

Contents

Preface

page ix

1. Earthquakes and fault motion	1
1.1. The origin of earthquakes	1
1.2. Faults in the Earth's crust	2
1.3. Geometry of a fault	5
1.4. Elastic rebound and the earthquake cycle	7
1.5. Energy, stress drop and seismic moment	9
1.6. Stick-slip motion on a fault	14
1.7. Seismicity and statistical properties of earthquakes	19
2. Processing and analysis of recorded seismic signals	22
2.1. Recorded ground motion in time and frequency domains	22
2.2. Analogical and digital data	25
2.3. Removing the instrumental response	27
2.4. Processing a seismic signal	30
2.5. Displacement, velocity and acceleration	36
2.6. Continuous GPS observations	39
3. Mathematical representation of the source	41
3.1. Fundamental equations of motion for an elastic medium	41
3.2. Green's and Somigliana's tensors	44
3.3. Representation theorem	45
3.4. Somigliana's tensor for an infinite homogeneous isotropic medium	48
3.5. Green's tensor for an infinite homogeneous isotropic medium	52
3.6. Green's functions for layered media	57
3.7. Focal region	59
3.8. Kinematic and dynamic models	61
4. Point source models	63
4.1. Point source approximation	63
4.2. Equivalent forces. Double couple	63
4.3. Shear fracture or dislocation	66
4.4. Point shear fracture in an infinite medium	68
4.5. The geometry of a shear fracture	77
4.6. Far-field displacements referred to geographical axes	78

4.7. Source representation using the focal sphere	80
4.8. The source time function	82
4.9. Spectral properties of the source time function	86
4.10. Seismic energy radiation	88
5. The seismic moment tensor	90
5.1. Definition of the moment tensor	90
5.2. Eigenvalues and eigenvectors	93
5.3. Components of the moment tensor	94
5.4. Moment tensor and elastic dislocations	95
5.5. Moment tensor components referred to geographical axes	98
5.6. The point source moment tensor	99
5.7. The separation of the moment tensor	102
5.8. Higher-order moment tensors	105
5.9. Moments of the moment-rate distribution	106
6. Determination of point source mechanisms	108
6.1. Parameters and observations	108
6.2. The focal sphere	109
6.3. Fault-plane solutions from P wave polarities	110
6.4. Inversion of body wave forms	117
6.5. Empirical Green's functions	123
6.6. Moment tensor inversion	124
6.7. Centroid moment tensor inversion	133
7. Kinematics of extended sources	135
7.1. Source dimensions	135
7.2. Rectangular fault. Haskell's model	138
7.3. Bilateral rupture propagation	141
7.4. Oblique rupture propagation	142
7.5. Corner frequency	145
7.6. Directivity effects	148
7.7. Rupture nucleation, propagation and arrest	151
7.8. Kinematic models with variable slip on the fault plane	155
7.9. The circular kinematic model of Sato and Hirasawa	157
8. Determination of source dimensions	163
8.1. Parameters of kinematic extended source models	163
8.2. Analysis of seismic wave spectra	163
8.3. Directivity effects on Rayleigh waves	167
8.4. Effects of directivity on body wave form modeling	170
8.5. Apparent source time function	172
8.6. Far-field inversion of the slip distribution on fault plane	173
8.7. Kinematic inversion of the near-field waves	181

9. Simple dynamic models	189
9.1. Kinematic and dynamic models	189
9.2. Static problem	190
9.3. Modes of propagating fractures	191
9.4. Circular fault. Static model	192
9.5. Circular fault. Brune's model	195
9.6. Scaling laws	200
10. Dynamics of fracture. Homogeneous models	205
10.1. Griffith's fracture model	205
10.2. Energy flow towards the fracture front for a growing crack	209
10.3. Stress singularities around a rupture front moving at constant speed	212
10.4. Spontaneous shear-fracture propagation	216
10.5. Friction models of fracture	220
10.6. Rupture of an expanding circular fault	223
10.7. Far-field displacements of a dynamic circular fault	227
11. Fracture dynamics. Heterogeneous models	232
11.1. The cohesive zone	232
11.2. The slip-weakening friction model	233
11.3. Friction laws	237
11.4. Determination of G_c from seismic data	243
11.5. Nucleation and arrest of rupture	246
11.6. Barriers and asperities	250
11.7. Healing and rupture pulse propagation	253
11.8. Super-shear rupture velocity	254
12. Modeling earthquakes using fracture dynamics	259
12.1. Dynamic models	259
12.2. Modeling earthquakes in three dimensions	260
12.3. Rupture propagation on a planar uniform fault	263
12.4. A finite circular fault in a homogeneous medium	265
12.5. Shallow strike-slip rectangular fault	269
12.6. Spontaneous rupture on a realistic fault: the Landers 1992 earthquake	270
12.7. Rupture of a geometrically complex earthquake: the Izmit event of August 1999	273
12.8. Dynamic inversion of the 2008 Iwate intermediate-depth earthquake	276
12.9. Conclusion and perspectives	281
<i>References</i>	284
<i>Index</i>	300