IB Physics SL *one-page formula sheet*

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Mathematical equations

Triangle; circle

$A = \frac{1}{2}(bh)$ (b base, h height) $A = \pi r^2$ (r radius)
$C = 2\pi r$

Cuboid; prism

$V = lwh$ (l length, w width, h height) $V = Ah$ (A area of cross-section)

Sphere; cylinder $V = \frac{4}{3}\pi r^3$ $V = \pi r^2 h$ $A = 2\pi rh$

Vector components $A_H = A\cos\theta$ $A_V = A\sin\theta$

Trigonometry $\tan\theta = \frac{\sin\theta}{\cos\theta}$ $\sin^2\theta + \cos^2\theta = 1$

Uncertainties

Sum or difference If $y = a \pm b$, then $\Delta y = \Delta a + \Delta b$

Product or quotient

If $y = \frac{ab}{c}$, then $\frac{\Delta y}{y} = \frac{\Delta a}{a} + \frac{\Delta b}{b} + \frac{\Delta c}{c}$

Power If $y = a^n$, then $\frac{\Delta y}{y} = \left|n\frac{\Delta a}{a}\right|$

Metric (SI) multipliers

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

Unit conversions

1 radian (rad) $\equiv \frac{180°}{\pi}$

Temperature (K) = temperature (°C) + 273

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 kilowatt-hour (kWh) = 3.60×10^{6} J

$hc = 1.99 \times 10^{-25}$ J m = 1.24×10^{-6} eV m

Fundamental constants

Free-fall acceleration	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	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	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 9.110×10^{-31} kg = 0.000549 u = 0.511 MeV c^{-2}

Proton rest mass
m_p 1.673×10^{-27} kg = 1.007276 u = 938 MeV c^{-2}

Neutron rest mass
m_n 1.675×10^{-27} kg = 1.008665 u = 940 MeV c^{-2}

Atomic mass unit u 1.661×10^{-27} kg = 931.5 MeV c^{-2}

Solar constant S $1.36 \times 10^{3}\ \mathrm{W\,m^{-2}}$

Fermi radius R_0 1.20×10^{-15} m

A. Space, time and motion

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

A.1 KINEMATICS

SUVAT $s = \frac{u+v}{2}t$ $v = u + at$ $s = ut + \frac{1}{2}at^2$
$v^2 = u^2 + 2as$

A.2 FORCES AND MOMENTUM

Static friction $F_f \le \mu_s F_N$ | Dynamic friction $F_f = \mu_d F_N$

Hooke's law $F_H = -kx$ | Stokes' drag $F_d = 6\pi\eta rv$

Buoyancy $F_b = \rho Vg$ | Weight $F_g = mg$

Momentum $p = mv$ | Impulse $J = F\Delta t$

Newton's second law $F = ma = \frac{\Delta p}{\Delta t}$

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

A.3 WORK, ENERGY AND POWER

Work $W = Fs\cos\theta$ | Power $P = \frac{\Delta W}{\Delta t} = Fv$

Kinetic energy $E_k = \frac{1}{2}mv^2 = \frac{p^2}{2m}$ | Change in GPE $\Delta E_p = mg\Delta h$

Elastic PE $E_H = \frac{1}{2}k\Delta x^2$

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 particle KE $\overline{E_k} = \frac{3}{2}k_B T$

Specific heat $Q = mc\Delta T$ | Latent heat $Q = mL$

Conduction $\frac{\Delta Q}{\Delta t} = -kA\frac{\Delta T}{\Delta x}$ | Luminosity $L = \sigma AT^4$

Apparent brightness $b = \frac{L}{4\pi d^2}$ | Wien's law $\lambda_{max}T = 2.9 \times 10^{-3}$ 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 $P = \frac{F}{A}$ | Moles $n = \frac{N}{N_A}$

Fixed amount of gas $\frac{PV}{T} = \text{constant}$ | Ideal gas $PV = nRT = Nk_B T$

Kinetic theory $P = \frac{1}{3}\rho v^2$ | Internal energy (monatomic) $U = \frac{3}{2}nRT = \frac{3}{2}Nk_B T$

B.5 CURRENT AND CIRCUITS

Current $I = \frac{\Delta q}{\Delta t}$ | Potential difference $V = \frac{W}{q}$

Resistance $R = \frac{V}{I}$ | Resistivity $\rho = \frac{RA}{L}$

Power $P = IV = I^2R = \frac{V^2}{R}$ | EMF $\varepsilon = I(R + r)$

Series $I = I_1 = I_2 = \ldots$ $V = V_1 + V_2 + \ldots$
$R_s = R_1 + R_2 + \ldots$

Parallel $I = I_1 + I_2 + \ldots$ $V = V_1 = V_2 = \ldots$
$\frac{1}{R_p} = \frac{1}{R_1} + \frac{1}{R_2} + \ldots$

C. Wave behaviour

C.1 SIMPLE HARMONIC MOTION

SHM $a = -\omega^2 x$ | Period $T = \frac{1}{f} = \frac{2\pi}{\omega}$

Mass on spring $T = 2\pi\sqrt{\frac{m}{k}}$ | Pendulum $T = 2\pi\sqrt{\frac{l}{g}}$

C.2 WAVE MODEL C.3 WAVE PHENOMENA

Wave equation $v = f\lambda = \frac{\lambda}{T}$ | Double-slit $s = \frac{\lambda D}{d}$

Snell's law $\frac{n_1}{n_2} = \frac{\sin\theta_2}{\sin\theta_1} = \frac{v_2}{v_1}$

Constructive; destructive
path difference $= n\lambda$ path difference $= \left(n + \frac{1}{2}\right)\lambda$

C.5 DOPPLER EFFECT

Light ($v \ll c$) $\frac{\Delta f}{f} = \frac{\Delta\lambda}{\lambda} \approx \frac{v}{c}$

D. Fields

D.1 GRAVITATIONAL FIELDS

Gravitation $F = G\frac{m_1 m_2}{r^2}$ | Field strength $g = \frac{F}{m} = G\frac{M}{r^2}$

D.2 ELECTRIC AND MAGNETIC FIELDS

Coulomb's law $F = k\frac{q_1 q_2}{r^2}$ where $k = \frac{1}{4\pi\varepsilon_0}$

Field strength $E = \frac{F}{q}$ | Parallel plates $E = \frac{V}{d}$

D.3 MOTION IN ELECTROMAGNETIC FIELDS

On a charge $F = qvB\sin\theta$ | On a wire $F = BIL\sin\theta$

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 E.5 FUSION AND STARS

Mass-energy $E = mc^2$

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