

Diploma Programme

Data booklet



Diploma Programme

Physics
Data booklet

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Contents

Fundamental constants	1
Metric (SI) multipliers	2
Unit conversions	3
Electrical circuit symbols	4
Equations—Core and AHL	5
Equations—Options SL	11
Equations—Options SL and HL	13
Equations—Options HL	15

Fundamental constants

Quantity	Symbol	Approximate value
Acceleration of free fall (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	$6.63 \times 10^{-34} \text{ J s}$
Elementary charge	e	$1.60 \times 10^{-19} \text{ C}$
Electron rest mass	m_e	$9.110 \times 10^{-31} \text{ kg} = 0.000549 \text{ u} = 0.511 \text{ MeV c}^{-2}$
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

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

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


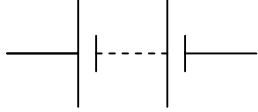
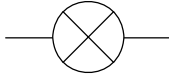

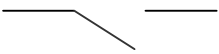
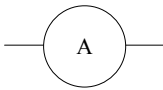
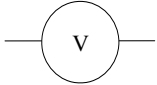
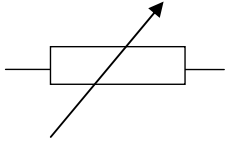

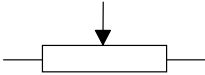
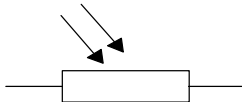
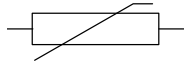
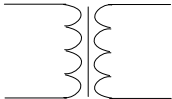

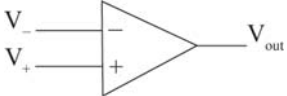
$$1 \text{ astronomical unit (AU)} = 1.50 \times 10^{11} \text{ m}$$

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

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

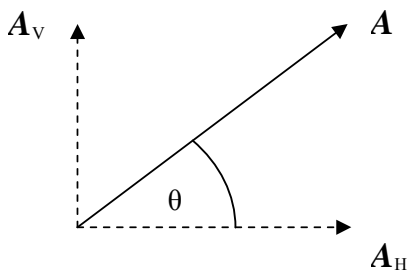
$$1 \text{ atm} = 1.01 \times 10^5 \text{ N m}^{-2} = 101 \text{ kPa} = 760 \text{ mm Hg}$$

Electrical circuit symbols

cell		battery	
lamp		ac supply	
switch		ammeter	
voltmeter		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
<p>Topic 1: Physics and physical measurement</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>$A_H = A \cos \theta$ $A_V = A \sin \theta$</p>	

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

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

Core	AHL										
<p>Topic 5: Electric currents</p> $K_e = \frac{1}{2}mv^2$ $I = \frac{\Delta q}{\Delta t}$ $R = \frac{V}{I}$ $R = \frac{\rho L}{A}$ $P = VI = I^2R = \frac{V^2}{R}$ $\mathcal{E} = I(R+r)$ $R = R_1 + R_2 + \dots$ $\frac{1}{R} = \frac{1}{R_1} + \frac{1}{R_2} + \dots$	<p>Topic 12: Electromagnetic induction</p> $\Phi = BA \cos \theta$ $\mathcal{E} = Bvl$ $\mathcal{E} = -N \frac{\Delta \Phi}{\Delta t}$ $\frac{I_s}{I_p} = \frac{V_p}{V_s} = \frac{N_p}{N_s}$ $I_{\text{rms}} = \frac{I_0}{\sqrt{2}}$ $V_{\text{rms}} = \frac{V_0}{\sqrt{2}}$ $R = \frac{V_0}{I_0} = \frac{V_{\text{rms}}}{I_{\text{rms}}}$ $P_{\text{max}} = I_0V_0$ $P_{\text{av}} = \frac{1}{2}I_0V_0$										
<p>Topic 6: Fields and forces</p> <table border="1" data-bbox="261 1266 786 1543"> <tbody> <tr> <td data-bbox="261 1266 522 1402">$F = G \frac{m_1m_2}{r^2}$</td> <td data-bbox="522 1266 786 1402">$F = k \frac{q_1q_2}{r^2}$</td> </tr> <tr> <td data-bbox="261 1402 522 1543">$g = \frac{F}{m}$</td> <td data-bbox="522 1402 786 1543">$E = \frac{F}{q}$</td> </tr> </tbody> </table> $F = \frac{q_1q_2}{4\pi\epsilon_0r^2}$ $F = qvB \sin \theta$ $F = BIL \sin \theta$	$F = G \frac{m_1m_2}{r^2}$	$F = k \frac{q_1q_2}{r^2}$	$g = \frac{F}{m}$	$E = \frac{F}{q}$	<p>Topic 9: Motion in fields</p> <table border="1" data-bbox="873 1266 1305 1719"> <tbody> <tr> <td data-bbox="873 1266 1089 1415">$\Delta V = \frac{\Delta E_p}{m}$</td> <td data-bbox="1089 1266 1305 1415">$\Delta V = \frac{\Delta E_p}{q}$</td> </tr> <tr> <td data-bbox="873 1415 1089 1564">$V = -\frac{Gm}{r}$</td> <td data-bbox="1089 1415 1305 1564">$V = \frac{kq}{r} = \frac{q}{4\pi\epsilon_0r}$</td> </tr> <tr> <td data-bbox="873 1564 1089 1719">$g = -\frac{\Delta V}{\Delta r}$</td> <td data-bbox="1089 1564 1305 1719">$E = -\frac{\Delta V}{\Delta x}$</td> </tr> </tbody> </table>	$\Delta V = \frac{\Delta E_p}{m}$	$\Delta V = \frac{\Delta E_p}{q}$	$V = -\frac{Gm}{r}$	$V = \frac{kq}{r} = \frac{q}{4\pi\epsilon_0r}$	$g = -\frac{\Delta V}{\Delta r}$	$E = -\frac{\Delta V}{\Delta x}$
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$g = -\frac{\Delta V}{\Delta r}$	$E = -\frac{\Delta V}{\Delta x}$										

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

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

Equations—Options SL

Option A: Sight and wave phenomena

$$f' = f \left(\frac{v}{v \pm u_s} \right) \quad \text{moving source} \quad \theta = \frac{\lambda}{b}$$

$$f' = f \left(\frac{v \pm u_o}{v} \right) \quad \text{moving observer} \quad \theta = 1.22 \frac{\lambda}{b}$$

$$\Delta f = \frac{v}{c} f \quad I = I_0 \cos^2 \theta$$

$$n = \tan \phi$$

Option B: Quantum physics and nuclear physics

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

$$hf = \phi + E_{\max} \quad N = N_0 e^{-\lambda t}$$

$$hf = hf_0 + eV \quad A = -\frac{\Delta N}{\Delta t}$$

$$p = \frac{h}{\lambda} \quad A = \lambda N = \lambda N_0 e^{-\lambda t}$$

$$E_k = \frac{n^2 h^2}{8m_e L^2} \quad T_{\frac{1}{2}} = \frac{\ln 2}{\lambda}$$

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

Option C: Digital technology

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

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

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

Core (SL and HL)	Extension (HL only)
<p>Option G: Electromagnetic waves</p> $\frac{1}{f} = \frac{1}{v} + \frac{1}{u}$ $P = \frac{1}{f}$ $m = \frac{h_i}{h_o} = -\frac{v}{u} \quad M = \frac{\theta_i}{\theta_o}$ $M = \frac{f_o}{f_e}$ $m = \frac{D}{f} + 1 \quad m = \frac{D}{f}$ $s = \frac{\lambda D}{d}$ $\sin \theta = \frac{n\lambda}{d}$ $\frac{x}{D} = \frac{n\lambda}{d}$ $\frac{x}{D} = (n + \frac{1}{2}) \frac{\lambda}{d}$ $d \sin \theta = n\lambda$	$\lambda_{\min} = \frac{hc}{eV}$ $2d \sin \theta = n\lambda$ $2nt = m\lambda$ $2nt = (m + \frac{1}{2})\lambda$ $2nt \cos \phi = m\lambda$ $2nt \cos \phi = (m + \frac{1}{2})\lambda$

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 \times quality factor

$$Z = \rho c$$

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

Option J: Particle physics

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

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

$$E = hf$$

$$E = mc^2 + E_K$$

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

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

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