

Appendix A

Reference

A.1 Glossary of Symbols

<i>Symbol</i>	<i>Description</i>	<i>Unit</i>
a	acceleration	m/s^2
$\mathbf{a}_n$	normal unit vector	
$\mathbf{a}_r$	radial unit vector	
A	area	m^2
B	magnetic flux density	T
B_r	residual flux density	T
C	capacitance	F
d	diameter	m
e, E	induced voltage	V
$\mathcal{E}$	electric field intensity	V/m
f	frequency	Hz
F	force	N
$\mathcal{F}$	magnetomotive force (mmf)	A(turn)
g	gravitational acceleration	m/s^2
g_e	effective air-gap length	m
G	conductance	Ω^{-1}
h	height	m
H	magnetic field intensity	A(turn)/m
H_c	coercive force, coercivity	A(turn)/m
i, I	current	A
J	current density	A/m^2
J	polar moment of inertia	$\text{kg} \cdot \text{m}$

<i>Symbol</i>	<i>Description</i>	<i>Unit</i>
l	length	m
L	inductance	H
m	mass	kg
M	magnetic moment per unit volume	A/m
n	turns ratio	
N	number of turns	
p, P	power	W
p_m	magnetic moment	A · m ²
q, Q	electric charge	C
r	radius	m
R	resistance	Ω
$\mathcal{R}$	reluctance	A(turn)/Wb
s	distance	m
t	time	s
T	time interval	s
u	linear velocity	m/s
v, V	voltage	V
V	volume	m ³
w	energy density	J/m ³
w	width	m
W	energy	J
x	linear displacement	m
X	reactance	Ω
y	linear displacement	m
z	linear displacement	m
Z	impedance	Ω
α	damping coefficient	
ζ	damping ratio	
η	efficiency	
λ, Λ	flux linkage	Wb
μ_r	relative permeability	
ρ	resistivity	Ω · m
τ	time constant	s
Φ	magnetic flux	Wb
ω	angular velocity or frequency	rad/s

A.2 Units

<i>Property</i>	<i>SI Unit</i>	<i>Equivalents</i>
Length	1 meter (m)	3.281 feet (ft) 39.37 inch (in.)
Angle	1 radian (rad)	57.30 degrees
Mass	1 kilogram (kg)	2.205 pounds (lb) 35.27 ounces (oz)
Force	1 newton (N)	0.2248 pounds force (lbf) 10^5 dynes 102 grams force
Torque	1 newton-meter (N·m)	0.7376 foot pounds (ft·lb)
Energy	1 joule (J)	1 watt-second 0.7376 foot-pounds (ft·lb) 0.2388 calorie (cal) 9.48×10^{-4} British thermal unit (BTU) 10^7 ergs
Power	1 watt (W)	1 joule/second 1.341×10^{-3} horsepower (hp)
Magnetic flux	1 weber (Wb)	10^8 maxwells
Magnetic flux density	1 tesla (T)	1 weber/meter ² 10^4 gauss
Magnetomotive force	1 ampere(turn) (A)	1.257 gilberts
Magnetic field intensity	1 ampere/meter (A/m)	1.257×10^{-2} oersted
Frequency	hertz (Hz)	1 cycle per second (cps)
Capacitance	farad (F)	
Inductance	henry (H)	1 Wb/A
Resistance	ohm (Ω)	
Charge	coulomb (C)	
Current	ampere (A)	1 C/s
Voltage	volt (V)	1 Nm/C

A.3 Constants

<i>Symbol</i>	<i>Description</i>	<i>Value</i>	<i>Unit</i>
G	gravitational constant	6.67×10^{-11}	$\text{Nm}^2/\text{kg}^{-2}$
g	gravitational acceleration	9.807	m/s^2
μ_0	permeability of free space	$4\pi \times 10^{-7}$	N/A^2 or H/m
ϵ_0	permittivity of free space	8.854×10^{-12}	$\text{C}^2/\text{N} \cdot \text{m}^2$ or F/m
Q_e	electronic charge	1.603×10^{-19}	C
μ_B	Bohr magneton	9.27×10^{-24}	$\text{A} \cdot \text{m}^2$

A.4 Properties of Materials

A.4.1 Coefficients of Friction

Materials	Coefficient of static friction μ_i		Coefficient of sliding friction μ	
	Dry	Lubricated	Dry	Lubricated
Steel/Steel	0.8	0.1	0.7	0.1
Steel/Aluminum	0.6		0.5	
Steel/Brass	0.5		0.4	
Steel/Cast iron		0.18	0.23	0.13
Steel/Teflon	0.04		0.04	
Steel/Nylon	0.3 - 0.5			
Rubber/Asphalt	0.5 - 0.8			
Aluminum/Aluminum			1.35	

A.4.2 Dielectric Constants

Material	ϵ_r
Teflon	2.1
Mylar	3.2
Paper	3.5
Quartz	3.8
Nylon	4-4.6
Pyrex glass	4.8
Rubber	7

A.4.3 Magnetic Materials

A.4.3.1 Non-Ferromagnetic Materials

Diamagnetics

Material	μ_r
Bismuth	0.999833
Mercury	0.999986
Silver	0.9999736
Lead	0.9999831
Copper	0.9999906
Water	0.9999912
Paraffin wax	0.99999942

Paramagnetics

Material	μ_r
Air	1.00000037
Oxygen	1.000002
Aluminum	1.000021
Tungsten	1.00008
Platinum	1.0003
Manganese	1.001

A.4.3.2 Ferromagnetic Materials

Material	Composition (%)	μ_i	μ_m	B_s
Magnetic iron	99.9 Fe	0.000251	0.00628	2.15
4% Silicon iron (HR)	4 Si 96 Fe	0.000502	0.0088	1.97
3% Silicon iron (GO)	3 Si 97 Fe	0.00188	0.0377	2.00
78.5 Permalloy	78.5 Ni 21.5 Fe	0.01004	0.125	1.07
45 Permalloy	45 Ni 55 Fe	0.00314	0.0314	1.60
47-50% Nickel-iron	49 Ni 51 Fe	0.00502	0.088	1.60
4-79 Mo Permalloy	4 Mo 79 Ni 17 Fe	0.0251	0.1004	0.87
Mumetal	75 Ni 2 Cr 5 Cu 18 Fe	0.0251	0.1632	0.65
Supermalloy	5 Mo 79 Ni 16 Fe	0.125	1.004	0.80
Sendust	9 Si 5 Al 85 Fe	0.0377	0.1508	1.00
Permendur	50 Co 50 Fe	0.0010	0.00628	2.45
Hiperco	35 Co 64 Fe	0.00125	0.0125	2.42
V Permendur	49 Co 49 Fe 2 V	0.0010	0.00565	2.40
2-81 Mo Permalloy (powder)	81 Ni 2 Mo 17 Fe	0.000157	0.000163	. . .
Carbonyl iron (powder)	99.9 Fe	0.0000691	0.000166	. . .
Feroxcube III	Mn Zn Fe ₄ O ₈	0.00125	0.00188	0.25

HR=Hot Rolled
GO=Grain Oriented

A.4.3.3 Permanent Magnet Materials

Material	Composition (%)	Coercivity H_c (A/m)	Residual flux density B_r (T)	Energy product BH_{max} (J/m ³)
Carbon steel	99 Fe 1 C	4000	0.9	1600
C-Mn Steel	98 Fe 1 Mn 0.9 C	3980	1.0	3980
Alnico 5	51 Fe 8 Al 14 Ni 24 Co 3 Cu	43800	1.25	54800
Sintered oxide	30Fe ₂ O ₃ 40Fe ₃ O ₄ 26Co ₂ O ₃	71700	0.16	11460
Ferrite	BaO SrO Fe ₂ O ₃	260000	0.35	22400
Platinum cobalt	77 Pt 23 Co	290000	0.6	52000
SmCo	Sm Co Fe Cu	752000	1.05	208000
NdFeB	Nd Fe B	840000	1.22	280000