MACMILLAN
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OF
PHYSICS

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M. P. LORD

M
MACMILLAN
REFERENCE
BOOKS

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Preface

This Dictionary is an enlarged and updated version of the Physics content of a Dictionary of Physical Science edited by Dr John Daintith, Pan Books 1978.

It is hoped that the book, which contains over 4000 entries and about 200 line drawings, will be of use to Physics students at first year undergraduate and lower levels, and also to amateur enthusiasts and lay persons. The aim is to state essential principles of the subject clearly and concisely and to cover topics, having a Physics content, from other sciences, including medical science.

I wish to thank my husband, Professor Arthur M. James for many interesting discussions and much forbearance during the compilation.

I express my appreciation to the staff of Macmillan Reference Books for their help and encouragement and am indebted also to all the referees, especially Valerie Illingworth who, in addition, edited the manuscript.

Notes on Use

Many, but not all, of the head words defined in the dictionary are shown in small capitals when they occur in another entry; so, if a word, not appearing in small capitals causes difficulty, it could be helpful to try looking it up.

For ease of reference any term whose description appears within an entry is usually italicized. For example, the entry for **drift tube** is *See* LINEAR ACCELERATOR. In the entry **linear accelerator**, *drift tube* is defined.

See also in an entry refers the reader to an entry which has some relevance to the one being read.

Some units appear as headwords and also, in the tables at the front of the dictionary.

Table 1. Base and supplementary SI units

<i>Physical Quantity</i>	<i>Unit Name (base)</i>	<i>Unit Symbol</i>
amount of substance	mole	mol
current	ampere	A
length	metre	m
luminous intensity	candela	cd
mass	kilogramme	kg
thermodynamic temperature	kelvin	K
time	second	s
	(supplementary)	
plane angle	radian	rad
solid angle	steradian	sr

Table 2. Derived SI units with special names

<i>Quantity</i>	<i>Symbol</i>	<i>Unit</i>	<i>Unit Name</i>	<i>Unit Symbol</i>
<i>Name</i>				
capacitance	C	$\text{A}^2 \text{s}^4 \text{kg}^{-1} \text{m}^{-2}$	farad	F
charge	Q	A s	coulomb	C
conductance	G	$\text{A}^2 \text{s}^3 \text{kg}^{-1} \text{m}^{-2}$	siemens	S
energy	E	kg s^{-2}	joule	J
force	F	kg m s^{-2}	newton	N
frequency	ν, f	s^{-1}	hertz	Hz
illuminance	E_{ν}, E	cd sr m^{-2}	lux	lx
inductance, self	L	$\text{kg m}^2 \text{s}^{-2} \text{A}^{-2}$	henry	H
inductance, mutual	M	$\text{kg m}^2 \text{s}^{-2} \text{A}^{-2}$	henry	H
luminous flux	Φ_{ν}, Φ	cd sr	lumen	lm
magnetic flux	Ψ	$\text{kg m}^2 \text{s}^{-2} \text{A}^{-1}$	weber	Wb
magnetic induction	B	$\text{kg s}^{-2} \text{A}^{-1}$	tesla	T
potential difference	V	$\text{kg m}^2 \text{s}^{-3} \text{A}^{-1}$	volt	V
power	P	$\text{kg m}^2 \text{s}^{-3}$	watt	W
pressure	p	$\text{kg m}^{-1} \text{s}^{-2}$	pascal	Pa
resistance	R, r	$\text{kg m}^2 \text{s}^{-3} \text{A}^{-2}$	ohm	Ω

Table 3. Prefixes used with SI units

<i>Factor</i>	<i>Prefix</i>	<i>Symbol</i>
10^{-1}	deci-	d
10^{-2}	centi-	c
10^{-3}	milli-	m
10^{-6}	micro-	μ
10^{-9}	nano-	n
10^{-12}	pico-	p
10^{-15}	femto-	f
10^{-18}	atto-	a
10	deca-	da
10^2	hecto-	h
10^3	kilo-	k
10^6	mega-	M
10^9	giga-	G
10^{12}	tera-	T
10^{15}	peta-	P
10^{18}	exa-	E

Table 4. Symbols and SI Units for some physical quantities

<i>Name of quantity</i>	<i>Symbol</i>	<i>SI unit</i>
absorptance	α	1
acceleration	a	m s^{-2}
angular frequency	ω	$\text{Hz} \equiv \text{s}^{-1}$
angular momentum	L	J s
angular velocity	ω	rad s^{-1}
area	A, S	m^2
atomic number, proton number	Z	1
Bohr magneton	μ_{B}	A m^2
bulk modulus	K	N m^{-2}
charge, volume density of	ρ	C m^{-3}
compressibility	κ, k	$\text{N}^{-1} \text{m}^2$
cross section	σ	m^2
Curie temperature	$\theta_{\text{C}}, T_{\text{C}}$	K
decay constant	λ	s^{-1}
degeneracy (multiplicity) of an energy level	g	1
density	ρ	kg m^{-3}
Dirac constant	$\hbar$	J s

Table 4 (*contd*)

<i>Name of quantity</i>	<i>Symbol</i>	<i>SI Unit</i>
efficiency	η	1
electric displacement	D	C m ⁻²
electric field strength	E	V m ⁻¹
electric flux	Ψ	C
electric polarization	P	C m ⁻²
electric susceptibility	χ_e	1
electromotive force	E	V
emissivity	ε	1
enthalpy	H	J
entropy	S	J K ⁻¹
Gibbs function	G	J
half life	$T_{1/2}, t_{1/2}$	s
Hamiltonian function	H	J
heat capacity: at constant pressure	C_p	J K ⁻¹
heat capacity: at constant volume	C_v	J K ⁻¹
Helmholtz function	A, F	J
impedance, electric	Z	Ω
internal energy	U, E	J
irradiance	E_e, E	J m ⁻²
Joule-Kelvin coefficient	μ	N ⁻¹ m ² K
kinematic viscosity	ν	m ² s ⁻¹
kinetic energy	T, E_k, K	J
Lagrangian function	L	J
linear absorption coefficient	α	m ⁻¹
linear attenuation (extinction) coefficient	μ	m ⁻¹
linear expansivity	α	K ⁻¹
luminance	L_v, L	cd m ⁻²
luminous emittance	M_v, M	lm m ⁻²
magnetic field strength	H	A m ⁻¹
magnetic moment	m	A m ²
magnetic quantum number	M, m_i	1
magnetic susceptibility	χ, χ_m	1
magnetization	M	A m ⁻¹
magnetomotive force	F_m	A

Table 4 (*contd*)

<i>Name of quantity</i>	<i>Symbol</i>	<i>SI Unit</i>
mass number, nucleon number	A	1
mean free path	λ, l	m
mean life	τ	s
moment of inertia	I	kg m ²
momentum	p	N s
Néel temperature	θ_N, T_N	K
neutron number	N	1
nuclear magneton	μ_N	A m ²
nuclear radius	r	m
nuclear spin quantum number	I, J	1
osmotic pressure	Π	N m ⁻²
packing fraction	f	1
period	T	s
permeability, absolute	μ	H m ⁻¹
permittivity, absolute	ϵ	F m ⁻¹
Planck function	Y	J K ⁻¹
polarizability	α, γ	C m ² V ⁻¹
potential energy	E_p, V, Φ	J
principal quantum number	n, n_i	1
quantity of heat	q, Q	J
radiance	L_e, L	W m ⁻² sr ⁻¹
radiant excitance	M_e, M	W m ⁻²
radiant flux, radiant power	Φ_e, Φ	W
radiant intensity	I_e, I	W sr ⁻¹
radioactivity	A	Bq*
reactance	X	Ω
reflection factor	ρ	1
refractive index	n	1
relative atomic mass	A_r	1
relative density	d	1
relative permeability	μ_r	1
relative permittivity (dielectric constant)	ϵ_r	1
relaxation time	τ	s
resistivity	ρ	Ω m
Reynolds number	(Re)	1

*See RADIATION UNITS

Table 4 (*contd*)

<i>Name of quantity</i>	<i>Symbol</i>	<i>SI Unit</i>
shear modulus	G	N m^{-2}
specific heat capacity: at constant pressure	c_p	$\text{J kg}^{-1} \text{K}^{-1}$
specific heat capacity: at constant volume	c_v	$\text{J kg}^{-1} \text{K}^{-1}$
specific optical rotatory power	α_m	$\text{rad m}^2 \text{kg}^{-1}$
specific volume	v	$\text{m}^3 \text{kg}^{-1}$
speed	u	m s^{-1}
spin quantum number	S, s	1
surface tension	γ, σ	N m^{-1}
susceptance	B	S
thermal conductivity	λ	$\text{W m}^{-1} \text{K}^{-1}$
thermal diffusivity	α	$\text{m}^2 \text{s}^{-1}$
torque	T	N m
transmittance	τ	1
viscosity, coefficient of volume	η V, ν	$\text{kg m}^{-1} \text{s}^{-1}$ m^3
wavelength	λ	m
wave number	σ	m^{-1}
weight	G	N
work	w, W	J
work function	Φ	J
Young's modulus	E	N m^{-2}

Table 5. Fundamental constants in SI units

<i>Constant</i>	<i>Symbol</i>	<i>Value</i>
acceleration due to gravity (standard value)	g	$9.806\,65\,\text{m s}^{-2}$
Avogadro constant	N_{A} or L	$6.022\,169 \times 10^{23}\,\text{mol}^{-1}$
Boltzmann constant	k	$1.380\,622 \times 10^{-23}\,\text{J K}^{-1}$
charge on electron	e	$-1.602\,1917 \times 10^{-19}\,\text{C}$
charge on proton	$-e$	$1.602\,1917 \times 10^{-19}\,\text{C}$
electric constant	ϵ_0	$8.854\,1853 \times 10^{-12}\,\text{F m}^{-1}$
electronic radius	r	$2.817\,939 \times 10^{-15}\,\text{m}$
Faraday constant	F	$9.648\,670 \times 10^4\,\text{C mol}^{-1}$
fine structure constant	α	$7.297\,351 \times 10^{-3}$
gravitational constant	G	$6.6732 \times 10^{-11}\,\text{N m}^2\,\text{kg}^{-2}$
Loschmidt's number	N	$2.687\,19 \times 10^{25}\,\text{m}^{-3}$
magnetic constant	μ_0	$1.256\,64 \times 10^{-6}\,\text{H m}^{-1}$
Planck constant	h	$6.626\,196 \times 10^{-34}\,\text{J s}$
rest mass of electron	m_{e}	$9.1095 \times 10^{-31}\,\text{kg}$
rest mass of neutron	m_{n}	$1.674\,92 \times 10^{-27}\,\text{kg}$
rest mass of proton	m_{p}	$1.672\,62 \times 10^{-27}\,\text{kg}$
Rydberg constant	R	$1.097\,373\,12 \times 10^7\,\text{m}^{-1}$
speed of light	c	$2.997\,924\,58 \times 10^8\,\text{m s}^{-1}$
Stefan's constant	σ	$5.6697 \times 10^{-8}\,\text{W m}^{-2}\,\text{K}^{-4}$
universal gas constant	R	$8.314\,35\,\text{J K}^{-1}\,\text{mol}^{-1}$

Table 6. Conversion factors for some other units

A

<i>Length</i>	m	cm	in	ft	yd
1 metre	1	100	39.3701	3.280 84	1.093 61
1 centimetre	0.01	1	0.393 701	0.032 808 4	0.010 936 1
1 inch	0.0254	2.54	1	0.083 333 3	0.027 777 8
1 foot	0.3048	30.48	12	1	0.333 333
1 yard	0.9144	91.44	36	3	1

	km	mile	n. mile
1 kilometre	1	0.621 371	0.539 957
1 mile	1.609 34	1	0.868 976
1 nautical mile	1.852 00	1.150 78	1

1 light year = $9.460\,70 \times 10^{15}$ metres = $5.878\,48 \times 10^{12}$ miles.
 1 astronomical unit = 1.496×10^{11} metres.
 1 parsec = 3.0857×10^{16} metres = 3.2616 light years.
 1 fathom = 6 feet.

B

Volume

1 minim	1/9600 pint	
1 fluid drachm	60 minims	
1 fluid ounce	8 fluid drachms	
1 gill	5 fluid ounces	
1 pint	4 gills	0.568 26 dm ³
1 quart	2 pints	
1 gallon	4 quarts	4.546 09 dm ³
1 gallon	0.160 544 cubic feet	
1 cubic foot	6.228 82 gallons	0.028 316 8 m ³

1 cubic decimetre (1000 cc) is 1 *litre*, although this name is not used in precision measurement.
 1 gallon (US) is equivalent to 0.83268 gallon (UK)

C

<i>Velocity</i>	m s ⁻¹	km h ⁻¹	mile h ⁻¹	ft s ⁻¹
1 metre per second	1	3.6	2.236 94	3.280 84
1 kilometre per hour	0.277 778	1	0.621 371	0.911 346
1 mile per hour	0.447 04	1.609 344	1	1.466 67
1 foot per second	0.3048	1.097 28	0.681 817	1

1 knot = 1 nautical mile per hour = 0.514 444 metre per second.

Table 6 (contd)
D

Mass	kg	g	lb	long ton
1 kilogramme	1	1000	2.204 62	$9.842\ 07 \times 10^{-4}$
1 gramme	10^{-3}	1	$2.204\ 62 \times 10^{-3}$	$9.842\ 07 \times 10^{-7}$
1 pound	0.453 592	453.592	1	$4.464\ 29 \times 10^{-4}$
1 long ton	1016.047	$1.016\ 047 \times 10^6$	2240	1

Apothecaries' Units of Mass

1 grain	1/7000 pound (avoirdupois)
1 scruple	20 grains
1 drachm	3 scruples
1 ounce (apoth)	8 drachms
1 pound (apoth)	12 ounces (apoth)

The grain (1/7000 pound avoirdupois) has the same value in the avoirdupois, troy and apothecaries' systems.

Avoirdupois Units of Mass

1 grain	1/7000 pound	0.064 799 g
1 dram	1/256 pound	
1 ounce	16 drams	
1 pound	16 ounces	0.453 592 kg
1 stone	14 pounds	
1 quarter	2 stones	
1 hundredweight	4 quarters	50.802 kg
1 ton	20 hundredweights	1016.047 kg
1 gramme	0.0353 ounces	
1 kilogramme	2.204 62 pounds	

The avoirdupois hundredweight and ton are sometimes called the *long hundredweight* and *long ton* to distinguish them from the US measures, the *short hundredweight* (100 pounds) and *short ton* (2000 pounds).

Troy Units of Mass

1 grain	1/7000 pound (avoirdupois)
1 carat	4 grains
1 pennyweight	6 carats
1 ounce (tr)	20 pennyweights
1 pound (tr)	12 ounces (tr)
1 hundredweight (tr)	100 pounds (tr)
1 ton (tr)	20 hundredweights (tr)

Table 6 (*contd*)

E

<i>Force</i>	N	kg	dyne	poundal	lb
1 newton	1	0.101 972	10^5	7.233 00	0.224 809
1 kilogramme force	9.806 65	1	$9.806\ 65 \times 10^5$	70.9316	2.204 62
1 dyne	10^{-5}	$1.019\ 72 \times 10^{-6}$	1	$7.233\ 00 \times 10^{-5}$	$2.248\ 09 \times 10^{-6}$
1 poundal	0.138 255	$1.409\ 81 \times 10^{-2}$	$1.382\ 55 \times 10^4$	1	0.031 081
1 pound force	4.448 22	0.453 592	$4.448\ 23 \times 10^5$	32.174	1

F

<i>Pressure</i>	N/m ²	kg/cm ²	lb/in ²	atm
1 newton per square metre	1	$1.019\ 72 \times 10^{-5}$	$1.450\ 38 \times 10^{-4}$	$9.869\ 23 \times 10^{-6}$
1 kilogramme per square centimetre	980.655×10^2	1	14.2234	0.967 841
1 pound per square inch	$6.894\ 76 \times 10^3$	0.070 306 8	1	0.068 046
1 atmosphere	$1.013\ 25 \times 10^5$	1.033 23	14.6959	1

1 newton per square metre = 10 dynes per square centimetre.

1 bar = 10^5 newtons per square metre = 0.986 923 atmosphere.

1 torr = 133.322 newtons per square metre = 1/760 atmosphere.

1 atmosphere = 760 mmHg = 29.92 in Hg = 33.90 ft water (all at 0° C).

G

<i>Work and Energy</i>	J	cal _{IT}	kW hr	btu _{IT}
1 joule	1	0.238 846	$2.777\ 78 \times 10^{-7}$	$9.478\ 13 \times 10^{-4}$
1 calorie (IT)	4.1868	1	$1.163\ 00 \times 10^{-6}$	$3.968\ 31 \times 10^{-3}$
1 kilowatt hour	3.6×10^6	$8.598\ 45 \times 10^5$	1	3412.14
1 British thermal unit (IT)	1055.06	251.997	$2.930\ 71 \times 10^{-4}$	1

1 joule = 1 newton metre = 1 watt second = 10^7 erg = 0.737 561 ft lb.1 electronvolt = $1.602\ 10 \times 10^{-19}$ joule.

Table 7. The Greek Alphabet

<i>Letters</i>		<i>Name</i>
<i>Capital</i>	<i>Small</i>	
A	α	alpha
B	β	beta
Γ	γ	gamma
Δ	δ	delta
E	ε	epsilon
Z	ζ	zeta
H	η	eta
Θ	θ	theta
I	ι	iota
K	κ	kappa
Λ	λ	lambda
M	μ	mu
N	ν	nu
Ξ	ξ	xi
O	ο	omicron
Π	π	pi
P	ρ	rho
Σ	σ	sigma
T	τ	tau
Υ	υ	upsilon
Φ	φ	phi
X	χ	chi
Ψ	ψ	psi
Ω	ω	omega