclear and quantum physics

E.1 STRUCTURE OF THE ATOM

Photon energy	$E = hf$

E.3 RADIOACTIVE DECAY

Mass–energy equivalence	$E = mc^2$

E.5 FUSION AND STARS

Distance from stellar parallax	$d\,(\text{parsec}) = \frac{1}{p\,(\text{arc-second})}$