

Physics A

Data and Formulae Booklet

DATA

FUNDAMENTAL CONSTANTS AND VALUES

<i>Quantity</i>	<i>Symbol</i>	<i>Value</i>	<i>Units</i>
speed of light in vacuo	c	3.00×10^8	m s^{-1}
permeability of free space	μ_0	$4\pi \times 10^{-7}$	H m^{-1}
permittivity of free space	ϵ_0	8.85×10^{-12}	F m^{-1}
magnitude of the charge of electron	e	1.60×10^{-19}	C
the Planck constant	h	6.63×10^{-34}	J s
gravitational constant	G	6.67×10^{-11}	$\text{N m}^2 \text{kg}^{-2}$
the Avogadro constant	N_A	6.02×10^{23}	mol^{-1}
molar gas constant	R	8.31	$\text{J K}^{-1} \text{mol}^{-1}$
the Boltzmann constant	k	1.38×10^{-23}	J K^{-1}
the Stefan constant	σ	5.67×10^{-8}	$\text{W m}^{-2} \text{K}^{-4}$
the Wien constant	α	2.90×10^{-3}	m K
electron rest mass (equivalent to 5.5×10^{-4} u)	m_e	9.11×10^{-31}	kg
electron charge/mass ratio	e/m_e	1.76×10^{11}	C kg^{-1}
proton rest mass (equivalent to 1.00728 u)	m_p	$1.67(3) \times 10^{-27}$	kg
proton charge/mass ratio	e/m_p	9.58×10^7	C kg^{-1}
neutron rest mass (equivalent to 1.00867 u)	m_n	$1.67(5) \times 10^{-27}$	kg
gravitational field strength	g	9.81	N kg^{-1}
acceleration due to gravity	g	9.81	m s^{-2}
atomic mass unit (1u is equivalent to 931.5 MeV)	u	1.661×10^{-27}	kg

GEOMETRICAL EQUATIONS

<i>arc length</i>	$= r\theta$
<i>circumference of circle</i>	$= 2\pi r$
<i>area of circle</i>	$= \pi r^2$
<i>surface area of cylinder</i>	$= 2\pi rh$
<i>volume of cylinder</i>	$= \pi r^2 h$
<i>area of sphere</i>	$= 4\pi r^2$
<i>volume of sphere</i>	$= \frac{4}{3}\pi r^3$

ASTRONOMICAL DATA

<i>Body</i>	<i>Mass/kg</i>	<i>Mean radius/m</i>
Sun	1.99×10^{30}	6.96×10^8
Earth	5.98×10^{24}	6.37×10^6

AS FORMULAE

PARTICLE PHYSICS

Rest energy values

class	name	symbol	rest energy /MeV
photon	photon	γ	0
lepton	neutrino	ν_e	0
		ν_μ	0
	electron	$e^\pm$	0.510999
	muon	$\mu^\pm$	105.659
mesons	π meson	$\pi^\pm$	139.576
		π^0	134.972
	K meson	$K^\pm$	493.821
		K^0	497.762
baryons	proton	p	938.257
	neutron	n	939.551

Properties of quarks

antiquarks have opposite signs

type	charge	baryon number	strangeness
u	$+\frac{2}{3}e$	$+\frac{1}{3}$	0
d	$-\frac{1}{3}e$	$+\frac{1}{3}$	0
s	$-\frac{1}{3}e$	$+\frac{1}{3}$	-1

Properties of leptons

	lepton number
particles: $e^-, \nu_e; \mu^-, \nu_\mu$	+1
antiparticles: $e^+, \bar{\nu}_e; \mu^+, \bar{\nu}_\mu$	-1

Photons and energy levels

photon energy $E = hf = hc/\lambda$ photoelectricity $hf = \phi + E_k$ energy levels $hf = E_1 - E_2$ de Broglie wavelength $\lambda = \frac{h}{p} = \frac{h}{mv}$

ELECTRICITY

current and pd $I = \frac{\Delta Q}{\Delta t}$ $V = \frac{W}{Q}$ $R = \frac{V}{I}$ emf $\varepsilon = \frac{E}{Q}$ $\varepsilon = I(R + r)$ resistors in series $R = R_1 + R_2 + R_3 + \dots$ resistors in parallel $\frac{1}{R} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3} + \dots$ resistivity $\rho = \frac{RA}{L}$ power $P = VI = I^2 R = \frac{V^2}{R}$ alternating current $I_{\text{rms}} = \frac{I_0}{\sqrt{2}}$ $V_{\text{rms}} = \frac{V_0}{\sqrt{2}}$

MECHANICS

moments moment = Fd velocity and acceleration $v = \frac{\Delta s}{\Delta t}$ $a = \frac{\Delta v}{\Delta t}$ equations of motion $v = u + at$ $s = \frac{(u+v)}{2}t$

$$v^2 = u^2 + 2as \quad s = ut + \frac{at^2}{2}$$

force $F = ma$ work, energy and power $W = Fs \cos \theta$ $E_k = \frac{1}{2}mv^2$ $\Delta E_p = mg\Delta h$

$$P = \frac{\Delta W}{\Delta t}, P = Fv$$

$$\text{efficiency} = \frac{\text{useful output power}}{\text{input power}}$$

MATERIALS

density $\rho = \frac{m}{V}$ Hooke's law $F = k \Delta L$ Young modulus = $\frac{\text{tensile stress}}{\text{tensile strain}}$ tensile stress = $\frac{F}{A}$
tensile strain = $\frac{\Delta L}{L}$ energy stored $E = \frac{1}{2}F\Delta L$

WAVES

wave speed $c = f\lambda$ period $T = \frac{1}{f}$ fringe spacing $w = \frac{\lambda D}{s}$ diffraction grating $d \sin \theta = n\lambda$ refractive index of a substance s, $n = \frac{c}{c_s}$ for two different substances of refractive indices n_1 and n_2 ,law of refraction $n_1 \sin \theta_1 = n_2 \sin \theta_2$ critical angle $\sin \theta_c = \frac{n_2}{n_1}$ for $n_1 > n_2$

A2 FORMULAE**MOMENTUM**

$$\text{force} \quad F = \frac{\Delta(mv)}{\Delta t}$$

$$\text{impulse} \quad F \Delta t = \Delta(mv)$$

CIRCULAR MOTION

$$\text{angular velocity} \quad \omega = \frac{v}{r}$$

$$\omega = 2\pi f$$

$$\text{centripetal acceleration} \quad a = \frac{v^2}{r} = \omega^2 r$$

$$\text{centripetal force} \quad F = \frac{mv^2}{r} = m\omega^2 r$$

OSCILLATIONS

$$\text{acceleration} \quad a = -(2\pi f)^2 x$$

$$\text{displacement} \quad x = A \cos(2\pi f t)$$

$$\text{speed} \quad v = \pm 2\pi f \sqrt{A^2 - x^2}$$

$$\text{maximum speed} \quad v_{\max} = 2\pi f A$$

$$\text{maximum acceleration} \quad a_{\max} = (2\pi f)^2 A$$

$$\text{for a mass-spring system} \quad T = 2\pi \sqrt{\frac{m}{k}}$$

$$\text{for a simple pendulum} \quad T = 2\pi \sqrt{\frac{l}{g}}$$

GRAVITATIONAL FIELDS

$$\text{force between two masses} \quad F = \frac{G m_1 m_2}{r^2}$$

$$\text{gravitational field strength} \quad g = \frac{F}{m}$$

$$\text{magnitude of gravitational field strength in a radial field} \quad g = \frac{GM}{r^2}$$

$$\text{gravitational potential} \quad \Delta W = m \Delta V$$

$$V = - \frac{GM}{r}$$

$$g = - \frac{\Delta V}{\Delta r}$$

ELECTRIC FIELDS AND CAPACITORS

$$\text{force between two point charges} \quad F = \frac{1}{4\pi\epsilon_0} \frac{Q_1 Q_2}{r^2}$$

$$\text{force on a charge} \quad F = EQ$$

$$\text{field strength for a uniform field} \quad E = \frac{V}{d}$$

$$\text{field strength for a radial field} \quad E = \frac{Q}{4\pi\epsilon_0 r^2}$$

$$\text{electric potential} \quad \Delta W = Q \Delta V$$

$$V = \frac{1}{4\pi\epsilon_0} \frac{Q}{r}$$

$$\text{capacitance} \quad C = \frac{Q}{V}$$

$$\text{decay of charge} \quad Q = Q_0 e^{-t/RC}$$

$$\text{time constant} \quad RC$$

$$\text{capacitor energy stored} \quad E = \frac{1}{2} QV = \frac{1}{2} CV^2 = \frac{1}{2} \frac{Q^2}{C}$$

MAGNETIC FIELDS

$$\text{force on a current} \quad F = BIl$$

$$\text{force on a moving charge} \quad F = BQv$$

$$\text{magnetic flux} \quad \Phi = BA$$

$$\text{magnetic flux linkage} \quad N\Phi = BAN$$

$$\text{magnitude of induced emf} \quad \varepsilon = N \frac{\Delta\Phi}{\Delta t}$$

$$\text{emf induced in a rotating coil} \quad N\Phi = BAN \cos \theta$$

$$\varepsilon = BAN \omega \sin \omega t$$

$$\text{transformer equations} \quad \frac{N_s}{N_p} = \frac{V_s}{V_p}$$

$$\text{efficiency} = \frac{I_s V_s}{I_p V_p}$$

RADIOACTIVITY AND NUCLEAR PHYSICS

$$\text{the inverse square law for } \gamma \text{ radiation} \quad I = \frac{k}{x^2}$$

$$\text{radioactive decay} \quad \frac{\Delta N}{\Delta t} = -\lambda N, \quad N = N_0 e^{-\lambda t}$$

$$\text{activity} \quad A = \lambda N$$

$$\text{half-life} \quad T_{1/2} = \frac{\ln 2}{\lambda}$$

$$\text{nuclear radius} \quad R = r_0 A^{1/3}$$

$$\text{energy-mass equation} \quad E = mc^2$$

GASES AND THERMAL PHYSICS

$$\text{gas law} \quad pV = nRT$$

$$pV = NkT$$

$$\text{kinetic theory model} \quad pV = \frac{1}{3} N m (c_{\text{rms}})^2$$

$$\text{kinetic energy of gas molecule} \quad \frac{1}{2} m (c_{\text{rms}})^2 = \frac{3}{2} kT = \frac{3RT}{2N_A}$$

$$\text{energy to change temperature} \quad Q = mc\Delta T$$

$$\text{energy to change state} \quad Q = ml$$

OPTIONS FORMULAE

ASTROPHYSICS

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

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

$$1 \text{ parsec} = 206265 \text{ AU} = 3.08 \times 10^{16} \text{ m}$$

$$= 3.26 \text{ light years}$$

$$\text{Hubble constant, } H = 65 \text{ km s}^{-1} \text{ Mpc}^{-1}$$

$$\text{lens equation} \quad \frac{1}{f} = \frac{1}{u} + \frac{1}{v}$$

$$M = \frac{\text{angle subtended by image at eye}}{\text{angle subtended by object at unaided eye}}$$

$$\text{in normal adjustment} \quad M = \frac{f_o}{f_e}$$

$$\text{resolving power} \quad \theta \approx \frac{\lambda}{D}$$

$$\text{magnitude equation} \quad m - M = 5 \log \frac{d}{10}$$

$$\text{Wien's law} \quad \lambda_{\max} T = 0.0029 \text{ m K}$$

$$\text{Hubble's law} \quad v = H d$$

$$\text{Stefan's law} \quad P = \sigma A T^4$$

$$\text{Doppler shift for } v \ll c \quad z = \frac{\Delta f}{f} = -\frac{\Delta \lambda}{\lambda} = \frac{v}{c}$$

$$\text{Schwarzschild radius} \quad R_s = \frac{2GM}{c^2}$$

MEDICAL PHYSICS

$$\text{lens equations} \quad P = \frac{1}{f}$$

$$m = \frac{v}{u}$$

$$\frac{1}{f} = \frac{1}{u} + \frac{1}{v}$$

$$\text{intensity level} \quad \text{intensity level} = 10 \log \frac{I}{I_0}$$

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

$$\mu_m = \frac{\mu}{\rho}$$

APPLIED PHYSICS

$$\text{moment of inertia} \quad I = \Sigma mr^2$$

$$\text{angular kinetic energy} \quad E_k = \frac{1}{2} I \omega^2$$

$$\text{equations of angular motion}$$

$$\omega_2 = \omega_1 + \alpha t$$

$$\omega_2^2 = \omega_1^2 + 2\alpha\theta$$

$$\theta = \omega_1 t + \frac{1}{2} \alpha t^2$$

$$\theta = \frac{1}{2} (\omega_1 + \omega_2) t$$

$$\text{torque}$$

$$T = I \alpha$$

$$\text{angular momentum}$$

$$\text{angular momentum} = I \omega$$

$$\text{work done}$$

$$W = T \theta$$

$$\text{power}$$

$$P = T \omega$$

$$\text{thermodynamics}$$

$$Q = \Delta U + W$$

$$W = p \Delta V$$

$$\text{adiabatic change}$$

$$pV^\gamma = \text{constant}$$

$$\text{isothermal change}$$

$$pV = \text{constant}$$

$$\text{heat engines}$$

$$\text{efficiency} = \frac{W}{Q_{\text{in}}} = \frac{Q_{\text{in}} - Q_{\text{out}}}{Q_{\text{in}}}$$

$$\text{maximum efficiency} = \frac{T_H - T_C}{T_H}$$

$$\text{work done per cycle} = \text{area of loop}$$

$$\text{input power} = \text{calorific value} \times \text{fuel flow rate}$$

$$\text{indicated power} = (\text{area of } p\text{-}V \text{ loop}) \times (\text{no of cycles per second}) \times \text{number of cylinders}$$

$$\text{output or brake power } P = T \omega$$

$$\text{friction power} = \text{indicated power} - \text{brake power}$$

$$\text{heat pumps and refrigerators}$$

$$\text{refrigerator: } COP_{\text{ref}} = \frac{Q_{\text{out}}}{W} = \frac{Q_{\text{out}}}{Q_{\text{in}} - Q_{\text{out}}}$$

$$\text{heat pump: } COP_{\text{hp}} = \frac{Q_{\text{in}}}{W} = \frac{Q_{\text{in}}}{Q_{\text{in}} - Q_{\text{out}}}$$

TURNING POINTS IN PHYSICS

$$\text{electrons in fields} \quad F = \frac{eV}{d}$$

$$F = Bev$$

$$r = \frac{mv}{Be}$$

$$\frac{1}{2} mv^2 = eV$$

$$\frac{QV}{d} = mg$$

$$F = 6\pi \eta r v$$

$$\text{wave particle duality} \quad c = \frac{1}{\sqrt{\mu_0 \epsilon_0}}$$

$$\lambda = \frac{h}{p} = \frac{h}{\sqrt{2meV}}$$

$$\text{special relativity}$$

$$E = mc^2 = \frac{m_0 c^2}{\left(1 - \frac{v^2}{c^2}\right)^{\frac{1}{2}}}$$

$$l = l_0 \left(1 - \frac{v^2}{c^2}\right)^{\frac{1}{2}} \quad t = t_0 \left(1 - \frac{v^2}{c^2}\right)^{-\frac{1}{2}}$$