

## Contents

Preface to the third edition	<i>page</i> xiii
Preface to the second edition	xv
Preface to the first edition	xvii
Physical constants relevant to ice	xix
Derived SI units and conversion factors	xxi
<b>1 Why study glaciers?</b>	<b>1</b>
<b>2 Some basic concepts</b>	<b>5</b>
A note on units and coordinate axes	5
Glacier size, shape, and temperature	5
The condition of incompressibility	8
Stresses, strains, and strain rates	10
<b>3 Mass balance</b>	<b>17</b>
The transformation of snow to ice	18
Snow stratigraphy	20
Mass balance principles	22
Mass balance of polar ice sheets	26
Effect of albedo on mass balance	26
Climatic causes of fluctuations in the meteorological component, $B_m$	28
Loss of ice by calving ( $\dot{B}_L$ )	34
Bottom melting	39
Effect of atmospheric circulation patterns on mass balance	40
Global mass balance and sea level	43
Summary	44
<b>4 Flow and fracture of a crystalline material</b>	<b>46</b>
Crystal structure of ice	47
Dislocations	49
Activation energy	52
Premelting	53
Deformation mechanisms	55
Rate-limiting processes	56
Recrystallization	60

Summary of ice deformation	68
Deformation mechanism maps	68
A flow law for glacier ice	70
Fracture and crevassing	73
Summary	79
<b>5 The velocity field in a glacier</b>	<b>81</b>
Measurement of velocity	82
Balance velocity	83
Shear stress	84
Horizontal velocity at depth in an ice sheet	86
Horizontal velocity in a valley glacier	88
Mean horizontal velocity and ice flux	92
Vertical velocity	93
Submergence and emergence velocities	96
Flow field	97
Transverse profiles of surface elevation on a valley glacier	99
Radar stratigraphy	101
Effect of drifting snow on the velocity field	105
Ice streams	112
Summary	113
<b>6 Temperature distribution in polar ice sheets</b>	<b>115</b>
Energy balance in an ice sheet	115
Dependence of $K$ on temperature	120
The steady-state temperature profile at the center of an ice sheet	120
Temperature profiles in the ablation zone	129
Temperature profiles near the surface of an ice sheet	130
Temperature profiles far from a divide	131
Englacial and basal temperatures along a flowline calculated using the column model	135
Basal temperatures in Antarctica – comparison of solutions using the column model and a numerical model	138
Climate change	143
Geomorphic implications	143
Summary	147
<b>7 The coupling between a glacier and its bed</b>	<b>149</b>
Sliding	149
Deformation of subglacial till	166

	Contents	ix
Abrasion	191	
Drumlins and flutes	194	
Summary	197	
<b>8 Water flow in and under glaciers: Geomorphic implications</b>	<b>199</b>	
The englacial hydraulic system	199	
Equipotential surfaces in a glacier	205	
Types of subglacial drainage system	208	
Melt rates in conduits	209	
Water pressures in subglacial conduits on hard beds	213	
Surges	232	
Jökulhlaups	236	
Subglacial drainage and the formation of eskers	238	
Tunnel valleys	247	
Water pressure and glacier quarrying	248	
Origin of cirques and overdeepenings	252	
Summary	254	
<b>9 Stress and deformation</b>	<b>256</b>	
Stress	256	
Momentum balance	265	
Deformation	266	
Condition that principal axes of stress and strain rate coincide	271	
Summary	273	
<b>10 Stress and velocity distribution in an idealized glacier</b>	<b>274</b>	
Solutions for stresses and velocities in plane strain	274	
Comparison with real glaciers	289	
Summary	290	
<b>11 Numerical modeling</b>	<b>291</b>	
Goals of modeling	291	
Numerical integration	292	
Finite-difference models	294	
Finite-element models	300	
Finite-volume models	302	
Coupling thermal and mechanical models	302	
Initial conditions and forcing	303	
Validation	304	
Sensitivity testing and tuning	304	

x	<b>Contents</b>	
	Intercomparison of models	305
	Non-deterministic models	306
	Examples	307
	Summary	318
	<b>12 Applications of stress and deformation principles to classical problems</b>	<b>320</b>
	Collapse of a cylindrical hole	320
	Calculating basal shear stresses using a force balance	332
	Longitudinal coupling	338
	Analysis of borehole-deformation data	342
	Summary	349
	<b>13 Ice streams and ice shelves</b>	<b>350</b>
	The grounding zone	350
	Ice streams	352
	Ice shelves	366
	Summary	385
	<b>14 Finite strain and the origin of foliation</b>	<b>387</b>
	The strain ellipse	387
	Simple and pure shear	389
	Parameters describing cumulative deformation	390
	Calculating cumulative strain	391
	Components of foliation	393
	Summary	406
	<b>15 Response of glaciers to climate change</b>	<b>408</b>
	Feedback processes	409
	Pleistocene climate	410
	Response of a temperate glacier	411
	Elementary kinematic wave theory	413
	Analysis of the effect of a small change in mass balance using a perturbation approach	416
	Effect of diffusion	420
	A novel approach to response times	420
	Numerical modeling of glacier responses	425
	Comparison with observation	429
	Summary	431

	Contents	xi
<b>16 Ice core studies</b>	433	
Laboratory techniques	434	
Establishing a time scale for a core	436	
The fruits of ice core studies	446	
Summary	453	
Problems	455	
References	465	
Index	506	