PHILOSOPHY AND THE FOUNDATIONS OF DYNAMICS

Although now replaced by more modern theories, classical mechanics remains a core foundational element of physical theory. From its inception, the theory of dynamics has been riddled with conceptual issues and differing philosophical interpretations, and throughout its long historical development, it has shown subtle conceptual refinement. The interpretive program for the theory has also shown deep evolutionary change over time. Lawrence Sklar discusses crucial issues in the central theory from which contemporary foundational theories are derived, and shows how some core issues (the nature of force, the place of absolute reference frames) have nevertheless remained deep puzzles, despite the increasingly sophisticated understanding of the theory which has been acquired over time. His book will be of great interest to philosophers of science, philosophers in general, and physicists concerned with foundational interpretive issues in their field.

LAWRENCE SKLAR is the Carl G. Hempel and William K. Frankena Distinguished University Professor at the University of Michigan. He is the author of Space, Time and Spacetime (1992), Philosophy of Physics (1992), Physics and Chance (Cambridge, 1995), and Theory and Truth (2000).
PHILOSOPHY AND THE
FOUNDATIONS OF DYNAMICS

LAWRENCE SKLAR
For Max and Mina


## Contents

1 Introduction  
1.1 The growth of theories  
1.2 The formulation and reformulation of theories  
1.3 The structure of this book  

2 The pre-history of classical dynamics  
2.1 Some Greek knowledge and speculation  
2.2 The growth of mathematical astronomy  
2.3 Greek dynamical theory  
2.4 Dynamics in medieval Islam and medieval Latin Europe  
  Suggested reading  

3 The astronomical revolution  
3.1 Copernicus  
3.2 Brahe and Kepler  
  Suggested reading  

4 Precursors to Newtonian dynamics  
4.1 Galileo  
4.2 Descartes  
4.3 Huyghens  
4.4 Other precursors of Newton  
  Suggested reading  

5 The Newtonian synthesis  
5.1 Newtonian dynamics  
5.2 Newtonian gravity and Newtonian cosmology  
  Suggested reading  

6 Philosophical aspects of the Newtonian synthesis  
6.1 The metaphysics of space, time and motion  
6.2 Issues concerning explanation  
6.3 Newton’s “Rules of reasoning in philosophy”  
  Suggested reading  

7 The history of statics  
  Suggested reading  

vii
## Contents

8 The development of dynamics after Newton 80
  8.1 From special problems and ad-hoc methods to general theory 80
  8.2 Three developmental streams 85
  8.3 Philosophical themes in dynamics 87

9 The “Newtonian” approach after Newton 89
  9.1 Kinematics, dynamics and constitutive equations 89
  9.2 The fundamental laws of dynamics 91
  9.3 Philosophical reflections on “force” 92
    Suggested reading 95

10 From virtual work to Lagrange’s equation 96
  10.1 From virtual work to “d’Alembert’s principle” 96
  10.2 From d’Alembert’s principle to Lagrange’s equation 99
    Suggested reading 100

11 Extremal principles 102
  11.1 From least time to least action 102
  11.2 Least action and the issue of explanatory legitimacy 106
    Suggested reading 109

12 Some philosophical reflections on explanation and theory 110

13 Conservation principles 118
  13.1 Discovery, controversy and consolidation 118
  13.2 Symmetry and conservation 122
    Suggested reading 127

14 Hamilton’s equations 128
  14.1 The Hamiltonian formalism 128
  14.2 Phase space 130
    Suggested reading 135

15 Canonical transformations, optical analogies and algebraic structures 137
  15.1 Canonical transformations 138
  15.2 Hamilton-Jacobi theory 139
  15.3 Poisson brackets 142
    Suggested reading 143

16 The search for new foundations 144
  16.1 A sampler of proposals 146
  16.2 Hertz’s neo-Cartesianism 149
  16.3 Mach’s relationism 157
  16.4 Further foundational reflections 161
    Suggested reading 169

17 New directions in the applications of dynamics 170
  17.1 From celestial mechanics to qualitative dynamics 171
  17.2 Chaos theory 187
## Contents

<table>
<thead>
<tr>
<th>Chapter</th>
<th>Title</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>17</td>
<td>Statistical mechanics</td>
<td>190</td>
</tr>
<tr>
<td>17.4</td>
<td>New applications and explanatory projects</td>
<td>194</td>
</tr>
<tr>
<td></td>
<td>Suggested reading</td>
<td>199</td>
</tr>
<tr>
<td>18</td>
<td>Spacetime formulations of Newtonian dynamics</td>
<td>201</td>
</tr>
<tr>
<td>18.1</td>
<td>Relativistic spacetimes</td>
<td>202</td>
</tr>
<tr>
<td>18.2</td>
<td>Galilean spacetime</td>
<td>205</td>
</tr>
<tr>
<td>18.3</td>
<td>Curved Galilean spacetime and Newtonian gravity</td>
<td>207</td>
</tr>
<tr>
<td>18.4</td>
<td>Philosophical reflections</td>
<td>209</td>
</tr>
<tr>
<td></td>
<td>Suggested reading</td>
<td>213</td>
</tr>
<tr>
<td>19</td>
<td>Formalization: mass and force</td>
<td>214</td>
</tr>
<tr>
<td>19.1</td>
<td>“Informal” formalization</td>
<td>215</td>
</tr>
<tr>
<td>19.2</td>
<td>“Formal” formalization: mass and force</td>
<td>221</td>
</tr>
<tr>
<td></td>
<td>Suggested reading</td>
<td>234</td>
</tr>
<tr>
<td>20</td>
<td>Relationist dynamics</td>
<td>235</td>
</tr>
<tr>
<td>20.1</td>
<td>Machian dynamics</td>
<td>235</td>
</tr>
<tr>
<td>20.2</td>
<td>Philosophical questions</td>
<td>239</td>
</tr>
<tr>
<td></td>
<td>Suggested reading</td>
<td>244</td>
</tr>
<tr>
<td>21</td>
<td>Modes of explanation</td>
<td>245</td>
</tr>
<tr>
<td>21.1</td>
<td>The variety of explanatory modes in dynamics</td>
<td>245</td>
</tr>
<tr>
<td>21.2</td>
<td>Internal issues concerning analytical dynamics</td>
<td>248</td>
</tr>
<tr>
<td>21.3</td>
<td>Extremal principles and the philosophy of explanation</td>
<td>253</td>
</tr>
<tr>
<td></td>
<td>Suggested reading</td>
<td>260</td>
</tr>
<tr>
<td>22</td>
<td>Retrospective and conclusions</td>
<td>261</td>
</tr>
</tbody>
</table>

**References** | 263  
**Index**     | 266  

© in this web service Cambridge University Press  
www.cambridge.org