

CONTENTS

<i>Glossary of Principal Symbols</i>	xv
CHAPTER 1 INTRODUCTION	1
<i>General Remarks on High Magnetic Fields</i>	1
Definitions and interaction effects 1 – Sources of ultrahigh fields 4 – Continuous fields 5 – Pulsed fields 7.	
<i>Historical Notes on High Magnetic Fields</i>	8
<i>Laboratories Engaged in High-Field Work</i>	13
Laboratories with conventional power sources 13 – Laboratories with explosive facilities 14 – The Colleferro explosive facility 14.	
CHAPTER 2 QUASISTATIONARY MAGNETIC FIELDS . . .	18
<i>Basic Elements of the Quasistationary Electro-Magnetic Theory</i>	18
Differential equations 18 – Quasistationary field approximation 19 – Boundary conditions 20 – Integral equations 20.	
<i>Magnetic Scalar Potential</i>	22
Introduction to the potential problem 22 – Conductor in a homo- geneous field 23 – Conductor carrying a given current 24.	
<i>Magnetic Vector Potential</i>	27
Basic equations 27 – Cylindrical solenoid 28 – Coil optimiza- tion 29 – Biot-Savart law 30 – Circular loop 31 – Homoge- neous fields 33.	
<i>Energy and Inductance Related to a Conductor System</i>	34
Energy equation 34 – Self-inductance 35 – Inductance and Faraday law 36 – Mutual inductance 38.	
<i>Computation Methods for Magnetic Fields</i>	39
Electrolytic tank 39 – Resistance network 41 – High-frequency fed models 43 – Numerical methods 44.	

CHAPTER 3	MAGNETIC DIFFUSION THEORY	46
	<i>Diffusion of Magnetic Fields into a Solid Conductor with Constant Conductivity</i> . .	46
	<i>Diffusion of Magnetic Fields into a Conducting Half Space</i>	49
	General one-dimensional equations 49 – General solution 50 –	
	Transient boundary condition $H_z = H_0$ (const.) 51 – Transient	
	boundary $H_z = H_0(t/t_0)^{\frac{1}{2}n}$ 52 – Skin depth concept 53 –	
	Boundary condition $H_z = H_0 e^{t/\tau}$ 54 – Transient boundary $H_z =$	
	$H_0 \sin \omega t$ 55 – Steady state boundary $H_z = H_0 \sin \omega t$ 57.	
	<i>Diffusion into a Conductor Limited by Plane Surfaces</i>	59
	Decay of a trapped magnetic field 59 – Slab with sinusoidal	
	boundary condition 60 – Slab with exponential boundary condi-	
	tion 61 – Diffusion into a rectangular bar 61.	
	<i>Cylindrical Diffusion Problems</i>	62
	One-dimensional equations 63 – Diffusion of a transient outer	
	field into a conducting bar 64 – Decay of a field contained within	
	a conducting bar 65 – Steady state solution with $H_z = H_0 \cos \omega t$ 66.	
	<i>Conducting Hollow Cylinder and Magnetic Diffusion</i>	68
	Boundary condition on the inner surface 68 – Diffusion into the	
	hollow conductor 69 – Decay of a field contained within a hollow	
	cylinder 70 – Decay of a field contained within an infinitely thick	
	hollow cylinder 72.	
CHAPTER 4	ENERGY DISSIPATION AND NONLINEAR	
	DIFFUSION IN PULSED MAGNETIC FIELD	
	SYSTEMS	73
	<i>Heating of a Conductor with Constant Conductivity</i>	73
	Joule's law 73 – Energy equations 75.	
	<i>Examples Related to the Conducting Half Space</i>	76
	Polynomial boundary condition 76 – Step-function boundary	
	condition 80 – Sinusoidal boundary condition 81 – Definitions	
	and results 81.	
	<i>Heating of "Thin" Conductors ($\sigma = \text{const.}$)</i>	83
	Plane geometry 83 – Cylindrical geometry 85 – The current	
	integral 87.	

<i>Nonlinear Magnetic Diffusion</i>	88
Conductivity law 88 – Nonlinear diffusion equations 89 – An approximated solution 89 – General results 93.	
<i>Magnetic Diffusion into a Hollow Conductor</i>	95
General equations for a thin-walled conductor 96 – Step-function boundary condition 98 – Sinusoidal boundary field 99.	
 CHAPTER 5 MAGNETIC PRESSURE AND RELATED EFFECTS	104
<i>Magnetic Pressure</i>	104
Biot-Savart force 104 – Maxwell's stress-tensor 105 – Shock waves 106 – Containment of magnetic pressures 109 – Forces acting on a solenoid 113 – Force-free conductors 115.	
<i>Propulsion of a Plane Sheet by Magnetic Pressure</i>	116
Kinematics of sheet propulsion 116 – Thermal velocity limitation for thin sheets 118 – Ablation effect for thick conductors 119 – Velocity limitation for thick sheets 121.	
<i>Acceleration of Macroparticles</i>	122
Various acceleration methods 122 – Magnetic expulsion velocity 123 – Acceleration by a travelling magnetic field configuration 124 – Diffusion velocity limitation 125.	
<i>Implosion of a Cylindrical Sheet</i>	126
General equations 126 – Particular solution for a constant current 128.	
 CHAPTER 6 CONVENTIONAL PULSED CURRENT GENERATORS	130
<i>Introduction</i>	130
<i>Capacitor Bank System</i>	131
Basic solutions of the lumped <i>LCR</i> -circuit 132 – Loss-free circuit 134 – Circuit including finite resistance 134 – Influence of variable circuit-elements 137 – General remarks on field generation by capacitor banks 138.	

<i>Inductive Circuits</i>	144
Inductive storage with resistive transfer impedance 145 – Inductive storage with capacitive transfer impedance 147 – Combined inductive systems 148 – Opening switches 149.	
<i>Rotating Machines and Accumulator Batteries</i>	150
Homopolar generator 151 – Alternator 154 – Lead-cell system 155.	
 CHAPTER 7 SOLENOIDAL COILS FOR PULSED OPERATION	157
<i>Multi-Turn Solenoidal Coil</i>	157
Mechanical elements 157 – Capacitor bank and solenoid 158 – Thermal limitations 160.	
<i>Helical Solenoid</i>	161
Mechanical setup 161 – Operative conditions 164.	
<i>Single-Turn Solenoid</i>	164
Conventional operation 164 – Flux concentrator 166 – Current and field distribution 167 – Limitations in the generation of maximum fields 170 – Experimental megaoersted results 173.	
 CHAPTER 8 MAGNETIC FLUX COMPRESSION	177
<i>Formal Circuit Analysis</i>	177
Flux compression circuit 177 – Initial conditions 180 – Switching problems 180.	
<i>Flux Compression by Incompressible Plane Conductors</i>	183
Field amplification 183 – Compression dynamics 187 – Flux loss through a sliding contact 189.	
<i>Explosive-Driven Flux Compression Devices</i>	191
Explosively propelled plates 191 – Bellows generators 194 – Coaxial generator 198 – Helical generators 199 – Some further remarks on flux compression devices 202.	

CHAPTER 9	CYLINDRICAL ULTRAHIGH FIELD GENER- ATORS	205
	<i>Implosion Dynamics of an Ideal Shell</i>	205
	Ideal flux compression 206 – Implosion dynamics 206 – Freely imploding shell 208 – Flux compressing shell 210.	
	<i>Flux Compression by Real Conductors</i>	211
	Incompressible shell with finite conductivity 212 – Compressible shell with infinite conductivity 216 – Real conductor 219.	
	<i>Metal-Field Interface</i>	221
	Rayleigh-Taylor instability 222 – Instabilities of the imploding cylindrical shell 225 – Skin-layer effects 229.	
	<i>Ultrahigh Field Generators</i>	231
	Liner implosion by explosive action 231 – Explosively driven gen- erators 234 – Electromagnetically driven generators 240 – Future developments 243.	
CHAPTER 10	ON METALLIC CONDUCTORS AT HIGH EN- ERGY DENSITIES	246
	<i>Introduction</i>	246
	A simple model for metals 246 – Specific heat 249.	
	<i>High Pressures</i>	250
	Equation of state 250 – Phase transitions 255 – Hugoniot rela- tions 256 – Shock transmission 260.	
	<i>Explosively Propelled Liners</i>	264
	Explosive systems 264 – Detonation wave 267 – Propulsion of plane liners 269.	
	<i>Electrical Conductivity</i>	272
	Introduction 272 – Conductivity in the solid state 273 – Conduc- tivity in the liquid, vapor and plasma states 279.	

CHAPTER 11	MEASUREMENT OF PULSED MAGNETIC FIELDS AND CURRENTS.	282
	<i>Methods of Measuring Pulsed Fields</i>	282
	Hall probe 282 – Magneto-resistance probe 284 – Optical methods 285.	
	<i>Inductive Magnetic Probe</i>	290
	Principle of operation 290 – Frequency response 292 – Electronic integrators 298 – Ultrahigh field effects 302 – Operation and con- struction elements 304.	
	<i>Measurement of Pulsed Currents</i>	306
	Shunt 306 – Rogowski belt 307 – Current transformer 310.	
APPENDIX 1	MAGNETIC FIELDS AND INDUCTANCES CORRESPONDING TO CONDUCTORS OF SIM- PLE GEOMETRY	312
	<i>Magnetic Field Formulae</i>	312
	<i>Inductance of Simple Conductors</i>	312
	<i>Formulae Collection</i>	312
APPENDIX 2	MATHEMATICAL FUNCTIONS AND FORMU- LAE	325
	<i>The Error Function</i>	325
	<i>Vector Forms in Different Coordinate Systems</i>	326
APPENDIX 3	ELECTROMAGNETIC UNITS AND CONVER- SION FACTORS	328
APPENDIX 4	MAGNETOHYDRODYNAMIC EQUATIONS .	334
	<i>General formulation</i>	334
	<i>Cylindrical One-Dimensional Geometry</i>	336
REFERENCES		338
AUTHOR INDEX		357
SUBJECT INDEX		364