Handbook of Radiation and Scattering of Waves:

- Acoustic Waves in Fluids
- Elastic Waves in Solids
- Electromagnetic Waves

Adrianus T. de Hoop

Professor of Electromagnetic Theory and Applied Mathematics Delft University of Technology Delft Netherlands



ACADEMIC PRESS Harcourt Brace and Company Publishers London • San Diego • New York • Boston • Sydney • Tokyo • Toronto

Sugg Printi	estions ing of sy	for classroom use
Part	1 Ra	diation and scattering of acoustic waves in fluids
1	Introd	uction
		Exercises
2	Basic	equations of the theory of acoustic waves in fluids 7
	2.1	Number density, drift velocity, volume density of mass, and mass flow density of a collection of moving particles
		Exercises
	2.2	Conservation of the number of particles and its consequences
	2.3	The equation of motion
	2.4	The deformation rate equation
	2.5	The constitutive relations
	2.6	The boundary conditions
	2.7	Low-velocity linearisation: the equations of linear acoustics
	2.8	Exchange of acoustic energy
	2.9	The frictional-force/bulk-viscosity acoustic loss mechanism
	2.10	Acoustic scalar and vector potentials in the theory of radiation from sources 44 Exercises
	2.11	Point-source solutions; Green's functions
	2.12	SI units of acoustic wave quantities

3		principle of superposition and its application to acoustic wave s in configurations with geometrical symmetry
	3.1 3.2	The principle of superposition 51 Symmetry with respect to a plane 52
	5.2	Exercises
	3.3	Symmetry with respect to a line
31	hat	Exercises
10/11	3.4	Symmetry with respect to a point
4		acoustic wave equations, constitutive relations, and boundary litions in the time Laplace-transform domain (complex frequency
	dom	ain)
ixz	4.1	The complex frequency-domain acoustic wave equations
lizz,		Exercises
VXX EVX		The complex frequency-domain constitutive relations; the Kramers-Kronig
PAY.		causality relations for a fluid with relaxation
	4.3	The complex frequency-domain boundary conditions
		Exercises
ε.	4.4	The complex frequency-domain coupled acoustic wave equations 76
15	4.5	Complex frequency-domain acoustic scalar and vector potentials
б.	4.6	Exercises
-	4.0	Exercises
		References
yau	ens baaa	
5		stic radiation from sources in an unbounded, homogeneous,
15		*
. 20	5.1	The coupled acoustic wave equations and their solution in the angular
	5.2	wave-vector domain
62 85	5.2	Exercises
	5.3	The complex frequency-domain source-type integral representations for the
		acoustic pressure and the particle velocity
	122 - 22	Exercises
	5.4	The time-domain source-type integral representations for the acoustic
		pressure and the particle velocity in a lossless fluid
	5.5	The Green's function of the dissipative scalar wave equation
		Exercises
	5.6	Time-domain source-type integral representations for the acoustic pressure and
		the particle velocity in a fluid with frictional-force/bulk-viscosity losses . 104
	5.7 5.8	The acoustic wave field emitted by a monopole transducer
	5.0	The acoustic wave new emitted by a upple transducer

Contents	nts
----------	-----

Cont	tents		
	5.9	Far-field radiation characteristics of extended sources	
		(complex frequency-domain analysis)	116
	5.10	Far-field radiation characteristics of extended sources	110
		(time-domain analysis for a lossless fluid)	
	5.11	The time evolution of an acoustic wave field. The initial-value problem	122
	5.11	(Cauchy problem) for a homogeneous, isotropic, lossless fluid	122
		Exercises	
		References	
6	Plane	acoustic waves in homogeneous fluids	127
	6.1	Plane waves in the complex frequency domain	127
	0.2010.00	Exercises	
	6.2	Plane waves in lossless fluids; the slowness surface	
		Exercises	132
	6.3	Plane waves in the real frequency domain;	
		attenuation vector and phase vector	
		Exercises	
	6.4	Time-domain uniform plane waves in an isotropic, lossless fluid	
	6.5	Exercises	142
	0.5	of an acoustically impenetrable object	144
			144
7	Acou	stic reciprocity theorems and their applications	149
	7.1	The nature of the reciprocity theorems and the scope of their consequences	149
		Exercises	
	7.2	The time-domain reciprocity theorem of the time convolution type	
		Exercises	
	7.3	The time-domain reciprocity theorem of the time correlation type	
	7.4	Exercises	104
	7.4	of the time convolution type	164
		Exercises	
	7.5	The complex frequency-domain reciprocity theorem	
	1705704	of the time correlation type	169
		Exercises	172
	7.6	Transmission/reception reciprocity properties	
		of a pair of acoustic transducers	
		Exercises	176
	7.7	Transmission/reception reciprocity properties of a single	
	7.0	acoustic transducer	177
	7.8	The direct (forward) source problem; point-source solutions	101
		and Green's functions	
	7.9	The direct (forward) scattering problem	
	7.10	The inverse source problem	
		NAMES OF ALL ALL ALL ALL ALL ALL ALL ALL ALL AL	

Contonts
Contents

	7.11	The inverse scattering problem
	7.12	Acoustic wave-field representations in a subdomain of the configuration space;
		equivalent surface sources; Huygens' principle and the Ewald-Oseen
		extinction theorem
		Exercises
ee.		References
100	Plane	e wave scattering by an object in an unbounded, homogeneous,
125		ppic, lossless embedding 221
	8.1	The scattering configuration, the incident plane wave and the far-field
		scattering amplitudes
127		Exercises
Child	8.2	Far-field scattered wave amplitude reciprocity of the time convolution type 231
	02	Exercises
	0.3	Exercises
	84	An energy theorem about the far-field forward scattered wave amplitude . 249
	0	Exercises
	8.5	The Neumann expansion in the integral equation formulation of the
521		scattering by a penetrable object
	8.6	Far-field plane wave scattering in the first-order Rayleigh-Gans-Born
		approximation; time-domain analysis and complex frequency-domain
P. 1. 1		analysis for canonical geometries of the scattering object
1.44		Exercises
		References
Part	2 R	adiation and scattering of elastic waves in solids
9	Intro	duction
		Exercises
		References
		References
10	Basic	equations of the theory of elastic waves in solids
25	10.1	Number density, drift velocity, volume density of mass, and mass flow
		density of a collection of moving particles
		Exercises
	10.2	Conservation of the number of particles and its consequences
	10.3	The equation of motion
	10.4	Exercises
	10.4	The deformation equation
	10.5	Exercises
	10.5	Exercises
	10.6	The boundary conditions
	10.7	Low-velocity linearisation; the equations of linear elastodynamics 325
	119 112 112 122 123 125 127 125 127 125 127 125 127 125 127 125 125 125 125 125 125 125 125 125 125	7.12 8 Plane isotra 8.1 8.2 8.3 8.4 8.5 8.6 Part 2 Ra 9 Introd 10 Basia 10.1 10.2 10.3 10.4 10.5 10.6

		Provident	200
	10.0	Exercises	
	10.8	Exchange of elastodynamic energy	
		Exercises	
	10.9	The frictional-force/viscosity elastodynamic loss mechanism	
		Exercises	336
	10.10	Elastodynamic vector and tensor potentials in the theory of radiation from	
		distributed sources	
		Exercises	
	10.11	Point-source solutions; Green's functions	340
		Exercises	341
	10.12	The elastodynamic wave equation for the particle velocity in a	
		lossless solid	341
	10.13	The equivalent fluid model for dilatational waves in a solid	343
		Exercises	
	10.14	SI units of elastic wave quantities	
	10.11	References	
			540
11	The n	rinciple of superposition and its application to elastic wave field	łe
•••		nfigurations with geometrical symmetry	
			U4 /
	11.1	The principle of superposition	349
	11.2	Symmetry with respect to a plane	350
		Exercises	356
	11.3	Symmetry with respect to a line	356
		Exercises	
	11.4	Symmetry with respect to a point	
		Exercises	
			000
12	The e	lastic wave equations, constitutive relations, and boundary	
		itions in the time Laplace-transform domain	
		plex frequency domain)	367
	12.1	The complex frequency-domain elastic wave equations	
		Exercises	
	12.2	The complex frequency-domain constitutive relations; the Kramers-Kronig	-
		causality relations for a solid with relaxation	369
	12.3	The complex frequency-domain boundary conditions	372
		Exercises	373
	12.4	The complex frequency-domain coupled elastic wave equations	373
	12.5	Complex frequency-domain elastodynamic vector and tensor potentials	
		Exercises	
	12.6	Complex frequency-domain point-source solutions; complex	
	12.0	frequency-domain Green's functions	376
		Exercises	
	12.7	The complex frequency-domain elastic wave equations for dilatational wav	
	12.7	(equivalent fluid model)	
		Exercises	
			201
		References	

13		odynamic radiation from sources in an unbounded, ogeneous, isotropic solid
	13.1	The coupled elastic wave equations in the angular
	15.1	wave-vector domain
	13.2	The elastodynamic wave equation for the particle velocity and its
	15.2	solution in the angular wave-vector domain
	13.3	Determination of G_P and G_S
	10.0	Exercises
	13.4	The complex frequency-domain source-type integral representations
		for the particle velocity and the dynamic stress
		Exercises
	13.5	The time-domain source-type integral representations for the particle
		velocity and the dynamic stress
	13.6	Point-source solutions
	13.7	Far-field radiation characteristics of extended sources
		(complex frequency-domain analysis)
		Exercises
	13.8	Far-field radiation characteristics of extended sources
		(time-domain analysis)
		Exercises
	13.9	The time evolution of an elastic wave field. The initial-value problem
		(Cauchy problem) for a homogeneous, isotropic, perfectly elastic solid 407
		Exercises
14	Plane	e elastic waves in homogeneous solids
	14.1	Plane waves in the complex frequency domain
		Exercises
	14.2	Plane waves in lossless solids; the slowness surface
58		Exercises
	14.3	Plane waves in the real frequency domain; attenuation vector
891		and phase vector
691		Exercises
	14.4	Time-domain uniform plane waves in an isotropic, lossless solid 423
69		Exercises
72		*
15	Elast	odynamic reciprocity theorems and their applications 429
55	15.1	The nature of the reciprocity theorems and the scope of
76		their consequences
		Exercises
ar	15.2	The time-domain reciprocity theorem of the time convolution type 437
77	F	Exercises
	15.3	The time-domain reciprocity theorem of the time correlation type 441
78		Exercises
.08	15 4	The complex frequency-domain reciprocity theorem of the
08		time convolution type

Contents

			•
		Exercises	,
	15.5	The complex frequency-domain reciprocity theorem of the	
		time correlation type)
		Exercises	3
	15.6	Transmission/reception reciprocity properties of a pair of elastodynamic	
		transducers	5
		Exercises	-
	15.7		,
	15.7	Transmission/reception reciprocity properties of a single elastodynamic	~
		transducer	,
	15.8	The direct (forward) source problem. Point-source solutions and Green's	
		functions	3
		Exercises	l
	15.9	The direct (forward) scattering problem	5
	15.10	The inverse source problem	
	15.11	The inverse scattering problem	
	15.12	Elastic wave-field representations in a subdomain of the configuration space;	'
	13.12		
		equivalent surface sources; Huygens' principle and the Ewald-Oseen	
		extinction theorem	
		Exercises	
		References	3
16	Plane	wave scattering by an object in an unbounded, homogeneous,	
	isotro	pic, lossless embedding	5
	16.1	The scattering configuration, the incident plane waves and the far-field	_
		scattering amplitudes	
		Exercises	
	16.2	0 1	
	16.2	Exercises	5
	16.2	Exercises	5
		Exercises	5
	16.2 16.3	Exercises 510 Far-field scattered wave amplitudes reciprocity of the 517 time convolution type 517 Exercises 533 Far-field scattered wave amplitudes reciprocity of the	5 7 3
	16.3	Exercises 516 Far-field scattered wave amplitudes reciprocity of the 517 time convolution type 517 Exercises 533 Far-field scattered wave amplitudes reciprocity of the 533 Far-field scattered wave amplitudes reciprocity of the 534 time correlation type 534	5 7 3
		Exercises 516 Far-field scattered wave amplitudes reciprocity of the 517 Exercises 517 Exercises 537 Far-field scattered wave amplitudes reciprocity of the 537 Far-field scattered wave amplitudes reciprocity of the 534 An energy theorem about the far-field forward scattered wave amplitudes 551	5 7 3 4
	16.3 16.4	Exercises 516 Far-field scattered wave amplitudes reciprocity of the 517 Exercises 517 Exercises 537 Far-field scattered wave amplitudes reciprocity of the 537 Far-field scattered wave amplitudes reciprocity of the 534 An energy theorem about the far-field forward scattered wave amplitudes 551 Exercises 559 Exercises 559	5 7 3 4
	16.3	Exercises 510 Far-field scattered wave amplitudes reciprocity of the 510 time convolution type 517 Exercises 532 Far-field scattered wave amplitudes reciprocity of the 532 Far-field scattered wave amplitudes reciprocity of the 534 An energy theorem about the far-field forward scattered wave amplitudes 551 Exercises 552 The Neumann expansion in the integral equation formulation of the	5 7 3 4 1 9
	16.3 16.4	Exercises 510 Far-field scattered wave amplitudes reciprocity of the 517 time convolution type 517 Exercises 532 Far-field scattered wave amplitudes reciprocity of the 533 Far-field scattered wave amplitudes reciprocity of the 534 time correlation type 534 An energy theorem about the far-field forward scattered wave amplitudes 551 Exercises 559 The Neumann expansion in the integral equation formulation of the 560 scattering by a penetrable object 560	5 7 3 4 1 9
	16.3 16.4	Exercises 510 Far-field scattered wave amplitudes reciprocity of the 517 time convolution type 517 Exercises 532 Far-field scattered wave amplitudes reciprocity of the 533 Far-field scattered wave amplitudes reciprocity of the 534 time correlation type 534 An energy theorem about the far-field forward scattered wave amplitudes 551 Exercises 559 The Neumann expansion in the integral equation formulation of the 560 scattering by a penetrable object 560	5 7 3 4 1 9
	16.3 16.4 16.5	Exercises 516 Far-field scattered wave amplitudes reciprocity of the 517 time convolution type 517 Exercises 532 Far-field scattered wave amplitudes reciprocity of the 533 Far-field scattered wave amplitudes reciprocity of the 534 An energy theorem about the far-field forward scattered wave amplitudes 551 Exercises 552 The Neumann expansion in the integral equation formulation of the 552 Scattering by a penetrable object 560 Far-field plane wave scattering in the first-order Rayleigh–Gans–Born 560	5 7 3 4 1 9
	16.3 16.4 16.5	Exercises516Far-field scattered wave amplitudes reciprocity of thetime convolution type517Exercises537Far-field scattered wave amplitudes reciprocity of thetime correlation type534An energy theorem about the far-field forward scattered wave amplitudes551Exercises552The Neumann expansion in the integral equation formulation of thescattering by a penetrable object560Far-field plane wave scattering in the first-order Rayleigh–Gans–Bornapproximation; time-domain analysis and complex frequency-domain	5 7 3 4 1 9 0
	16.3 16.4 16.5	Exercises510Far-field scattered wave amplitudes reciprocity of thetime convolution type517Exercises533Far-field scattered wave amplitudes reciprocity of thetime correlation type534An energy theorem about the far-field forward scattered wave amplitudesExercises555The Neumann expansion in the integral equation formulation of thescattering by a penetrable object560Far-field plane wave scattering in the first-order Rayleigh–Gans–Bornapproximation; time-domain analysis and complex frequency-domainanalysis for canonical geometries of the scattering object560	5 7 3 4 1 9 5
	16.3 16.4 16.5	Exercises510Far-field scattered wave amplitudes reciprocity of thetime convolution type517Exercises537Far-field scattered wave amplitudes reciprocity of thetime correlation type534An energy theorem about the far-field forward scattered wave amplitudesExercises557The Neumann expansion in the integral equation formulation of thescattering by a penetrable object560Far-field plane wave scattering in the first-order Rayleigh–Gans–Bornapproximation; time-domain analysis and complex frequency-domainanalysis for canonical geometries of the scattering object560Exercises591	5 7 3 4 1 9 5 1
	16.3 16.4 16.5	Exercises510Far-field scattered wave amplitudes reciprocity of thetime convolution type517Exercises533Far-field scattered wave amplitudes reciprocity of thetime correlation type534An energy theorem about the far-field forward scattered wave amplitudesExercises555The Neumann expansion in the integral equation formulation of thescattering by a penetrable object560Far-field plane wave scattering in the first-order Rayleigh–Gans–Bornapproximation; time-domain analysis and complex frequency-domainanalysis for canonical geometries of the scattering object560	5 7 3 4 1 9 5 1
Dert	16.3 16.4 16.5 16.6	Exercises 516 Far-field scattered wave amplitudes reciprocity of the 517 Exercises 532 Far-field scattered wave amplitudes reciprocity of the 533 Far-field scattered wave amplitudes reciprocity of the 534 time correlation type 534 An energy theorem about the far-field forward scattered wave amplitudes 551 Exercises 535 The Neumann expansion in the integral equation formulation of the 556 scattering by a penetrable object 560 Far-field plane wave scattering in the first-order Rayleigh–Gans–Born approximation; time-domain analysis and complex frequency-domain analysis for canonical geometries of the scattering object 560 Exercises 591 References 591	5 7 3 4 1 9 5 1
Part	16.3 16.4 16.5 16.6	Exercises510Far-field scattered wave amplitudes reciprocity of thetime convolution type517Exercises537Far-field scattered wave amplitudes reciprocity of thetime correlation type534An energy theorem about the far-field forward scattered wave amplitudesExercises557The Neumann expansion in the integral equation formulation of thescattering by a penetrable object560Far-field plane wave scattering in the first-order Rayleigh–Gans–Bornapproximation; time-domain analysis and complex frequency-domainanalysis for canonical geometries of the scattering object560Exercises591	5 7 3 4 1 9 5 1
Part 17	16.3 16.4 16.5 16.6 3 Ro	Exercises 516 Far-field scattered wave amplitudes reciprocity of the 517 Exercises 533 Far-field scattered wave amplitudes reciprocity of the 534 time correlation type 534 An energy theorem about the far-field forward scattered wave amplitudes 551 Exercises 534 An energy theorem about the far-field forward scattered wave amplitudes 551 Exercises 552 The Neumann expansion in the integral equation formulation of the 560 Far-field plane wave scattering in the first-order Rayleigh–Gans–Born 560 Far-field plane wave scattering in the first-order Rayleigh–Gans–Born 561 Exercises 591 References 591 References 591 References 591 Approximation and scattering of electromagnetic waves	5 7 3 4 1 9 0 5 1 7
Part 17	16.3 16.4 16.5 16.6 3 Ro	Exercises 510 Far-field scattered wave amplitudes reciprocity of the 511 time convolution type 517 Exercises 532 Far-field scattered wave amplitudes reciprocity of the 532 time correlation type 534 An energy theorem about the far-field forward scattered wave amplitudes 551 Exercises 532 The Neumann expansion in the integral equation formulation of the 552 scattering by a penetrable object 560 Far-field plane wave scattering in the first-order Rayleigh–Gans–Born 560 approximation; time-domain analysis and complex frequency-domain 560 Exercises 591 References 591 References 591 diction and scattering of electromagnetic waves 591 diction 601	5 7 3 4 1 9 0 5 1 7 7 1
	16.3 16.4 16.5 16.6 3 Ro	Exercises 516 Far-field scattered wave amplitudes reciprocity of the 517 Exercises 533 Far-field scattered wave amplitudes reciprocity of the 534 time correlation type 534 An energy theorem about the far-field forward scattered wave amplitudes 551 Exercises 534 An energy theorem about the far-field forward scattered wave amplitudes 551 Exercises 552 The Neumann expansion in the integral equation formulation of the 560 Far-field plane wave scattering in the first-order Rayleigh–Gans–Born 560 Far-field plane wave scattering in the first-order Rayleigh–Gans–Born 561 Exercises 591 References 591 References 591 References 591 Approximation and scattering of electromagnetic waves	5 7 3 4 1 9 0 5 1 7 1 4

18	The e	electromagnetic field equations
	18.1	Force exerted on an electric point charge
		Exercises
	18.2	The electromagnetic field equations in vacuum
		Exercises
	18.3	The electromagnetic field equations in matter
	10.4	Exercises
	18.4	The electromagnetic field equations for time-independent fields
		(quasi-static field equations)
	18.5	SI units of the electromagnetic field quantities
	10.5	References
19	The e	electromagnetic constitutive relations
	19.1	Conductivity, permittivity and permeability of an isotropic material 618
	19.2	Conductivity, permittivity and permeability of an anisotropic material 619
	19.3	Conductivity, permittivity and permeability of a material with relaxation . 620
		Exercises
	19.4	Electric current as a flow of electrically charged particles. The
		conservation of electric charge
	10 5	Exercises
	19.5	The conduction relaxation function of a metal
	10 6	Exercises
	19.6	Exercises
	19.7	The dielectric relaxation function of an isotropic dielectric
	19.7	Exercises
	19.8	SI units of the quantities associated with the electromagnetic constitutive
	17.0	behaviour of matter
		References
20	The e	electromagnetic boundary conditions
	20.1	Boundary conditions at the interface of two media
		Exercises
	20.2	Boundary condition at the surface of an electrically impenetrable object . 650
	275 0	Exercises
	20.3	Boundary condition at the surface of a magnetically impenetrable object . 651
16.		Exercises
21	Exch	ange of energy in the electromagnetic field
	21.1	Energy theorem for the electromagnetic field associated with the flow of a
1		collection of electrically charged particles
100	21.2	Energy theorem for the electromagnetic field in stationary matter 657
604	21.3	Energy theorem for the electromagnetic field in a medium with
		conductivity, permittivity and permeability

Contents	5
----------	---

	21.4	Exercises	63
		electromagnetic energy	666
22		or potentials, point-source solutions and Green's functions in the y of electromagnetic radiation from sources 6	67
	22.1	Vector potentials in the theory of electromagnetic radiation from distributed sources	
	22.2	Exercises 6 Point-source solutions; Green's functions 6 Exercises 6	70
23		principle of superposition and its application to electromagnetic in configurations with geometrical symmetry	73
	23.1	The principle of superposition	73
	23.2	Symmetry with respect to a plane	
		Exercises	
	23.3	Symmetry with respect to a line	81
		Exercises	85
	23.4	Symmetry with respect to a point	86
		Exercises	90
24	The e	lectromagnetic field equations, constitutive relations and	
		dary conditions in the time Laplace-transform domain	
		dary conditions in the time Laplace-transform domain plex frequency domain)	93
		The complex frequency-domain electromagnetic field equations 6	94
	(com	plex frequency domain) 64 The complex frequency-domain electromagnetic field equations 6 Exercises 6 The complex frequency-domain electromagnetic constitutive relations; 6 The complex frequency-domain electromagnetic constitutive relations; 6 Kramers–Kronig causality relations for a medium with relaxation 6	94
	(com 24.1 24.2	plex frequency domain) 64 The complex frequency-domain electromagnetic field equations 6 Exercises 6 The complex frequency-domain electromagnetic constitutive relations; 6 Kramers–Kronig causality relations for a medium with relaxation 6 Exercises 7	94 95 95 06
	(com 24.1	aplex frequency domain) 64 The complex frequency-domain electromagnetic field equations 66 Exercises 67 The complex frequency-domain electromagnetic constitutive relations; 67 Kramers–Kronig causality relations for a medium with relaxation 67 Exercises 77 The complex frequency-domain boundary conditions 77	94 95 95 06 10
	(com 24.1 24.2 24.3	aplex frequency domain) 64 The complex frequency-domain electromagnetic field equations 66 Exercises 67 The complex frequency-domain electromagnetic constitutive relations; 67 Kramers-Kronig causality relations for a medium with relaxation 67 Exercises 77 The complex frequency-domain boundary conditions 77 Exercises 77 The complex frequency-domain boundary conditions 77 Exercises 77	94 95 95 06 10 11
	(com 24.1 24.2	aplex frequency domain) 64 The complex frequency-domain electromagnetic field equations 66 Exercises 66 The complex frequency-domain electromagnetic constitutive relations; 67 Kramers–Kronig causality relations for a medium with relaxation 66 Exercises 77 The complex frequency-domain boundary conditions 77 The complex frequency-domain boundary conditions 77 The complex frequency-domain coupled electromagnetic wave equations 77 The complex frequency-domain coupled electromagnetic wave equations 77	94 95 95 06 10 11
	(com 24.1 24.2 24.3	aplex frequency domain) 64 The complex frequency-domain electromagnetic field equations 66 Exercises 67 The complex frequency-domain electromagnetic constitutive relations; 67 Kramers-Kronig causality relations for a medium with relaxation 66 Exercises 77 The complex frequency-domain boundary conditions 77 Exercises 77 The complex frequency-domain boundary conditions 77 Exercises 77 The complex frequency-domain coupled electromagnetic wave equations 77 Exercises 77 The complex frequency-domain coupled electromagnetic wave equations 76 Exercises 77 The complex frequency-domain coupled electromagnetic wave equations 76 Exercises 77 The complex frequency-domain coupled electromagnetic wave equations 77 Exercises 77 Exercises 77 Exercises 77 The complex frequency-domain coupled electromagnetic wave equations 76 Exercises 77 Exercises 77 Exercises 77	94 95 06 10 11 11
	(com 24.1 24.2 24.3	aplex frequency domain) 64 The complex frequency-domain electromagnetic field equations 66 Exercises 67 The complex frequency-domain electromagnetic constitutive relations; 67 Kramers-Kronig causality relations for a medium with relaxation 66 Exercises 77 The complex frequency-domain boundary conditions 77 Exercises 77 The complex frequency-domain coupled electromagnetic wave equations 77 Exercises 77 The complex frequency-domain coupled electromagnetic wave equations 77 Exercises 77 The complex frequency-domain coupled electromagnetic wave equations 76 Exercises 77 The complex frequency-domain coupled electromagnetic wave equations 77 Exercises 77 The complex frequency-domain coupled electromagnetic wave equations 77 Exercises 77 The complex frequency-domain coupled electromagnetic wave equations 77 Exercises 77 Exercises 77 The complex frequency-domain coupled electromagnetic wave equations 77 Exercises 77<	94 95 95 06 10 11
25	(com 24.1 24.2 24.3 24.4 Com	aplex frequency domain) 64 The complex frequency-domain electromagnetic field equations 66 Exercises 67 The complex frequency-domain electromagnetic constitutive relations; 67 Kramers-Kronig causality relations for a medium with relaxation 68 Exercises 77 The complex frequency-domain boundary conditions 77 The complex frequency-domain coupled electromagnetic wave equations 77 The complex frequency-domain coupled electromagnetic wave equations 77 References 77 References 77 Plex frequency-domain vector potentials, point-source solutions 74	94 95 06 10 11 11
	(com 24.1 24.2 24.3 24.4 Com and c	aplex frequency domain) 64 The complex frequency-domain electromagnetic field equations 6 Exercises 6 The complex frequency-domain electromagnetic constitutive relations; 6 Kramers-Kronig causality relations for a medium with relaxation 6 Exercises 7 The complex frequency-domain boundary conditions 7 Exercises 7 The complex frequency-domain coupled electromagnetic wave equations 7 Exercises 7 The complex frequency-domain coupled electromagnetic wave equations 7 References 7 References 7	94 95 06 10 11 12 12 14
	(com 24.1 24.2 24.3 24.4 Com and c	aplex frequency domain) 64 The complex frequency-domain electromagnetic field equations 66 The complex frequency-domain electromagnetic constitutive relations; 67 Kramers-Kronig causality relations for a medium with relaxation 68 Exercises 77 The complex frequency-domain boundary conditions 77 The complex frequency-domain coupled electromagnetic wave equations 77 The complex frequency-domain coupled electromagnetic wave equations 77 References 77 References 77 Plex frequency-domain vector potentials, point-source solutions 76 Screen's functions in the theory of electromagnetic radiation sources 77 Complex frequency-domain vector potentials in the theory of electromagnetic radiation from distributed sources 77	94 95 06 10 11 11 12 14 15
	(com 24.1 24.2 24.3 24.4 Com from	aplex frequency domain) 64 The complex frequency-domain electromagnetic field equations 66 The complex frequency-domain electromagnetic constitutive relations; 67 Kramers-Kronig causality relations for a medium with relaxation 68 Exercises 77 The complex frequency-domain boundary conditions 77 The complex frequency-domain coupled electromagnetic wave equations 77 The complex frequency-domain coupled electromagnetic wave equations 77 References 77 References 77 Plex frequency-domain vector potentials, point-source solutions 76 Screen's functions in the theory of electromagnetic radication 70 Sources 77 Complex frequency-domain vector potentials in the theory of	94 95 06 10 11 12 14 15 15

26		romagnetic radiation from sources in an unbounded, ogeneous, isotropic medium	719
	26.1	The electromagnetic field equations and their solution in the angular wave-vector domain	719
	26.2	The Green's function of the scalar Helmholtz equation	723
	20.2		726
	26.3	The complex frequency-domain source-type representations for the	
		electric and the magnetic field strengths	726
		Exercises	729
	26.4	The time-domain source-type representations for the electric and the	
		magnetic field strengths in a lossless medium	730
	065	Exercises	733
	26.5	The Green's function of the dissipative scalar wave equation	734
	26.6	Exercises	740
		magnetic field strengths in a medium with conductive electric and linear	740
	267	hysteresis magnetic losses	740
	26.7	The Green's function of the scalar wave equation associated with plasma	740
	26.0	oscillations and superconductivity	743
	26.8	Time-domain source-type integral representations for the electric and the	740
	26.0	magnetic field strengths in an electron plasma or a superconducting metal	749
	26.9	The electromagnetic field emitted by a short segment of a thin, conducting,	
	26.10	current-carrying wire	
		current-carrying loop	757
	26.11	Exercises	
		(complex frequency-domain analysis)	
		Exercises	765
	26.12	Far-field radiation characteristics of extended sources	
		(time-domain analysis for a lossless medium)	765
	26.13	Exercises	768
		problem (Cauchy problem) for a homogeneous, isotropic, lossless medium	
		Exercises	770
		References	771
27	Plane electromagnetic waves in homogeneous media		
	27.1	Plane waves in the complex frequency domain	773 778
	27.2	Plane waves in lossless media; the slowness surface	780
	2,.2	Exercises	782
	27.3	Plane waves in the real frequency domain; attenuation vector and phase vector	782
			800
	27.4	Time-domain uniform plane waves in an isotropic, lossless medium	800

		Exercises	805
28	Electr	romagnetic reciprocity theorems and their applications	807
	28.1	The nature of the reciprocity theorems and the scope of their	
		consequences	
		Exercises	
	28.2	The time-domain reciprocity theorem of the time convolution type	
	a a a		817
	28.3	The time-domain reciprocity theorem of the time correlation type	
	28.4	Exercises	822
	28.4	The complex frequency-domain reciprocity theorem of the time convolution type	877
	28.5	The complex frequency-domain reciprocity theorem of the	820
	20.5	time correlation type	827
			830
	28.6	Transmission/reception reciprocity properties of a pair of electromagnetic	
			832
			836
	28.7	Transmission/reception reciprocity properties of a single electromagnetic	
			837
	28.8	The direct (forward) source problem. Point-source solutions and Green's	
		functions	
		Exercises	
	28.9	The direct (forward) scattering problem	
	28.10	The inverse source problem	
	28.11	The inverse scattering problem	863
	28.12	Electromagnetic wave-field representations in a subdomain of the	
		configuration space; equivalent surface sources; Huygens' principle	070
		and the Ewald–Oseen extinction theorem	
		References	
		References	0/0
29		wave scattering by an object in an unbounded,	
	homo	ogeneous, isotropic, lossless embedding	879
	29.1	The scattering configuration, the incident plane wave and the far-field	
		scattering amplitudes	879
		Exercises	887
	29.2	Far-field scattered wave amplitude reciprocity of the	
		71	888
			896
	29.3	Far-field scattered wave amplitude reciprocity of the	
		¥1	897
			906
	29.4	An energy theorem about the far-field forward scattered wave amplitude .	
		Exercises	910

	29.5	The Neumann expansion in the integral equation formulation of the
		scattering by a penetrable object
	29.6	Far-field plane wave scattering in the first-order Rayleigh-Gans-Born
		approximation; time-domain analysis and complex frequency-domain
		analysis for canonical geometries of the scattering object 915
		Exercises
		References
30	Inter	ference and shielding of electromagnetic systems accessible via
		requency terminations. ElectroMagnetic Compatibility (EMC) . 943
	30.1	The reciprocity surface interaction integral for a low-frequency
		multiport system
		Exercises
	30.2	The electromagnetic N-port system as a transmitting system
		(electromagnetic emission analysis)
		Exercises
	30.3	The electromagnetic N-port system as a receiving system
		(electromagnetic susceptibility analysis)
		Exercises
	30.4	Remote interaction between an M-port system and an N-port system 959
		Exercises
	30.5	Electromagnetic interference
		Exercises
	30.6	The shielding effectiveness of a spherical shield for a radiating electric dipole
		placed at its centre (complex frequency-domain analysis) 979
	30.7	The shielding effectiveness of a spherical shield for a radiating magnetic
		dipole placed at its centre (complex frequency-domain analysis) 984
		References

Appendices

Appendix	A Cartesian tensors and their properties
A.1	Introduction
A.2	The summation convention
	Exercises
A.3	Cartesian reference frames in affine space and in Euclidean space 993
	Exercises
A.4	Definition of a Cartesian tensor
	Exercises
A.5	Addition, subtraction and multiplication of tensors
	Exercises
A.6	Symmetry properties
	Exercises
A.7	Unit tensors

Cont	ents
------	------

		References	10/4
			1073
E			1071 1073
			1070
E			1065
			1064
Е	3.2	Spatial Fourier transformation	1060
L			1057
F	3.1	Laplace transformation of a causal time function	1049
Appe	ndix E	B Integral-transformation methods	1049
		Exercises	1046
A			1045
		Exercises	1044
A	A .11	The Taylor expansion	1043
			1042
4		2	1032
			1023
P		Geometrical objects of a particular shape in <i>N</i> -dimensional Euclidean space	1023
			1022
1	4.8		1019
Δ			