

Contents

Overview

Quantum Gravity – A General Introduction

<i>Claus Kiefer</i>	3
1 Quantum Theory and the Gravitational Field	3
2 Approaches to Quantum Gravity	6
3 Quantum Black Holes and Quantum Cosmology	9
4 Semiclassical Approximation and Decoherence	11
References	13

Part I General Formalism and Specific Approaches

That Strange Procedure Called Quantisation

<i>Domenico Giulmi</i>	17
1 Introduction and Motivation	17
2 Canonical Quantisation	18
3 Constrained Systems	32
References	39

Lectures on Loop Quantum Gravity

<i>Thomas Thiemann</i>	41
1 Motivation and Introduction	43
2 Mathematical and Physical Foundations of Quantum General Relativity	67
3 Selected Areas of Current Research	85
4 Selection of Open Research Problems	124
References	127

A Discrete History of the Lorentzian Path Integral

<i>Renate Loll</i>	137
1 Introduction	137
2 Quantum Gravity from Dynamical Triangulations	139
3 Brief Summary of Discrete Gravitational Path Integrals	141
4 Geometry from Simplices	143
5 Lorentzian Nature of the Path Integral	146
6 Brief Conclusion	167
References	169

Introduction to String Theory

<i>Thomas Mohaupt</i>	173
1 Introductory Remarks	173
2 Free Bosonic Strings	175
3 Interacting Bosonic Strings	192
4 Supersymmetric Strings	213
5 p-Branes in Type II String Theories	227
6 Outlook	236
References	247

Part II Black Holes and Cosmology

Quantum Theory of Gravitational Collapse (Lecture Notes on Quantum Conchology)

<i>Petr Hájíček</i>	255
1 Introduction	255
2 Gauge-Invariant Method in the Canonical Theory of Generally Covariant Systems	257
3 A Model: Gravitating Shell	267
4 Quantum Theory	284
References	298

Primordial Black Holes as a Probe of the Early Universe, Gravitational Collapse, High Energy Physics and Quantum Gravity

<i>Bernard J. Carr</i>	301
1 Introduction	301
2 Historical Overview	302
3 PBHs as a Probe of Primordial Inhomogeneities	304
4 PBHs as a Probe of Cosmological Phase Transitions	307
5 PBHs as a Probe of a Varying Gravitational Constant	310
6 PBHs as a Probe of Gravitational Collapse	311
7 PBHs as a Probe of High Energy Physics	312
8 PBHs as a Probe of Quantum Gravity	317
9 Conclusions	319
References	319

On the Assignment of Entropy to Black Holes

<i>Daniel Sudarsky</i>	323
1 Introduction	323
2 The Assignment of Entropy	324
3 The Schrödinger Black Hole	326
4 The Problem and the Lessons	329
References	333

Part III Experimental Search

**Physics with Large Extra Dimensions
and Non-Newtonian Gravity at Sub-mm Distances**

<i>Ignatios Antoniadis</i>	337
1 Introduction	337
2 Hiding Extra Dimensions	346
3 Low-Scale Strings	348
4 Gravity Modification and Sub-millimeter Forces	350
5 Conclusions	352
References	353

**Quantum States of Neutrons in the Gravitational Field
and Limits for Non-Newtonian Interaction
in the Range between 1 μm and 10 μm**

<i>Hartmut Abele, Stefan Baeßler, Alexander Westphal</i>	355
1 A Quantum System	355
2 Limits for Non-Newtonian Interaction Below 10 μm	356
3 The Experiment at the Institut Laue-Langevin	358
4 Gravity and Quantum Mechanics Work Together	361
5 Summary	365
References	365

**The Einstein Equivalence Principle
and the Search for New Physics**

<i>Claus Lämmerzahl</i>	367
1 Introduction	367
2 The Einstein Equivalence Principle	369
3 Implications of the Einstein Equivalence Principle	373
4 Models Which Violate the Einstein Equivalence Principle	375
5 Experimental Tests of the Einstein Equivalence Principle	381
6 New Experimental Devices and Developments	386
7 EEP and Modern Metrology	388
8 Conclusion	393
References	394