

Index

- 2π Lemma, 359
 $\mathbb{H}^2, \mathbb{H}^3$; hyperbolic 2D, 3D space, 12
 $\Lambda(G)$; limit set of group G , 62
 $\mathcal{M}(G)$; hyperbolic manifold
 $\mathbb{H}^3 \cup \Omega(G)/G$, 66
 $\Omega(G)$; discontinuity set of group G , 64
 δ -hyperbolic, δ -thinness, 109
 λ -Lemma, 362
 $\log(2k - 1)$ theorem on group actions,
272, 439
 $\mathcal{MCG}(R)$; mapping class group of
surface R , 91
 $\mathfrak{R}(G)$; representation space of group G ,
277
 $\mathfrak{R}_{\text{disc}}(G)$; discreteness locus = $\mathcal{AH}(G)$,
279
 $\mathfrak{T}eich(R)$; Teichmüller space of surface
 R , 87
 $\mathfrak{T}(R), \mathfrak{T}(G)$; quasifuchsian space,
surface R , group G , 280
- Abikoff, William, 198
absolute measure of length, 7
accidental parabolic, 198, 239
Accola, Robert D. M., 65
acylindrical manifold, 198, 239, 382
Adams, Colin, 191, 252
Adams, Scot, xviii
Agard, Steve, 96
- Agol, Ian, xvii, xviii, 84, 114, 248, 252,
293, 300, 358, 359, 363, 386, 389,
396, 405, 422
Ahlfors, Lars, xiii, 17, 25, 42, 61, 77, 91,
94, 96, 154, 186, 200, 204, 308,
332, 336, 368, 456
Conjecture/Theorem, 184, 202, 295
Finiteness Theorem, 64, 66, 115, 122,
192, 194, 234, 363
Akiyoshi, Hirotaka, 144
algebraic convergence, 219
algebraic surface, 77
Anderson, James, xvii, 81, 196, 209,
238, 284, 285, 329, 347, 349, 416,
439
Andreev-Thurston Theorem, 10
annulus, 25
modulus of, 336
Anosov mappings of tori, 340
anti-Möbius transformation, 1, 44
Antonakoudis, Stergios, 381
Aougab, Terik, 103
area
as a function of topology, 187
of disk, ball, 16
of tube boundary, 104
arithmetic kleinian group, 401
Arnoux, Pierre, 343
Artin, Emil, 295
Astala, Kari, 202

496

atoroidal manifold, 382
 automatic group, 111
 automorphism
 Dehn twist, 322
 iterated, 321
 discrete group on \mathbb{S}^1 , 395
 extention from \mathbb{S}^1 to disk, 395
 inner and outer, 283, 286, 353
 of a 3-manifold, 370
 of fundamental group, 283
 pseudo-Anosov, 322
 reducible, 322
 pseudo-Anosov, 322
 automorphism of a surface, 371, *see also*
 Dehn twist
 Anosov maps on tori, 102
 finite order, 92
 Nielsen Realization Problem, 92

 B-groups, 309
 Baba, Shinpei, 415
 Baba, Shipei, xviii
 ball
 circumference, 17
 volume, 17
 ball, upper halfspace (UHS) models
 formulas for ball model, 30
 Ballmann, Werner, 358
 baseball, 11
 Basmajian, Ara, xviii, 217
 Bass, Hyman, 383
 Beardon, Alan, 42, 133, 142, 145, 185,
 199, 267, 444, 457
 Beltrami differential, 90, 288, 353, 368
 Beltrami, Eugenio, xvi
 differential, 86
 for finitely generated kleinian
 group, 183
 equation, 85, 86
 Belyĭ functions, 117, 461
 bending
 angle, 168

Index

 lamination, 170, 178, 179, 296, 302,
 366
 lines, 172
 measure, 169
 existence theorem, 178
 Benedetti, Riccardo, 250
 Bergeron, Nicolas, 386, 389
 Bers (analytic) boundary
 geometric limits, 321, 346
 limit of iteration, 322
 locally connected case, 311
 Bers slice, 306
 Bers (analytic) boundary, 310, 353
 extended, 308, 413
 quasifuchsian locus, 413
 extened, 415
 Bers, Lipman, 94, 145, 272, 281, 308,
 310, 336, 369
 conjecture, *see* Density Conjecture
 Bessières, Laurent, 395
 Besson, Gérard, 188, 395
 Bestvina, Mladen, 258, 259, 261, 354,
 390
 Betti number/rank of $H_1(M^3)$, 387
 Bianchi groups, 400
 bilipschitz map, 201
 billiards, 116
 Biringer, Ian, 239, 334
 Birman, Joan, 160, 342
 Bishop, Christopher, 201, 202, 334
 Bleiler, Steven, 34, 80, 192, 358
 Bobenko, Alexander, 10, 268
 Boileau, Michel, 199, 395, 402, 403
 Bólyai, János, xvi
 Bonahon, Francis, xvii, 26, 158, 160,
 164, 165, 172, 178, 180, 195, 214,
 270, 282, 293, 295, 297, 298, 302,
 316, 385, 407
 Criteria A and B, 292, 294, 310, 313,
 357
 Bonk, Mario, 77
 Borromean rings, 398, 399, 401
 approximation of complement, 397

- boundary
 groups, 309
 parallel embedded surface, 333
 boundary component
 compressible (indecomposable), 355
 conformal, 73
 ideal, 76
 incompressible, 151, 382
 bounded geometry, 303, 329
 Bounded Image Theorem, 382
 Bowditch
 manifold constant, 176
 Bowditch, Brian, xviii, 24, 75, 110, 176, 184, 215, 279, 298, 300, 438
 Bowers, Philip, 10, 268
 brain cortex, 268
 branch cover, point, value, 68, 80
 branch locus, 70
 Brendle, Tara, 92
 Bridgeman, Martin, 174, 178, 198, 378
 Bridson, Martin R., 294
 Brin, Matthew, 358
 Brock, Jeffrey, xi, xviii, 238, 239, 293, 299, 300, 302, 303, 305, 314, 316, 321, 322, 352, 353, 373, 390, 406, 416
 Bromberg, Kenneth, xviii, 50, 238, 239, 287, 289, 293, 305, 310, 314, 373, 406, 410, 411, 416
 Brooks, Robert, xi, 117, 264, 440
 Brunner, Andrew, 401
 bumping, 289, 416, 418, 419
 self-bumping, 289, 310
 Burger, Marc, 253, 334
 Buser, Peter, 133, 456
 Button, Jack, 393

 Calegari, Daniel, 293, 300
 Callahan, David, 393
 Canary, Richard, xviii, 11, 115, 158, 160, 172, 173, 198, 201, 238, 279, 282, 285, 286, 288, 292–295,
- 298–300, 303, 334, 337, 347, 349, 354, 356–359, 363, 416, 439
 Cannon Conjecture, 110
 Cannon, James, 36, 38, 42, 110, 111, 199
 Cannon-Thurston mappings, 327
 a sufficient condition, 370
 degenerate Schottky groups, 332
 of kleinian groups, 330
 singly or doubly degenerated
 quasifuchsian groups, 330
 Cao, Chun, 251
 Cao, Jian Guo, 212
 Carathéodory convergence, 233
 Casson, Andrew, 34, 80, 341, 386, 395
 CAT(−1), 294
 CAT(0), 393
 Cauchy–Riemann equations, 85
 Cayley graph, 108
 δ -thin, 109
 dual to polyhedra tessellation, 143
 geodesic, 108
 Cayley–Hamilton identity, 425
 census of manifolds, 393
 cerebral cortex, 268
 character variety, 362
 Chavel, Isaac, 262
 Cheeger constant, 335
 Cheeger, Jeff, 34
 Choi, Young-Eun, 179
 Chow, Bennett, 395
 circle packing, 10, 264, 413
 obtaining polyhedra, 268
 circles
 euclidean and hyperbolic centers, 26
 circumference of a disk, 16
 closed manifold, 69
 collapsing laminations, 329
 collapsing map, 329, 339
 Collar Lemma, 133, 456
 combining groups, 152, 193
 commensurable groups, 196
 commensurator of a group, 196
 commutator, 2, 19

498

subgroup, 67
 compact core, 180, 197, 281, 284, 291, 359, 435
 relative compact core, 181, 281, 291
 ends of manifold, 291, 357
 companion knot/link, 396, 397
 complex length/distance, 431, 438, 441, 446
 between lines, 431
 complex probabilities, 47
 complex projective structure, 412
 grafting, 413
 monodromy (holonomy) group, 413
 composition of Möbius t., 2
 compressible/incompressible
 boundary component, 149
 surface, 151
 compressible/incompressible surface, 151
 compressing curve, 83
 compressing disk, 151
 compression body, 83, 194, 354
 embedding in S^3 , 397
 computer software, *see also* Snap, SnapPi, OPTi
 for Bers slices, 415
 for cyclic loxodromic groups, 245
 Conder, Marston, 252
 cone
 angle/axis, 71, 254
 manifold, 255, 256, 406
 point, 69, 71, 76, 80
 conformal
 averaging, 440
 boundary, 12, 73
 groups, 107
 map, 1, 77
 metric, 85
 model, 8
 congruence subgroup, 96
 conical limit point, 184, 198, 199
 conjugate
 groups, 55

Index

Möbius transformations, 2
 convergence, *see also* algebraic, geometric, Hausdorff
 Carathéodory, 233
 Gromov-Hausdorff c. of metric spaces, 259
 of limit sets, 236
 of simple loops, 163
 type, 203
 convex cocompact group, 177
 convex core, 115, 175, 177, 256, 279
 bending measure, 178, 179
 boundary, 178, 303, 338, 363
 bounded embedded balls, 280
 bounded thickness, 176
 compact, 179
 in \mathbb{H}^2 , 211
 maximal cusp, 319
 totally geodesic boundary, 377
 volume, 378
 convex hull, 167
 bending measure, 169
 floor and dome, 169
 in \mathbb{H}^2 , 419
 Cooper, Daryl, xviii, 199, 262, 360, 402
 corner in manifold boundary, 420
 coset graph, 354
 Coulson, David, 400
 cover transformation, 68
 covering surface
 branched, 68, 69
 normal, 68
 Covering Theorem, 292
 coverings of surfaces/3-manifolds
 normal coverings, 67
 regular coverings, 67
 Riemann surfaces, 67
 topological branched coverings, 393
 Coxeter, H. M. S., 18
 critical exponent, 202
 cross ratio, 3, 5, 26, 35
 and distances, angles, 25
 convergence, 54

- cube complex/hyperplanes, 393
 Culler, Marc, 66, 246, 258, 277, 288, 303, 354, 399, 439
 curvature, *see also under* sectional
 Gaussian, 47
 of arcs, 45
 of circle, 46
 of equidistant arc, 46
 of equidistant surface, 47
 of horocycles, 45
 sectional, 19
 curve complex, 350
 arc complex, 352
 disk complex, 352
 pants complex, 352
 cusp, *see also under* maximal cusp
 cusp cylinders/cusp tori **Definitions**, 125
 density, 288
 elimination, 359
 on deformation space boundary, 287, 313, 338
 paired punctures, solid pairing tube **Definition**, 125
 rank of, 145
 solid cusp cylinders/solid cusp tori **Definitions**, 125
 cyclic group, 56, 441
 Cylinder Theorem, 150, 156, 194
 cylindrical manifold, 198
 Dahmani, Francois, 343
 De-Spiller, D. A., 200
 deck (=cover) transformation, 68
 deformation, *see also under* Teichmüller space
 of kleinian groups, 281
 quasiconformal, 280, 287
 space, 276
 interior of closure, 363
 space boundary
 inclusiveness of groups, 305
 local connectivity, 416
 degenerate group
 compression body, 304
 doubly, 304, 310, 373, 401
 partially, 313
 singly, 310, 313, 373
 degenerate hexagon, 448
 degree of map to closed manifold, 393
 Dehn filling
 exceptional slopes, 249
 on link complements, 398
 Dehn surgery, 248, 404
 Dehn Surgery Theorem, 248, 404
 Dehn twist, 91, 339, 343
 fixed point, 342
 iteration in $\mathfrak{T}(R)$, 344
 surface automorphism, 339
 variation of length, 120
 Dehn's Lemma, xiii
 Dehn's Lemma and Loop Theorem, 195
 applications, 151
 equivariant, 150
 Dehn-Nielsen-Baer Theorem, 353
 Delaunay triangulation, 206
 Density Conjecture/Theorem, 290, 305, 310
 dessins d'enfants, 117, 461
 developing map, 255, 413
 dihedral group, 60, 119
 dilatation, 85
 Dirichlet fundamental polyhedron, 135
 generic:Jørgensen-Marden conjecture, 208
 discontinuity set $\Omega(G)$, 64
 discrete group, 55
 with all real traces, 190
 discreteness locus, 279
 in projective structure, 415
 disk
 area, 17
 circumference, 17
 diskbusting curves, 294, 357, 359, 405
 diskbusting link, 357
 divergence type, 203

500

dodecahedral group, 60, 119
 dome over $\Omega \subset \mathbb{S}^2$, 168
 relation to geometry of Ω , 177
 Donaldson, Simon, 77
 Douady, Adrien, 154
 double horocycle, 147
 Double Limit Theorem, 304, 373
 double of a surface, 81
 doubling a manifold, 403
 drilling out simple geodesics, 404
 Drilling Theorem, 407
 Dumas, David, xi, 382, 412, 414, 415, 420
 Dunbar, William, 10, 252
 Dunfield, Nathan, 386, 390, 393, 396, 399, 424
 Duren, Peter, 233

Earle, Clifford, xvii, 94, 120, 141, 154, 212, 218, 274, 309, 325, 344, 362
 Earle–Marden coordinates, 274, 275
 earthquake, 210, 270
 Earthquake Theorem, 211
 edge cycle, 137
 edge relation, 135, 137
 Edmonds, Allan, 70
 Edmonds, Allan L., 393
 Efremovich, V., 199
 Ehrenpreis Conjecture, 87
 eigenvalues
 geometrically finite/infinite, 333
 of a 2×2 matrix, 4
 properties of $\lambda_1(\mathcal{M}(G))$, 335
 when $\lambda_0(\mathcal{M}(G)) = 0$, 334
 electrification in geometric groups, 111
 elementary group, 56, 61, 94
 all elements elliptic, 222
 elementary representation, 277
 elliptic transformation, 3
 axis, 13
 maximal order in closed surface, 190
 end reduction, 358

Index

end/relative end of a manifold, 290, 291, 294
 case of a surface, 76
 compressible/incompressible, 293
 geometrically (in)finite, 291
 indecomposable, 293
 tame end, 291
 ending lamination, 297, 298
 Conjecture/Theorem, 286, 290, 296, 300, 304, 373, 407
 definition, 301
 existence, 298
 endpoint of geodesic, 12
 engulfing property, 358
 Epstein, David B. A., xviii, 27, 111, 142, 158, 160, 168–174, 177, 197, 206, 211, 215, 217, 286, 398
 equidistant curve/surface, 13, 46
 ergodicity, 204
 and rigidity, 200
 unique, 166, 343
 Eskin, Alex, 184
 essential cylinder (annulus), 150, 198
 primitive, 349
 essential disk, 149
 ETH Zürich, xviii
 Euclid, 6
 Euler characteristic, 69, 187
 Evans, Richard, xviii, 238, 239, 279, 293
 excess angle, 51
 exponential growth, 11
 extended (quasi)fuchsian group, 194
 extension $\partial\mathcal{M}(G) \rightarrow \mathcal{M}(G)$, 155, 240
 extension to \mathbb{S}^2 from $\Omega(G)$, 212
 extension to \mathbb{H}^3 of a univalent function, 50
 extremal length, 365

Farb, Benson, 92, 93, 111, 190, 343, 353
 Farey graph, 351
 Farey sequence, 49, 103, 104
 Farkas, Hershel, 77, 188

- Fathi, Albert, 158, 163, 213, 316, 343, 372, 456
 Fatou, Pierre, 133
 Fay, John, 66
 Feighn, Mark, 197, 354
 Fenchel, Werner, 42, 44, 167, 208, 444
 Fenchel-Nielsen coordinates of $\mathcal{T}eich(R)$, 94
 Ferguson, Helaman, 78, 379
 Fermat curve, 77
 Fermat's Last Theorem, 96
 fibering over the circle, 374
 figure-8 knot, 190, 401
 filling/arational lamination, 166
 filling pair, 167, 373
 finite group of Möbius transformations, 60
 finitely generated kleinian groups, 197
 finitely presented group, 74
 finiteness theorem
 for cusps, 197
 for finite subgroups, 197
 Fletcher, Alastair, 91
 foliation, *see also* measured foliation
 (un)stable, 342
 Ford region/polygon/polyhedron, 138, 140
 Ford region/polyhedron, 245
 finite-sided, 145
 generalization, 217
 Ford, Lester R., 21, 60, 61, 119
 four-manifolds, 75
 Fox, Ralph, 295
 fractal, 64, 81, 114, 201
 fractional linear transformations, 1
 Frame, Michael, 401
 free group, 74, 81, 82
 outer space, 354
 two generator, 335
 free homotopy, 150
 Freedman, Michael, 293
 Fricke, Robert, 50
 fuchsian centers, 414
 fuchsian group, 50, 62, 80
 1st and 2nd kind, 81
 deformations, 88
 extended, 194
 finite index subgroups, 118
 finitely generated, 144
 geometric limits, 256
 least area, 189
 maximal, 189
 naming of, xvi
 Nielsen kernel, 211
 representation variety, 360
 triangle group, 61, 72, 98, 105, 189
 universal horodisks, 218
 Fujii, Michihiko, 378
 function group, 65, 194
 fundamental group, 67
 fundamental polyhedron, 105, 135, 441
 Dirichlet, 137
 Ford, 138
 generalized, 138
 not locally finite, 142
 Gabai, David, 133, 252, 283, 293, 300, 341, 386, 395, 409, 454
 with Meyerhoff and N. Thurston, 130, 182, 437
 Gallo, Daniel, 413, 415
 Gardiner, Fred, 96
 Gaster, Jonah, 376, 409
 Gauss, Johann Friedrich, xv
 Gauss, map, hyperbolic, 50
 Gauss-Bonnet formula, 18, 179, 187, 188, 359
 gaussian curvature, 17
 gaussian integer, 105
 Gehring, Fred, 153, 155, 186, 200, 441
 Gelander, Tsachik, 253
 geodesic, 159, 264, 428
 arclength, 32
 complex length, 431
 exiting sequence, 297
 length spectra of closed surfaces, 436

502

penetration of horodisk, 190
 recurrent, 158
 self-intersecting, 217
 space of $-s$, 264
 unknotted, 409
 geodesic lamination, 158, 419
 filling pair, 373
 maximal, 167
 measured, 161
 projective, 162
 total angle measure of transverse
 arc, 214
 uniquely ergodic, 167
 minimal, 167
 realizable, 173, 296
 geometric convergence, 185, 225, 257
 at Bers slice boundary, 344
 at quasifuchsian boundary, 323
 Benjamini-Schramm (BS)
 convergence, 272, 390
 by renormalization, 271
 polyhedral, 226
 geometric group theory, 108
 geometric intersection number, 101, 162,
 339
 estimates, 213
 two measured laminations, 165
 geometric structures, 394
 geometrically (in)finite end, 291
 geometrically finite groups, 144, 149
 definitions, 145
 density on boundary, 305
 essential compactness, 144
 minimally parabolic, 284
 Geometrization Conjecture/Theorem,
 xiv, 394, 396
 Geometry Center, 111, 379
 Gilman, Jane, 56, 82, 115
 Goldman, William, 24, 31, 411, 412, 420
 Goodman, Oliver, 271, 400
 Gordon, Cameron, 396
 grafting, 410–412
 2π -grafting, 411

Index

Gray, Jeremy, xv, xvi
 Green's formula, 19
 Green's function, 204
 Green, Paul, 158, 160, 172, 173
 Greenberg, Leon, 41, 56, 65, 145, 147,
 189, 196, 209, 235, 278, 369
 Gromov, Mikhail, 34, 110, 249, 259, 358
 –'s Theorem, 263
 hyperbolicity, 109–111
 a summary, 353
 norm, 263
 Grothendieck, Alexandre, 117, 461
 group, *see* free, kleinian, quasifuchsian
 etc.
 δ -hyperbolic, 110
 combination theory, 152, 193
 complex conjugate, 103
 containing only elliptics, 222
 Gromov hyperbolic, 110
 HNN extension, 293
 hyperbolic, 110
 indecomposable, 292
 inverse limit, 113
 Klein 4-group, 62
 LERF, 114
 marked, 277
 normalizer, 68
 presentation, 74
 profinite completion, 113
 relatively hyperbolic, 111
 residually finite, 114
 separable subgroup, 114
 word hyperbolic, 110
 group properties, summary, 114
 Groves, Daniel, 386
 Guirardel, Vincent, 343
 Gunn, Charlie, 398, *see* *Not Knot*
 Guo, Ren, xviii, 45
 Haefliger, André, 294
 Haglund, Frédéric, 386
 Haken manifold, 282, 383
 half-rotation, 425, 434, 444

- Halpern, Naomi, 141, 218
 Hamenstädt, Ursula, 316, 351, 436
 Hamilton, Richard, 395
 handle, 76
 handlebody, 83, 340, 341
 harmonic (hyperbolic) maps, 154, 332
 Hartshorn, Kevin, 423
 Harvey, William, 65, 256, 350
 Hausdorff
 convergence
 definition, 232
 of limit sets, 238, 239, 254
 dimension, 201
 of limit sets, 333
 union of simple geodesics, 160
 measure, 201
 Heard, Damian, 400
 Heegaard splitting, 84
 Heegaard genus of $\mathcal{M}(G)$, 84
 splitting distance, 423
 Hejhal, Dennis, 415, 418
 Hempel, John, 84, 112, 149, 152, 153,
 195, 282, 382, 384, 394, 403
 Hersonsky, Sa'ar, 288, 303
 hexagonal, *see also* right hexagon
 packing, 191, 268
 punctured torus, 103, 207
 torus, 190, 308, 309
 Hidalgo, Rubén, 409
 hierarchy, 383
 Hilbert, David, 18
 metric, 44
 Hildebrand, Martin, 393
 Hilden, H M, 399
 HNN-extension, 383
 Hocking, John, 65
 Hodgson, Craig, 41, 192, 248, 255, 358,
 393, 400, 402, 405, 406
 holomorphic motion, 362
 holonomy group, 413
 holonomy map, 255
 Holt, John, 289, 310
 homeomorphisms between manifolds,
 282
 homology
 \mathbb{S}^3 , 390, 424
 basis, 101, 116
 group, 67
 Torelli group, 423
 homotopy, 183, 205
 homotopy equivalence, 187, 281, 284
 between manifolds, 282
 between surfaces, 282
 homeomorphisms, 282
 primitive shuffle, 285
 shuffle of rolodex, book pages, 285
 horizon, 32
 horocycle, 14
 double, 147
 foliation by $-s$, 214
 horodisk, 14
 general form in $\Omega(G)$, 140
 in a torsion free fuchsian group, 218
 in simply connected region, 218
 penetration by geodesics, 190
 horosphere and horoball, 14, 21, 123,
 127
 maximal, 192
 penetration by planes, 190
 Hubbard, John H., 10, 77, 91, 94
 hyperbolic
 cone manifold, 255, 256, 406
 based on unknotted geodesic, 411
 deformations, 407
 cube, 453
 Gauss map, 50
 geometry, 6
 group, 111
 harmonic maps, 154, 332
 law of (co)sines
 for hexagons, 446
 for pentagons, 451
 for quadrilaterals, 452
 for triangles, 453
 manifold, 66, *see also under* manifold

504

boundary area, 350
 Bowditch constant, 176
 covering, 70
 cubulation, 393
 diameter bound, 262
 manifold double, 378
 Minsky Model Theorem, 299
 noncuspidal part, 294
 random choices, 423
 totally geodesic, 377
 volume bound, 262
 with corners, 420
 zero first homology, 397
 metric
 simply connected domain, 42
 orbifold, 71, 256
 existence theorem, 402
 structure of singular set, 72
 quadrilaterals, 454
 Ptolemy relation, 463
 right hexagon, 446, 453, 455
 degenerate, 448, 450
 generic, 444
 right triangle, 451
 space, 8
 transformation, 4
 trigonometry, 446
 hyperbolic group, 109, 110
 hyperbolic knots, 396
 hyperbolic metric, 30
 annulus, 95
 cylindrical (Fermi) coordinates, 457
 horocyclic coordinates, 457
 polar coordinates, 457
 punctured disk, 95
 solid angle, 13
 hyperbolic plane, 8
 disk, upper half-plane (UHP) models, 8
 hyperbolic space, 8
 ball, upper halfspace (UHS) models, 8
 polyhedra, 10

Index

Hyperbolization Theorem, 110, 284, 338, 348, 360, 371, 378, 382, 385
 for surfaces, 79
 hyperboloid model, 37
 imaginary length, 37
 light cone, 37
 timelike, lightlike, spacelike, 37
 hyperelliptic involution, 100, 106
 I-bundle, 81
 icosahedral group, 60, 119
 ideal
 bigon, 162
 boundary component, 76
 line, 448, 449
 point, 14
 tetrahedra, 34, 191, 433, 437
 triangle, 7, 14
 triangulation, 269
 vertex, 7
 incomplete hyperbolic metric, 254
 incompressible surface, 151, 382
 doubly incompressible, 173
 indecomposable group, 151
 injectivity radius, 126, 397
 positive lower bound, 303
 interval exchange transformations, 214
 invariant spiral, 4
 involution
 conjugation by, 47
 hyperelliptic, 100, 106
 irreducible manifold, 382
 irreducible representations, 278
 isometric circle, 20, 22
 excess, 51
 isometric plane, 20
 isoparametric inequality, 111, 262
 isothermal coordinates, 85
 isotopy, 183, 205
 mapping class group, 91
 of metrics, 314
 Ito, Kentaro, 418
 Ivanov, Nikolai, 93, 343, 351

- Jørgensen, Troels, xiv, xvii, 33, 47, 49, 51, 56, 105, 134, 143–145, 219, 225, 231, 234, 235, 237, 245, 284, 308, 310, 319, 425, 434, 441
 complex probabilities, 308
 inequality, 56, 57, 105, 127, 143, 220, 223, 225, 226, 229, 441
 cases of equality, 105
 new parabolics, 237
- Jaco, William, 84, 149, 152, 363, 382, 384, 394
- Jacobi identity, 441
- jet, 50
- Johannson, Klaus, 240, 281, 394
- Jones, Gareth, 117, 188
- Jones, Peter, 201, 202, 334
- Jungreis, Douglas, 341, 386, 395
- Kahn, Jeremy, xvii, 87, 378, 389
- Kamishima, Yoshinobu, 419, 420
- Kapovich, Michael, 123, 184, 208, 248, 253, 259, 277, 333, 363, 385, 402, 413, 415, 420
- Kapovich, Misha, xviii
- Keen, Linda, 103, 133
- Kellerhals, Ruth, 252
- Kent IV, Richard P., 382, 408
- Kerckhoff, Steven, xviii, 92, 164, 165, 211, 214, 248, 255, 314, 325, 341, 344, 346, 356, 365, 402, 404–406
- Kiikka, Maire, 105
- Klarreich, Erica, 329, 351
- Klein, Felix, 7
 bottle, 403
 model, 37
 surface, 78
- Klein, Peter, 219
- Klein–Maskit combination theory, 152, 193
- Kleinedam, Gero, 304, 354–356
- Kleiner, Bruce, 395
- kleinian group, 62
 arithmetic, 401
- convergence, 231
 determined by its traces, 435
 doubly degenerate, 374
 finitely generated, 197
 higher dimensional, 253
 infinitely generated, 66, 326, 421
 naming of, xvi
 presentation, 74
 quaternion representation, 42
 two-generator, 49, 363, 435
- Knopf, Dan, 395
- knot
 complement, 105
 hyperbolic structure, 396
 figure-8, 190, 375
 longitude and meridian, 397
 Seifert surface, 397
- Knotted Wye, 379
- knotted/unknotted geodesic, 409
- Kojima, Sadayoshi, xviii, 255, 404, 413
- Komori, Yohei, 308, 415
- Korkmaz, Mustafa, 351
- Koundouros, Stelios, 397
- Kra, Irwin, 94, 188, 281, 369
- Kulkarni, Ravi, 70, 197
- Labourie, Francois, 68
- Lackenby, Marc, 249, 360
- Lakes of Wada, 65
- Lakic, Nikola, 96
- lamination, *see also under* geodesic
 lamination
 (un)stable, 342, 372
 ending, 301
 minimal, 161
- Lamping, John, 11
- laplacian (hyperbolic), 332, 333
- Lascurain, Antonio, 105
- lattice, 99
- Laudenbach, Francois, 158, 163, 213, 316, 343, 372
- Le Calvez, Patrice, 92
- Le, Thang, 390

506

Lecuire, Cyril, 178, 354
 Lee, Youn, 401
 Leeb, Bernhard, 402, 403
 Lehner, Joseph, 57, 96
 Lehto, Olli, 91, 107
 Leininger, Chris, 114
 LERF, (all f.g. subgroups separable),
 112, 114
 Leung, Naichung, 182
 level k congruence subgroup, 96
 Levy, Silvio, xi, xviii
 Li, Peter, 155
 Li, Tao, 84
 Lickorish, Raymond, 397
 Lie product, 426
 Lieninger, Chris, 196
 lifting to a matrix group, 66
 limit set, 63, *see also under* conical limit
 set
 convergence, 236
 Hausdorff dimension, 201
 Hausdorff distance, 238
 locally connected, 331
 tangents, 107
 line geometry, 425
 link
 complement, 105
 Dehn surgery along, 249
 diskbusting, 358, 359
 indecomposable, 397
 linked/unlinked geodesics, 409
 Liouville measure of geodesics, 26
 Liu, Yi, 262, 389
 Lobachevsky, function, 35
 Lobachevsky, Nikolai Ivanovich, xvi
 local connectivity, 287
 quasifuchsian discreteness locus, 287
 of limit sets, 327
 Long, Darren D., 196
 longitude and meridian, 397
 Loop Theorem, *see* Dehn's Lemma
 Lott, John, 395
 loxodromic

Index

curve, 4
 transformation, 3
 axis, 13
 Lozano, M T, 399
 Lubotzky, Alexander, 253
 Luecke, John, 396
 Luo, Feng, 351
 Lyndon, Roger C., 354

 Möbius strip, 264
 Möbius transformation, 1
 axis, 13, 427, 434
 composition, 2
 composition of reflections, 27
 convergence, 53
 eigenvalues and eigenvectors, 4
 extension to 3-space, 6
 half-rotation, 425
 images of horizontal lines, 121
 in ≥ 3 dimensions (*Liouville's
 theorem*), 28
 normalized, 2
 normalized matrix representation, 2
 square roots, 429
 standard forms, 4
 Maclachlan, Colin, 383, 401
 Magid, Aaron, 287
 magnetic resonance imaging, 268
 Magnus, Wilhelm, 50, 98
 Maher, Joseph, 111, 423
 Maillot, Sylvain, 395
 Maloni, Sara, xviii
 Mané, Ricardo, 362
 Mandelbrot, Benoît, 81, 201
 manifold, *see also under* hyperbolic
 manifold
 aspherical, 386
 boundary topology, 152
 containing knots/unknobs, 409
 from face pairing of polyhedra, 424
 geometrically atoroidal, 383
 graph of manifolds, 354
 Haken, 383

- incompressible, 383
 - boundary incompressible, 383
- irreducible, 383
- pared, 383
- random choice, 424
- toroidal=homotopically t., 383
- manifold vs orbifold, 67
- manifolds
 - higher dimensional, 253
- Manning, Jason, 386
- mapping class group, 111, 372
 - 5-punctured sphere, 343
 - action on Thurston boundary, 316
 - classification of elements, 341
 - closed hyperbolic 3-manifold, 183
 - definition, 91
 - exceptional cases, 92
 - extended, 92
 - extension to $\mathcal{M}(G)$, 364
 - finite index subgroup, 93
 - finite subgroups, 341
 - not realizable by homeos, 92
 - puncture fixing subgroup, 93
 - random walk, 424
 - rigidity, 187
 - torsion free, finite index normal subgroup, 341
- mapping torus, 374
- Marden, Albert, 27, 80, 82, 123, 141, 152, 168–171, 174, 177, 195, 197, 211, 218, 234, 235, 237, 274, 280, 281, 286, 313, 325, 343, 344, 364, 365, 369, 377, 413, 415
 - Conjecture, *see* Tameness Conjecture
 - Isomorphism (or Rigidity) Theorem, 182, 183, 346
- Margalit, Dan, 93, 190, 353
- Margulis, Grigori, 200, 400
 - constant, 134
- Markov identity and conjecture, 23, 24
- Markovic, Vlad, 155
- Markovic, Vladimir, xvii, xviii, 87, 91, 92, 110, 118, 154, 168–170, 174, 177, 208, 212, 389
- Marshall, Timothy, 252
- Martin, Gaven, 252, 441
- Maskit, Bernard, xiv, 65, 82, 107, 152, 157, 185, 193, 195, 198, 199, 281, 290, 309, 310, 313, 329, 338, 369, 409
 - Planarity Theorem, 82, 115, 153
- Masur, Howard, xvii, xviii, 111, 116, 184, 214, 300, 316, 350, 353, 356, 364, 463
 - domain, 354–356
- Matelski, Peter, 440
- Mathematical Sciences Research Institute, 78
- matrix group from kleinian group, 66
- Matsuzaki, Katsuhiko, 73, 202, 204, 240
- maximal cusp, 287, 289, 313, 338
 - density of $-s$, 314
- maximal lamination, 166
- Maxwell, Delle, *see* *Not Knot*
- McCullough, Darryl, 180, 195, 197, 282, 285, 286, 355
- McMullen, Curtis, xi, 96, 154, 215, 254, 279, 288, 303, 308, 314, 329, 336, 338, 363, 373, 377, 381, 400, 416
- McReynolds, David, 114
- McShane, Gregory
 - Mcshane identity, 438
- measured
 - foliation, 165
 - from interval exchange, 214
 - horocyclic, 214
 - quadratic differentials, 366
- lamination, 161
 - arational/filling, 166
 - by sequence of lengths, 164
 - finite, 163
 - length, 164
 - quadratic differentials, 364
 - sequence convergence, 163

508

uniquely ergodic, 166, 167
 Meeks III, William H., 150
 meromorphic
 function, 117, 411, 419
 locally injective, 412
 lamination, 419
 quadratic differential, 461
 Mess, Geoffrey, 75, 197
 Meyerhoff, Robert, 129, 130, 133, 134,
 182, 249, 251, 252, 283, 409, 454
 Miller, Andrew, 180, 195, 355
 Milley, Peter, 133, 252
 Milnor, John, xvi, 35, 395
 minimal lamination, 161, 166
 minimally parabolic, 284
 Minkowski space, 38
 light cone, 40
 timelike, lightlike, spacelike, 40
 Minsky Model Theorem, 299
 Minsky, Yair, xi, xviii, 111, 173, 293,
 298–300, 303, 308, 328, 334, 339,
 350, 353, 365, 375, 410, 416
 Mirzakhani, Maryam, 160
 geodesic length formula, 438
 Mitra, Sudab, 154
 Miyachi, Hideki, 308
 Mj, Mahan, xvii, 330, 375
 Möbius transformation
 orientation reversing, *see* anti-Möbius
 modular group, 96
 = mapping class group, 92
 extended, 92, 94
 Farey sequence, 104
 modular transformation, 100
 moduli space, 94
 compactifications, 94
 definition, 93
 manifold cover, 94
 of a 3-manifold, 370
 triangulation and compactification,
 215
 modulus
 of annulus, 336

Index

 of circular quadrilateral, 265
 monodromy group, 413
 Montel's Theorem, 53
 Montesinos, José Maria, 394, 399
 Moore, R.L., 328, 332
 Mordell Conjecture, 77
 Morgan, John, 258, 385, 395
 Mosher, Lee, 343
 Mostow, George, xiii, 187, 200, 377
 Rigidity Theorem, 182, 186, 283, 378
 history, 200
 Mozes, Shasar, 253
 MSRI, 78
 multicurve, 162, 412
 intersection numbers, 162
 Mumford, David, xvii, 49, 81, 104, 115,
 142, 253, 257, 287
 Munkres, James, 153
 Munzner, Tamara, 11, 66, 96
 Myers, Robert, 358, 405, 408

 Namazi, Hossein, 305
 Nash, John, 76
 navigation, 4
 nearest point retraction, 168, 169, 175,
 419
 negative curvature, *see also* pinching
 and hyperbolic
 characterizations, 17
 discrete, 17
 of groups, 109, 111
 nerve, 265
 Neumann, Walter, 191, 271, 400
 new parabolics, 237
 Nicholls, Peter, 202, 204, 205
 Nielsen Realization Problem, 92, 211,
 341
 Nielsen, Jakob, 167, 208
 kernel, 211
 transformation, 335
 non-Euclidean geometry, xv
 normal subgroup, 68
 normalizer of a subgroup, 68

- Not Knot, 66, 96, 398
 number theory, 96
- octagon, hyperbolic, 427
 octahedral group, 60, 119
 Ohshika, Ken'ichi, xvii, xviii, 110, 238, 258, 293, 295, 305, 323, 337, 422
 Ol'shanskiĭ, A. Yu., 111
 OPTi, 308
 orbifold, 67, 70, 402
 cover, 73
 euclidean, 120
 minimum volume, 252
 spherical, 119
 theorem, 402
 Orbifold Theorem, 403
 orbital counting function, 203
 ordinary set $\Omega(G)$, 64
 oriented lines, 431, 446
 orthogonal projection, 11, 460
 Osin, Denis, 343
 Otal, Jean-Pierre, 164, 178, 258, 259, 355, 356, 374, 385, 407, 409, 420
 outer circles, 20, 21
 Outer space, 354
- page shuffling, *see* rolodex
 paired punctures, 147
 joining, 274
 opening up, 284
 pants, 455
 all medium sized, 272
 cuff lengths, 456
 decomposition, 165, 269, 288, 304, 421
 pants complex, 352
 Papakyriakopoulos, Christos, xiii
 parabolic group, 98, 190
 discrete extension, 102
 horosphere and horoball, 14
 intrinsic horosphere euclidian metric, 124
 least (translation) length, 126
 parabolic transformation, 3
 accidental, 198
 associated geometric structures, 145
 formulas for, 427
 new parabolics, 237
 parallel loops, 337
 pared manifold, 382
 Parker, John, xi, 180, 468, 471
 Parker–Series bending formulas, 468, 471
 Patterson, Samuel J., 202, 205
 Patterson–Sullivan measure on limit sets, 204
 Peano curve
 equivariant construction, 327, 332
 Penner, Howard, xi
 Penner, Robert C., 217, 343, 463
 pentagon, 451, 454, 460
 Perelman, Grigori, xiv
 Geometerization Theorem, 385
 Petersen–Morley Theorem, 445
 Petronio, Carlo, 142, 207, 248, 250, 270
 Picard group, 105
 Pignataro, Thea, 105
 pinching
 curvature bounds, 358
 estimate, 288, 336
 limiting process, 253, 287, 289, 304, 309, 312, 319, 337
 loops, 313, 323
 Theorem (Ohshika), 337
 Pirelli, Peter, 11
 planar
 covering surface, 81
 pentagon, 451, 455
 quadrilateral, 454
 Riemann surface, 82
 right hexagon, 455
 pleated surfaces, 171, 173
 uniform injectivity, 173
 pleating locus, 172
 plumbing coordinates, 274
 PNC manifolds, 358, 360

510

Poénaru, Valentin, 158, 163, 213, 316, 343, 372

Poincaré, Henri, xiii, xvi, 12, 38, 135
 Conjecture, 12, 84, 382
 dodecahedral space, 12
 Polyhedron Theorem, 142
 series, 205

point of approximation, *see also under*
 conical limit set

Poisson integral formula, 332

Pollicott, Mark, 369

polygon, hyperbolic, 7

polyhedral
 convergence, 226
 deformation, 36
 group, 60, 116, 118
 surface, 17, 76

polyhedron
 hyperbolic, 10
 volume, 36

Pommerenke, Christian, 201, 212, 233, 329, 331

Porti, Joan, 248, 250, 395, 402, 403

Prasad, Gopal, 182, 187

presentation, 74
 length, 262

primitive curve, 271

primitive group element, 59

profinite completion, 118

projective model, 37

projective structure
 discreteness locus, 415, 419
 extended Bers slice, 414
 quasifuchsian locus, 414
 Thurston coordinates, 420

properly discontinuous, 56, 64, 78

Przeworski, Andrew, 133, 252

pseudo-Anosov mappings, 342, 372

pseudosphere, 18

puncture, 76, 78

punctured torus, 103, 335, 439, 441
 group, 103, 144, 313, 319, 439, 441, 465

Index

hexagonal, 103, 207

Purcell, Jessica S., 397

quadratic differential, 90, 205, 364
 Abelian differential, 463
 bundle over $\mathfrak{T}(R)$, 415, 419
 singular euclidean metric, 463

quadratic differentials, 90

quadratic forms, 96

quadrilateral
 circular, 264
 marked, 265
 planar with two right angles, 454
 with three right angles, 452

quasiconformal
 definition, 85
 deformation, 86, 463
 deformation space, 280
 extension $\Omega(G)$ to \mathbb{S}^2 , 213
 metric definition, 85, 200

quasifuchsian, *see also* degenerate group
 deformation space, 305, 373
 group, 155, 194, 305
 illustration, 311, 312

quasifuchsian space, 308
 Bers slices, 308
 Earle slice, 309
 Maskit slice, 308
 nonlocal connectivity of closure, 416

quasiisometry, 155, 199, 200

quasisymmetric boundary mapping, 91

quaternions, 42, 436

RAAG: right-angled Artin group, 392

Rafi, Kasra, 184, 351

ramification, *see* branch

rank of cusp, 145

rank two subgroups, 272

Rao, Ramana, 11

Ratcliffe, John, 35, 73, 191, 252

real \mathbb{R} -trees, 258, 259, 362

real projective structure, 411

realizable lamination, 173, 296

- recurrent geodesic, 158
 recurrent ray, 185, 199
 reducible, *see also* irreducible
 reducible automorphism, 341
 reducible group, 95
 representation, 277
 Rees, Mary, 165
 reflection
 in a point, 44
 in a sphere or plane, 1, 25, 29, 44
 regular exhaustion, 290
 regular set $\Omega(G)$, 64
 Reid, Alan, 196, 271, 383, 401
 Reimann, Hans Martin, 154
 relatively hyperbolic group, 111
 with respect to subgroup, 111
 relator, 74
 representation variety, 276
 character variety, 362
 discreteness locus, 279, 289, 416, 418
 fuchsian groups, 360
 local coordinates, 179
 quasiconformal deformation space,
 280
 residually finite, 112
 residually finite group, 112, 114
 retraction
 in hyperbolically convex set, 197
 nearest point, 168, 169, 175, 419
 of \mathbb{H}^3 to line, 11
 rhumb line, 4
 Ricci flow, 395
 Riemann Mapping Theorem, 77
 Riemann surface, 75
 (integral) grafting, 412
 Belyi functions, 117, 461
 built from pants, 455
 canonical hyperbolic triangulations,
 215
 compact bordered, 81
 conformal embedding in \mathbb{R}^3 , 76
 cut into polygons, 463
 Ehrenpreis Conjecture, 87
 from equilateral triangles, 461
 from ideal triangles, 269
 from interval exchange, 214
 from pentagons, 460
 genus 2, 107
 isometric embeddings in \mathbb{R}^{17} , \mathbb{R}^{51} , 76
 length of closed geodesics, 133
 marked, 88
 polygon decompositions, 217
 projective structure, 415
 spine, 216
 translation surface, 463
 Riemann–Hurwitz formula, 69, 118
 riemannian 3-manifolds
 pinched negative sectional curvature,
 386
 right triangle, 450, 454
 rigidity
 3-manifolds with boundary, 183
 mapping class group, 187
 of homotopies, 182
 of homotopy equivalences, 282
 quasiconformal, 281
 topological, 303
 Riley, Robert, xiv, 143, 375, 400, 401
 Rips, Eliahu, 109
 Rivin, Igor, 10, 268
 Rodin, Burt, 266
 Roeder, Roland K.W., 10, 268
 Rogness, Jonathan, xi
 Rolfsen, Dale, 399
 rolodex, 285, 347, 349
 Royden, Halsey, 93
 Rüedy, Reto, 76

 Sad, Ricardo, 362
 Sageev, Michah, 386, 390
 Sakai, Tsuyoshi, 404
 Sakuma, Makoto, 144
 Sarić, Dragomir, 118
 Sario, Leo, 77, 82
 satellite knot/link, 396, 397
 Scannell, Kevin P., 412

512

Schafer, James, 117
 Schläfli formula, 36
 Schleimer, Saul, xviii, 351, 352
 Schneps, Leila, 461
 Schoen Conjecture, 155
 Schottky group, 81, 87, 114, 115, 144,
 152, 195, 257
 boundary cusp, 289
 classical, 82
 degenerated, 331
 dimension of limit set, 201
 illustration, 307
 simply degenerate, 332
 Schroeder, Viktor, 358
 Schupp, Paul E., 354
 Schwartz, Rick, 439
 Schwarz Lemma, 456
 schwarzian derivative, 50, 413
 schwarzian differential equations, 413
 Scott, Peter, xiv, xviii, 74, 75, 112, 180,
 194, 295, 385, 394, 405
 Scott–Shalen theorem, 276
 sectional curvature, 19, 182
 pinched, 358
 Seifert Conjecture, 386, 395
 Seifert fiber space, 394, 395
 Seifert–Weber dodecahedral space, 139
 Selberg’s Lemma, 57, 73, 148, 184, 197,
 359
 separable subgroup, 112, 114
 Seppälä, Mika, 436
 Series, Caroline, xi, 49, 81, 104, 115,
 120, 142, 160, 179, 180, 257, 287,
 468, 471
 Shalen, Peter, 74, 133, 180, 197, 246,
 258, 277, 288, 303, 363, 394, 439
 Sharp, Richard, 369
 Shiga, Hiroshige, 414
 Shimizu, Hideo, 134
 Shinnar, Meir, 134
 short geodesics, 127, 438
 drilling out, 407
 shrinkwrapping, 294

Index

shuffle, 285, 347, 349
 Siegel, Carl Ludwig, 57, 96
 Sierpiński gasket (carpet), 378, 379
 simplicial volume, 264
 simultaneous uniformization, 157, 305,
 306
 Singerman, David, 117
 singular fiber, 394
 singular set of an orbifold, 71, 402
 Skinning Lemma, 323, 376, 408
 skinning map, 376
 Skora, Richard, 259
 Ślodkowski, Zbigniew, 362
 Smillie, John, 463
 SnapPea/SnapPy, 270, 399
 solenoid, 118
 solid torus, 83
 longitude and meridian, 397
 Soma, Teruhiko, xvii, 294, 323, 408, 422
 Sorvali, Tuomas, 436
 soul, 212
 Souto, Juan, xviii, 238, 239, 280, 293,
 294, 305, 334, 354–356, 397, 405,
 409
 sphere at infinity, 12
 sphere theorem, 382
 spherical manifold, 12
 spine, 135
 spinning, 269
 Springborn, Boris, 10
 Springer, George, 77
 square root of Möbius t., 429
 stabilizer, 55
 standard form of Möbius t., 4
 Stephenson, Kenneth, xi, 10, 267, 268
 stereographic projection, 1, 28, 36
 $\mathbb{B}^3 \rightarrow \text{UHS.}$, 29
 Stillwell, John, xvi
 Stong, Robert, 70
 Storm, Peter, 188, 378, 396, 403
 Strebel, Kurt, 89, 343, 364, 365
 strong convergence, 239
 strong stability, 280

- Strong Torus Theorem, 385
 structural stability of groups, 363
 Struik, Dirk, 17, 19
 Sturm, Jacob, 134
 subgroup separable, 114
 Sugawa, Toshiyuki, 308, 415
 Sullivan, Dennis, 110, 170, 197, 204,
 205, 266, 334, 362, 363
 group stability, 363
 K-theorem, floor to dome, 170
 Rigidity Theorem, 86, 183, 303, 308,
 310
 Sun, Hongbin, 390
 surface area and volume, 262
 surface automorphisms
 finite order, 341
 surface automorphisms
 Dehn twists
 iterates, 316, 325
 pseudo-Anosov, 327, 341, 372
 axis, 342
 fixed points, 372
 iterates, 322, 325
 rank and abelian group, 372
 reducible, 322, 341
 Surface Subgroup Conjecture/Theorem,
 387
 counting immersed surfaces, 388
 Swarup, Ananda, 180
 symmetry lines, 442
 systole, 103, 437
 Tam, Luem-Fai, 155
 tame
 end, 291, 386
 manifold, 291, 292, 422, *see also*
 Ahlfors' Conjecture, Bonahon's
 Criteria, untameness
 Tameness Conjecture (Theorem), 360
 Tameness Conjecture/Theorem, 238,
 239, 289, 293, 294, 299, 334, 363
 Tan, Ser Peow, 413, 419, 420
 tangent bundle of a hyperbolic surface,
 33
 tangents to limit sets, 107
 Tanigawa, Harumi, 414
 Taylor, Edward, 201, 334
 Teichmüller lemma, 87
 Teichmüller mapping, 89
 extremal, 90
 Teichmüller modular group
 = mapping class group, 92
 Teichmüller space
 Bers (analytic) boundary, 310
 Bers slice, 307
 biholomorphic automorphisms, 94
 bounded orbits, 381
 comparison Bers and Thurston
 boundaries, 316
 complex structure, 94
 definitions, 88
 dimension, 89
 geodesic rigidity, 215
 geodesics, 90
 global complex analytic coordinates,
 94
 global real analytic coordinates, 94
 higher Teichmüller space, 369
 isometries, 94
 metric, 89
 natural tessellation, 215
 pseudo-Anosov action, 373
 quasi-isometric rigidity, 184
 ray, 364
 relative hyperbolicity, 111
 surface with cone points, 369
 Thurston (geometric) boundary, 316
 convergent sequences, 315
 pseudo-Anosov fixed points, 373
 Teichmüller, Oswald, 87
 tetrahedral group, 60, 119
 tetrahedron, flattened, 270
 tetrahedron, ideal, 433, 437
 thinness, 36
 volume, 36

514

Index

- Theorema Egregium, 18
 thick/thin decomposition, 134, 173, 192
 Thickstun, Thomas, 358
 thin part, *see* thick/thin decomposition
 Thurston, Nathaniel, 130, 182, 283, 409, 454
 Thurston, William, xiv, xvii, 50, 111, 112, 154, 163, 167, 169, 187, 191, 199, 215, 246, 248, 249, 253, 268, 290, 292, 293, 295, 297, 298, 314, 325, 334, 339, 341, 343, 344, 346, 358, 372, 373, 375, 377, 379, 382, 386, 393–396, 398, 401–403, 419, 424
 orbifold/reflection trick, 420
 Compactness Theorem, 240, 261, 279, 280, 338
 coordinates, 420
 earthquakes, 210, 211
 geometric finiteness, 149, 192
 Gluing Theorem, 381
 Hyperbolization Theorem, 385
 pleated surfaces, 173
 thick/thin, 173
 Tihomirova, E., 199
 topological rigidity, 182, 282
 Torelli group
 homology spheres, 424
 torsion-free, 55, 66
 Torstensen, Anna, 252
 torus, 99, 190, *see also* punctured torus
 hexagonal, 190, 308, 309
 knot, 396
 marked, 100
 slope of simple loop, 100
 square, 103
 Torus Theorem, 405
 totally geodesic boundary, 179, 377
 trace
 –s determine group, 435
 and Dehn twist, 343
 calculations for cyclic groups, 32
 definition, 2
 identities, 23, 32, 47, 50
 signed, 24
 train tracks, 366
 switch condition, 367
 weighted, 367
 Tranah, David, xviii
 triangle
 area, 7, 19, 459
 area and side length, 27
 group, 61, 98
 uniform thinness, 15
 tripod, 258
 Tschantz, Steven, 252
 tubular neighborhood
 of geodesic, 13, 26, 123, 130, 133
 volume/area, 104
 of systole, 437
 universal, 134
 Tucker, Thomas, 295
 Tukia, Pekka, 154, 183, 184, 186, 209
 twisted I-bundle over Klein bottle, 403
 type preserving, 88, 277
 UHP, 28, *see* upper half-plane
 uniform injectivity, 269
 Uniformization Theorem, 77
 uniformization, simultaneous, 157, 305
 uniformly perfect set, 43, 272
 uniquely ergodic, 166, 343
 universal
 ball, 127
 ball $\subset \mathcal{M}(G)$, 127
 constants, 127
 cover, 67
 PSL(2, \mathbb{R}), 68
 elementary neighborhood, 127
 horoball/horosphere, 127
 horodisk, 190
 extended form in $\Omega(G)$, 141
 hyperbolic solenoid, 118
 isolation of cone axes, 127
 tubular neighborhoods, 127, 134
 universe, curvature of, 12

- University of Minnesota, xviii, 379
 University of Warwick, xviii
 Unknottedness Theorem, 409
 untameness, 296

 van Kampen's Theorem, 151, 383
 Van Vleck, Edward, 27
 vector space of 2×2 matrices, 436
 Virtual Domination
 Conjecture/Theorem, 390
 Virtual Fiberings Conjecture/Theorem,
 387
 Virtual Haken Conjecture/Theorem, 386
 visual angle, 32
 visual sphere, 12
 Vogtmann, Karen, 354
 volume
 3-manifold minimums, 251
 3-orbifold minimums, 251
 estimated by thick part, 104
 geometrically finite, 149
 higher dimensions, 252
 manifold bound, 262
 of ball, 16
 of convex core, 378
 of hyperbolic manifolds, 245, 396
 of maximal horoball, 192
 of polyhedra, 36
 of tetrahedra, 36
 of tubes, 104
 simplicial (of a manifold), 264
 well ordering, 251
 Voronoi diagram, 206
 Vuorinen, Matti, 28

 Wada, Masaaki, 47, 144, 308, 415, 439
 Waldhausen, Friedhelm, xiv, 84, 152,
 186, 282, 383, 386
 Wan, Tom, 182
 Wang, Hsien-chung, 134, 253
 Waterman, Peter, 82, 115
 Weeks manifold, 401
 Weeks, Jeffrey, xvii, 12, 41, 207, 270,
 393, 399
 Weil-Petersson metric, 352, 353
 Weiss, Hartmut, 256
 Whitehead link, 252, 401
 Whitehead, George, 282
 Whitten, W C, 399
 Wielenberg, Norbert, 105, 143, 149, 400,
 401
 wild embedding, 295
 Wiles, Andrew, 96
 Wise, Daniel T., xvii, 389
 Wolf, Michael, 353, 412
 Wolpert, Scott, 120, 353, 436
 word-hyperbolic, 109
 wormhole, 379
 wrapping around a loop, 417
 Wright, David, xi, xvii, 49, 81, 104, 115,
 142, 257, 287, 378

 Yamada, Akira, 217
 Yamashita, Yasushi, 144, 308
 Yau, Shing-Tung, 150
 Yoccoz, Jean-Christophe, 343
 Young, Gail S., 65

 Zhu, Xiaodong, 302