Contents

1 Evolution of Dynamics 1
1.1 Early Concepts and Aristotelian Physics 1
1.1.1 The Earth 2
1.1.2 Earth–Moon Distance 2
1.1.3 Measuring the Sun's Distance 2
1.1.4 Size of the Universe 2
1.2 Role of Astronomy 4
1.3 Difficulties in Discovering the Laws of Motion 5
1.4 Pre-copernican Astronomy 5
1.4.1 Hipparchus 5
1.4.2 The Epicycle–Deferent Model and Ptolemy 6
1.4.3 Problems with Explaining the Observations with Ptolemaic Model 10
1.4.4 Progress During the Period Between Ptolemy and Copernicus 11
1.5 Copernican Model: Rediscovery of the Heliocentric Theory 12
1.6 Tycho Brahe: Improvement in Accuracy for Naked-Eye Astronomy 14
1.7 Kepler: Beginning of Modern Astronomy and Foundation of Science of Motion 14
1.7.1 Discovery of the Laws of Planetary Motion 15
1.7.2 Transition from Geometric to Physical Model 19
1.7.3 Early Concept of Action-at-a-Distance and Gravitation, and the Concept of Force 19
1.8 Galileo: Naked Eye to Telescopic Astronomy 20
1.8.1 Observation of the Moon and Discarding the Concept of Fifth Element 20
1.8.2 Discovery of Jupiter's Moons and its Implications 21
1.8.3 Discovery of the Phases of Venus: A Further Proof of Heliocentric Model 21
1.9 Galileo: Experimental Mechanics 22
1.9.1 Early Works on Accelerated Change: Merton School 23
1.9.2 Galileo's Work on Free Fall and Uniformly Accelerated Motion 23
1.9.3 Discovery of the Law of Inertia of Motion in Its Primitive Form 25
1.9.4 Laws of Compound Motion: Projectiles 25
1.9.5 Galilean Relativity 27
1.10 Collapse of the Old Science 27

1.11 Descartes: Beginning of Inertial Science 28
1.11.1 Law of Inertia of Motion 28
1.11.2 Collision Problems and Early Concept of Momentum Conservation. 29
1.11.3 Descartes' Concept of Motion. 29
1.12 Huygens: Breakthrough in the Discovery of Dynamics 30
1.12.1 Theory of Collision and Conservation of Momentum. 30
1.12.2 Kinematics of Circular Motion and 'Centrifugal Force' 32
1.12.3 Modern Concept of Force and the 'Force–Acceleration' Relation: Second Law of Motion in Primitive Form. 34
1.12.4 Early Concept of the Principle of Equivalence 35
1.13 Halley, Wren and Hooke: Rudiments of Gravitation. 36
1.14 Newton and the Final Synthesis. 37
1.14.1 Concepts of Mass, Momentum, Force and the Second Law of Motion. 37
1.14.2 Collision Problem and the Discovery of the Third Law 38
1.14.3 Law of Universal Gravitation and Planetary Motion. 39
1.14.4 Universality of Gravitational Force 41
1.14.5 Orbit for Inverse Square Law 42
1.15 Newtonian Dynamics in Matured State. 44
1.15.1 Concept of Mass. 45
1.15.2 Principia and Subsequent Development 45

2 Some Basic Concepts in Newtonian Mechanics 47
2.1 Nature of Motion and Space 47
2.1.1 Newton's Concept of Absolute Space and Time 47
2.1.2 Newton's Bucket Experiment 48
2.1.3 Newton's Bucket Experiment Follow up 49
2.1.4 Ernst Mach and Mach's Principle 50
2.1.5 Quantification of Mach's Principle—Concept of Inertial Induction 50
2.1.6 Origin of Inertia 52
2.2 Relative–Absolute Duality of Nature of Motion. 53
2.2.1 The Nature of the Universe 53
2.2.2 Absolute Motion in Terms of Relative Motion 53
2.3 Inertial and Gravitational Mass 55
2.3.1 Inertial Mass. 56
2.3.2 Gravitational Mass. 56
2.3.3 Equivalence of Inertial and Gravitational Mass 57
2.4 Space–Time and Symmetry in Newtonian Mechanics. 58
2.5 Early Concept of Energy 59
2.6 The Principle of Relativity and Galilean Transformation. 60
2.6.1 The Principle of Relativity 61
2.6.2 Symmetry and Relativity 62
2.6.3 Form Invariance of Physical Laws. 63
2.6.4 Energy and Energy Function. 64
2.6.5 Energy Function 65
2.7 Laws of Motion and the Properties of Space and Time. 66
2.7.1 The Second Law of Motion 67
2.7.2 The Third Law of Motion 68

2.8 Action-at-a-Distance and Spatiotemporal Locality 70
2.8.1 Early Work on Non-contact Forces 70
2.8.2 Spatiotemporal Locality and Action-at-a-Distance 71
2.8.3 The Concept of Field 71
2.8.4 Field and Absolute Space 74

3 Post 'Principia' Developments 75
3.1 Early Concepts and Aristotelian Physics 75
3.1.1 Diffusion of Newton's Mechanics in Europe 75
3.1.2 Multiplicity in the Concept of Force 76
3.1.3 Degeometrization of Newtonian Mechanics 76
3.2 Emergence of Analytical Mechanics 78
3.2.1 New Principles for Dynamical Problems 79
3.2.2 Principle of Virtual Velocity and Virtual Work 79
3.2.3 D'Alembert's Principle 81
3.2.4 Principle of Least Action 82
3.2.5 Lagrangian Mechanics 83
3.3 Dynamics of Rigid Bodies 84

4 Special Theory of Relativity 87
4.1 Introduction 87
4.1.1 Space–Time in Newtonian Mechanics 87
4.2 Euler's Work on Relativity: Confrontation of Dynamics with Optics 88
4.2.1 Principle of Relativity in Solving Rigid Body Dynamics Problem 88
4.2.2 Euler's Work on the Problem of Stellar Aberration 88
4.3 Efforts to Detect Ether Speed: The Null Result of Michelson–Morley Experiment 91
4.3.1 Early Attempts 91
4.3.2 Michelson–Morley Experiment 92
4.4 Electromagnetism: Challenge to the Principle of Relativity 93
4.5 Einstein's Special Theory of Relativity 96
4.5.1 Lorentz's Transformation from the Two Principles of Relativity 97
4.5.2 Special Relativity in Electromagnetic Phenomenon 98
4.5.3 Need for a Relativistic Mechanics 100

5 General Theory of Relativity and Extension of Mach's Principle 103
5.1 Introduction 103
5.2 Transition to General Relativity 104
5.2.1 Minkowski's Four-Dimensional Space–Time Continuum 104
5.2.2 Principle of Equivalence 105
5.2.3 Freely Falling Frames 106
5.2.4 Uniformly Accelerating Frames and the 'Entwurf' Theory 109
5.2.5 The Field Equation and Final Formulation 110
5.3 Extension of Mach's Principle 111
5.3.1 Velocity-Dependent Inertial Induction 112
5.3.2 Some Features of Velocity-Dependent Inertial Induction 114
5.3.3 Concluding Remarks 115

Bibliography 117

Index 119

http://www.springer.com/978-981-10-6252-0

Conceptual Evolution of Newtonian and Relativistic Mechanics

Ghosh, A.

2018, XVI, 122 p. 153 illus., Hardcover
ISBN: 978-981-10-6252-0