

Contents

<i>Preface</i>	<i>xi</i>
<i>Conventions and notation</i>	<i>xiv</i>
1 Introduction	1
1.1 What is the scalar–tensor theory of gravitation?	2
1.2 Where does the scalar field come from?	9
1.2.1 The scalar field arising from the size of compactified internal space	9
1.2.2 The dilaton from string theory	12
1.2.3 The scalar field in a brane world	16
1.2.4 The scalar field in the assumed two-sheeted structure of space-time	22
1.3 Comments	25
1.3.1 The weak equivalence principle	25
1.3.2 The value of ω and mass of the scalar field	28
1.3.3 Conformal transformation	29
1.3.4 Mach’s principle and Dirac’s suggestion for time-dependent G	31
1.3.5 Does the scalar–tensor theory have any advantage over simple scalar theories?	34
2 The prototype Brans–Dicke model	37
2.1 The Lagrangian	38
2.2 Field equations	40
2.3 The weak-field approximation	43
2.4 The parameterized post-Newtonian approximation	47

viii	<i>Contents</i>	
2.5	A spinor field as matter	53
2.6	The mechanism of mixing	57
3	Conformal transformation	61
3.1	What is a conformal transformation?	62
3.2	Nonminimal coupling	66
3.3	Coupling to matter	71
3.4	The geodesic in the E frame	74
4	Cosmology with Λ	77
4.1	How has the cosmological constant re-emerged?	77
4.2	The standard theory with Λ	82
4.3	The prototype BD model without Λ	84
4.4	The prototype BD model with Λ	88
	4.4.1 Solution in the J frame	88
	4.4.2 Solution in the E frame	91
	4.4.3 A proposed revision and remarks	101
5	Models of an accelerating universe	105
5.1	Dark energy	106
5.2	Quintessence	110
5.3	Quintessence in the brane world	115
	5.3.1 A scalar field in the brane world	116
	5.3.2 Quintessence in the brane world	118
5.4	Scalar-tensor theory	124
	5.4.1 Hesitation behavior	124
	5.4.2 A two-scalar model	128
	5.4.3 Qualitative features unique to the two-scalar model	139
6	Quantum effects	145
6.1	Scale invariance	147
6.2	The dilaton as a Nambu-Goldstone boson	151
6.3	The contribution from loops	155
	6.3.1 The coupling to matter of σ , a self-coupled scalar field	155
	6.3.2 The coupling to matter of σ , scalar QED	160
6.4	Non-Newtonian gravity	168
6.5	A consequence of the suspected occurrence of the scalar field in the Maxwell term	177
6.6	Time-variability of the fine-structure constant	179
	6.6.1 Electromagnetic coupling of Φ_*	180
	6.6.2 The behavior of the scalar field	184

<i>Contents</i>	ix
Appendix A: The scalar field from Kaluza–Klein theory	187
Appendix B: The curvature scalar from the assumed two-sheeted space-time	192
Appendix C: The field equation of gravity in the presence of nonminimal coupling	195
Appendix D: The law of conservation of matter	198
Appendix E: Eddington’s parameters	200
Appendix F: Conformal transformation of a spinor field	204
Appendix G: Conformal transformation of the curvature scalar	209
Appendix H: A special choice for conformal invariance	214
Appendix J: The matter energy–momentum nonconservation law in the E frame	216
Appendix K: A modification to the Λ term	217
Appendix L: Einstein’s equation in the brane world	219
Appendix M: Dilatation current	223
Appendix N: Loop integrals in continuous dimensions	225
Appendix O: A conformal frame in which particle masses are finally constant	227
<i>References</i>	230
<i>Index</i>	237