

NAVAL ARCHITECTURE: EXAMPLES AND THEORY

**Comprising 100 worked examples and 420 problems
covering branches of the subject used by naval architects,
draughtsmen, and apprentices in their design- and
drawing-offices**

B. BAXTER

M.Sc., C.Eng., M.R.I.N.A., M.I.Mar.E.

Director and Naval Architect, Yarrow & Co. Ltd, Glasgow

**Formerly:
External Examiner in Naval Architecture,
University of Glasgow**

**Lecturer in Naval Architecture,
King's College, Newcastle upon Tyne,
in the University of Durham**

**Examiner in Shipbuilding,
City and Guilds of London Institute**



**CHARLES GRIFFIN & COMPANY LTD
London and High Wycombe**



CONTENTS

<i>Chapter</i>	<i>Page</i>
1 Quadrature	1
2 Transverse Stability	48
3 Longitudinal Stability	103
4 Flooding and Watertight Sub-division	127
5 Launching Calculations	157
6 Freeboard	185
7 Tonnage	225
8 The Strength of Ships	242
9 Vibration	303
10 Resistance and Powering	337
11 Propulsion and Propellers	370
12 Waves and Ship Motions	406
Answers	434
Greek Alphabet	444
Index	445

INDEX

- Activated fins, 354
 Added virtual mass, 308
 — weight calculations, 128, 143, 152
 Addition of weights, large, 71
 — — —, small, 70
 Admiralty coefficient, 364, 379, 395
 Advance constant, 383
 Air resistance, 337
 Alexander formula for C_d , 34, 46
 — — — heaving, 424
 All-seasons freeboard, 217
 Amplitude of oscillation, 421, 430
 — — vibration, 306
 Amsler, J., integrator, planimeter, 3
 Angle of loll, 75, 94
 Anti-rolling tanks, 408, 429
 Archimedes, principle of, 32
 Area, wetted surface, 45
 Atwood's formula, 92
 Augment of resistance, 381
 Augustin-Normand, M.C.T.1", 118
- B_p and B_u , 371
 Barnaby, N., stability, 48
 Barnes, F. K., stability, 48
 Bending moment, effect of heaving, 424,
 431
 — — on a wave, 252, 255
 — — —, stress due to, 255
 — — —, tabular calculation of, 251
 Bernoulli's theorem, 146, 364, 411
 Bibliography, ix
 Biles, Sir John H., standard strength
 calculations, 243
 Bilging a compartment, 131
 Blade area ratio, 394
 — element theory, 370
 — thickness ratio, 394
 Block coefficient, 33, 34, 40
 Blockage, 364
 BM , longitudinal, 113
 —, transverse, 54, 82
 Bonjean curves, 28, 29
 Boss diameter ratio, 394
 Bouguer, P., launching, 157
 — — —, metacentre, 48
 — — —, trapezoidal rule, 3
 Boundary layer speed, 356
 — — thickness, 360
 Bow height, minimum, 205
 Brake horsepower, 378
 Buckling stress, critical, 254
 Bulkhead deck, 128
- Bunyan, T., vibration, 331
 Buoyancy, centre of, 32
 —, curve of, 257, 260
 Bureau Veritas, 187, 197, 243
 Burrill, L. C., cavitation, 376, 400
 — — —, vibration, 331
 Burtner, propeller diameter, 396
- (C)**, 351
- Camber, deck, 195
 —, effect of, when launching, 159
 —, launching ways, 158, 163
 Captain, H.M.S., loss of, 48
 Cargo settling down, 72, 95
 — ship freeboard, 198, 203
 Cavitation, 375, 400
 — chart, 376, 389
 — number, 376, 390
 Centre of
 areas, 15, 16
 buoyancy, 24, 120
 buoyancy, movement, horizontal, 91
 buoyancy, movement, vertical, 120
 flotation, 18, 30, 31
 gravity, 15, 17
 — — — ship, 61, 69
 Change of C with change of draught, 40
 Change of draught, passing from S.W.
 to F.W., 32
 Change of trim, 103, 105
 due to adding large weight, 104
 due to adding small weight, 103
 moving weight on board, 106
 when docking or grounding, 105, 122
 Changes, small, in beam, draught,
 length, 79, 80
 Chine line, 94
 Classification Societies, major, 247
 Closed shelter deck, freeboard, 215
 — — —, tonnage, 234
 Coefficient of fineness, 187, 191, 192, 204
 — — — friction, launching, 161
 — midship section, 33
 Cole, A., vibration calculation, 322
 Comparison, law of, for propellers, 382
 — — —, for ships, 338
 Complete superstructure ship, 210
 — — —, freeboard, 211
 Computer, 4, 5
 Conditions of equilibrium, 55
 Co-ordinates, polar, 16
 Corresponding speed, 345

- Cotes, R., quadrature, 2
 Criterion of Service, 129, 151
 Cross curves of stability, 68
 Curve, bending moment, 243
 — of flotation, 31
 —, shearing force, 243
 —, statical stability, 68, 95
- Daphne*, loss of, 157
 Deadweight, similar at different speeds, 46
 — tonnage, 237
 Declivity, launching, 167, 170
 Deducted tonnage spaces, 226, 231
 Deflection, calculation of, 251
 Delivered horsepower, 378
 Denny-Mumford, wetted surface area, 45
 Derricks, heavy lift, 91, 99, 100
 Difference in draught, S.W. and F.W., 32, 33
 Direct calculation of stability, 92, 93
 Displacement, 14, 29, 35
 curve, 39
 extreme, 27
 known, find draughts, 109
 lightship, 35, 63
 moulded, 24, 27, 28
 stations, 18, 25, 28, 29, 41
 table, 25, 26
 tonnage, 237
 Dock, floating, 88, 89
 —, off-shore, 64
 Drags, launching, 182
 Draught
 change of, due to a compartment being open to the sea, 131
 displacement curve equation, 35, 46
 due to different densities, 32, 111
 effect of added weights, 113, 115, 118, 119
 extreme, 28
 given, find displacement, 107
 mean, hog and sag correction, 37, 107, 119
 moulded, 28
 unchanged, aft, 112
 Durand's Rule, 10
 Dynamical stability, 75, 95, 96
 Dynamics of launching, 159, 171
- E* for aluminium, 263
 — — concrete, 273
 — — steel, 263, 273
 Eddy-making resistance, 337
 Effect of camber when launching, 159
 — — shift of cargo, 72, 95
 Effective horsepower, 349, 378
 Elgar, F., stability, 49
 Emerson, A., Q.P.C., 374
- Entrained water, 308
 Entrance, 41
 Equation to curve, 15
 Equilibrium, conditions of, 74
 —, stable, 74
 —, unstable, 74
 Euler, buckling load, 281
 Exempted tonnage spaces, 226, 231
- Factor of sub division, 129, 151
 Fatigue, 246
 Fernandez and Smith correction, 284
 Fins, activated, 354
 —, stabilizing, 354, 407
 Five-eight rule, Simpson's, 6
 Floating dock, 88, 89
 Floodable length, 128, 137, 148
 — —, curves, 128, 138
 — —, direct calculations, 128, 140, 149
 — —, standard diagrams, 129
 Flooding, effect on draught, 131
 — — — stability, 130, 144
 — — — trim, 131
 — — — equalization, 144
 Flotation, longitudinal centre of, 18
 Fluids, two in a compartment, 86, 87
 Flush deck ship, 193, 216
 Fore poppet load, 158, 169, 180
 Form coefficients, 33
 — variation, 41
 Frame modulus, 245
 Free surface corrections, 60, 90
 Freeboard, 185, 197, 205
 all-seasons, 217
 cargo ship, 198, 203
 deck, 214
 depth, 187, 209
 for steamers, 188, 192
 for tankers, 188, 192
 history of, 186
 length, 209
 marks, 185
 ore carrier, 219
 passenger ship, 217
 Freight tonnage, 237
 Frequency of vibration, fixed beam, 325
 — — —, longitudinal, 326
 — — —, simply supported beam, 323
 — — —, torsional, 327
 — — —, transverse, 324
 Frictional resistance, 342
 Froude, R. E., circular constant system, 350, 351
 Froude, W., frictional resistance, 342
 — — —, law of comparison, 338, 345, 382
 — — —, number, 343
 — — —, rolling equation, 429
 — — —, wetted surface area, 45
 Full scantling ship, 214

- Geosims, 361
 Gertler resistance curves, 346
 GM , longitudinal, 103, 117
 —, transverse, 48, 55
Great Eastern launch, 157
 Greek alphabet, 444
 Gross tonnage, 226, 230, 238
 Grounding, 66, 122, 123
 —, loss of GM on, 66, 105
 Gumbel, statistical theory, 245
 GZ , 49, 52
- Hardy Cross strength calculation, 245
 Haslar, wetted surface area, 45
 Heaving, 408
 —, period of, 420, 431
 Heavy loads, 91, 99, 115, 125
 Heel, 48, 49, 85, 91
 Heeling moments, 50, 86
 Hogging correction to displacement, 37, 119
 Horsepower, 378, 400
 Hoste, Father, book on naval architecture, 48
 Hull efficiency, 379, 382
 Hydrostatic curves, 27, 104
- I.M.C.O., 228
 Inclining experiment, 58, 60, 83
Indipendenzia, launch of, 157
 Indicated horsepower, 378
 Inertia, moment of, 15, 20, 22, 23
 Initial stability, 49
 Intact waterplane, 132
 Integral formulae, 15
 Integrator, 3
 Integration, approximate, 1
 —, mathematical, 1, 4, 21
 —, mechanical, 3
 Integrator, 3
 Interference, wave, 413
 Isovolum, 97
 I.T.T.C. model-ship correlation, 340, 344
- J*, advance constant, 383
- (K), 351
 K_Q and K_T , 383
 Karman, von, friction formula, 360
 KB -draught curve, slope of, 40
 KM_L , 27, 140
 KM_T , 27, 56, 80
 Kinematic viscosity, 343, 348, 360
 Kinetic energy, 173
 Knot, 400
- (L), 351
 Lackenby, H., frictional resistance, 340
 Laminar flow, 343
 Lanchester, F., propeller theory, 371
 Large angle stability, 49
 Launching calculations, 162
 — diagram, 169
 —, dynamics of, 159, 171
 — forces, 174
 — lubricant, 157, 161
 —, side, 159, 175
 — velocities, 171, 174, 177, 181
 Law of comparison, propeller, 382
 — — —, resistance, 338
 Least squares, method of, 84
 Leclerc's theorem, 31, 44, 117
 Length, correction for resistance, 354
 —, formula for ship, 34
 —, subdivision, 138, 151
 —, wave, 410
 Lewis, F., added virtual mass, 309
Lexington launch, 159
 Lightship displacement, 35, 63
 Lloyd's Register of Shipping, 187, 197, 247
 Load Line conferences, 186, 187, 203
 — — Rules, 186
 — — —, standard of strength, 187, 246
 Lockwood Taylor, J., added virtual mass, 310
 — — —, frequency of vibration, 305
 — — —, shear lag, 265
 Loll, angle of, 75, 94
 Longitudinal,
 bending, 242
 BM , 113
 centre of buoyancy, 24, 108
 centre of flotation, 18, 106
 centre of gravity, 61, 108, 117
 metacentre, 103
 stability, 103
 strength modulus, 190, 211
 Lost buoyancy calculations, 128, 131, 142, 152
- (M), 351
 Margin line, 128, 140, 150
 Martell, B., freeboard, 48
 Masts, stayed, 268, 280, 281
 Merchant Shipping Acts, 127
 Metacentre, longitudinal, 103
 —, transverse, 54
 Metacentric curve of inclined ship, 82
 — — —, tangent to, 80
 — diagram, 57, 77, 80
 — evolute, 97
 — height, 58

- Metacentric involute, 97
 — height, negative, 74, 75, 91, 99
 Method of least squares, 84
 Methods of checking ship at launch, 159
 — — releasing — — —, 160
 Middle body, parallel, 34, 41
 Midship section area coefficient, 33
 Minimum bow height, 205
 Modification to strength section, 287
 Modulus of elasticity, 265
 — — rigidity, 265
 Moment of an area, 15
 — — inertia, 15, 20, 22, 23
 — — —, longitudinal, 23
 — — — of rectangle, 42
 — — — of triangle, 43
 — — —, transverse, 22
 — to change trim one inch, 104, 107
 — — — —, approximate formula, 118
 Momentum theory of propellers, 370
 Montgomerie, J., buckling formula, 292
 Moor, D., resistance, 364
 Moorsom, G., tonnage, 226
 Morrish, S., formula for KB, 38
 Morrow, J., vibration method, 305
 Moseley's formula, 96
 Movement of centre of buoyancy, 120
 — — — gravity, 91
 Moving weights on board a ship, 70, 71
 Muckle, W., buoyancy calculation, 257
 Murnford formula for wetted surface, 45
 Murray, J., bending moment calculation, 255, 282
 Negative metacentric height, 74, 75, 91, 99
 Net tonnage, 227, 230
 Newton, I., integration, 2
 Normand, A., wetted surface area, 45
 O, values, 342, 354
Ocean Vulcan strength experiments, 245
 Off-shore dock, 64
 One-minus prismatic rule, 41
 Open shelter deck ship, 229
 — — — —, freeboard, 214
 — — — —, tonnage, 234
 Open water efficiency, 379
 Ore carrier, freeboard, 219
 Oscillation, amplitude, 421, 430
 —, vibration, 306
- (P), 364
- Panama Canal Tonnage, 227
 Parabola, 2, 39, 77, 86
 Parallel axis theorem, 23
- Parallel body, 34, 41
 Period of wave encounter, 415, 428
 Permanent list, 72
 Permeability, 129, 134
 Permissible length, 129
 Perpendiculars, 25, 119, 138
Perseverance, H.M.S., lack of stability, 48
 Pitching, 408, 420
 Pitch ratio, 371, 394
 Planimeter, 3
 Planing equation, 365
 Plating, load and narrowness factors, 282
 Poisson's ratio, 274
 Polar co-ordinates, 16
 Polynomial, 2nd order, 4, 46
 Potential energy, 172, 364
 Prandtl resistance formula, 359, 360
 Pressure energy, 146, 364, 411
 — on launching ways, 165, 179, 180
 — resistance, 341
 Prismatic coefficient, 33, 41
 Prohaska, C. W., stability, 50, 97
 —, —, vibration, 333
 Pro-metacentre, 97
 Propeller
 back, 394
 blade width ratio, 394
 boss diameter ratio, 394
 design, 370
 excited vibration, 306
 face, 394
 law of comparison, 382
 pitch, 394
 theory, 370
 Propulsive efficiency, 362, 381
 Quadrature, 1
 Quasi propulsive coefficient, 379, 381
Queen Mary launch, 159
 Radial integration, 16, 44
 Radius of gyration, 43, 274, 429
 Raised quarter deck ship, 194, 213
 Range of stability, 69
 Rankine, W. J., strength calculations, 243
 Rayleigh, Lord, law of comparison, 358
 Read, T., heaving correction, 243
 Relation coefficient, 35
 Relative rotative efficiency, 379, 382
 Removal of weights from a ship, 63, 70, 115
 Residuary resistance, 337
 Resistance during launching, 173
 —, frictional, 337
 —, residuary, 337
 — wave making, 337

- Reynolds' Number, 343
 Riddlesworth, W. H., form coefficients, 34
 Righting moments, 51
 Rolling, decremental equation, 420, 423
 — period, 419
 —, resisted, 419
 —, unresisted, 419
 Round of beam, *see Camber*
Rover inclining experiment, 48
 Rudder stock diameter, 276, 277, 278
 Run, 41
- (S), 351
- Sagging correction to displacement, 37, 119
 Schlichting, H., shallow water resistance, 365
 Schlick, O., vibration formula, 307
 Schoenherr, K., frictional coefficient, 339, 361
Scylla inclining experiment, 48
 Settling down of cargo, 72, 95
 Shaft horsepower, 378
 Shear lag effect, 265
 Shearing force, 251, 258
 — stresses, 282, 286
 Sheer of deck, 196
 Shelterdeck ship, closed, 214
 — —, —, freeboard, 215
 — —, —, tonnage, 234
 — —, open, 214
 — —, —, freeboard, 214
 — —, —, tonnage, 234
 Ship form, 4
 — grounding, 66, 122, 123
 — motions, 407
 Side launching, 159
 Simple beam theory, 244
 Simpson's First Rule, 7
 — five-eight rule, 6
 — Second Rule, 8
 — Rules, combination of, 11
 Sinkage due to bilging, 131
 Skin friction, 337, 353, 354
 Sliding ways, 157, 161
 Slip, apparent, 380
 —, constant, 371
 —, effective, 380
 —, true, 380
 Slope of *KB* curve, 40
 — — wave, 427
 Small cargo ship, freeboard, 212
 — passenger ship, freeboard, 216
 Smith correction, 243, 260, 283
 Speed, corresponding, 345
 —, formula, 362
 — of wave, 410, 427
- Speed trials, 391, 400
 St Denis, M., wave spectrum, 415
 Stability
 change of due to docking, 66
 criteria, 52
 cross curves of, 68
 curves of statical, 68
 docking, 87
 dynamical, 75
 effect of flooding on, 130
 effect of moving weights on, 70
 initial, 49
 large angle, 49, 68
 longitudinal, 103
 passenger ship, 51
 range of, 69
 residuary lever, 50
 transverse, 48
 Stabilizers, 354, 407
 Stabilograph, 58
 Stable equilibrium, 49, 55
 Standard series model tests, 346
 Statics of launching, 158
 Steamer, definition of, 217
 —, freeboards, 188, 192
 Stern trawler tonnage, 235
 Sticking declivity, 162
 Still water bending moment, 189, 256
 Strain energy, 271, 311
 Streamline flow, 343
 Strength experiments, dynamical, 244
 — —, statical, 245
 —, standard calculations, 243, 406
 —, welded joints, 274
 Stress, buckling, 292, 293
 Subdivision, 127
 —, history of, 127
 Sue, when docking, 123
 Suez Canal Tonnage, 227
 Superstructures, added to hull, 254
 —, height of, 194
 —, length of, 187, 194
 —, minimum sectional area of, 254, 284, 288
 Surging, 420
 Suspended weights, 71, 91, 99, 100
 Swaying, 420
- Tanker, definition, 217
 —, freeboard, 219, 220
 Taylor, D., propeller constants, 371
 — —, diagrams, 373, 387
 — —, standard series model tests, 346
 — —, wetted surface area, 45, 46
 Taylor Lockwood, J., added virtual mass, 310
 — —, —, vibration, 305
 Tchebycheff's Rules, 3, 12
 Telfer, E. V., resistance coefficient, 350

- Temperature stresses, 263
 Theory of bending, 244
 — least work, 245
 Thickness of boundary layer, 360
 Thrust constant, 383
 — deduction fraction, 381
 — horsepower, 378
 Timber freeboards, 202
Titanic, loss of, 127
 Todd, F., vibration formula, 304, 329,
 330
 Tonnage
 gross, 226
 history of, 225
 mark, 229
 net, 227, 230
 opening, 214, 229
 Panama, 227
 Rules, 226
 Suez, 227
 tanker, 233
 under-deck, 230, 237
 Tons per inch, 18, 37
 Torque constant, 384
 Towing tanks, 337, 341
 Townsin, R., added virtual mass, 304
 Transitional flow, 338
 Transverse *BM*, 54
 — *GM*, 58
 — stability, 48
 — strength, 185, 245
 Trapezoidal Rule, 3, 9
 Travel during launch, 181
 Trawler freeboard, 221
 — tonnage, 235
 Trim, 103
 — and displacement, 105
 — and transverse stability, 105, 110, 121
 —, change due to different densities,
 105, 111
 —, effect on *KB*, 110
 —, moment to change 1°, 107
 Trimming lever, 108
 Trochoidal wave, theory, 406, 410
 Troost, L., propeller diagrams, 389
 Trunk, 193
 Tug freeboard, 221
 Turbulent flow, 343
 — friction line, 339
 Underdeck tonnage, 237
 Unstable equilibrium, 49, 55, 91
 Unsymmetrical bending, 293
 Variation of *KM* curve with draught, 56
 V.C.B., 24, 39, 120
 V.C.G., 20, 120
 Venturi meter, 146
 Vertical prismatic coefficient, 35
 Vibration, amplitude of, 306
 —, causes of, 306
 —, corrections, 311, 313
 —, frequency, 303, 306
 —, fundamental modes, 314, 332
 —, prevention of, 306
 —, types of, 303
 Virtual *GM*, 67, 87, 94
 — weight in waves, 412
 Viscosity, 343
 Vivet, strength calculation, 243
 Volumes, 24
 Vortex theory, 371
 Wake, 370
 — fraction, Froude, 372, 380
 — —, Taylor, 372
 Wall-sided formula, 73, 99
 Water, free, 60, 90
 — resistance, 171, 182
 Waterplane area coefficient, 33
 Wave bending moment, 256
 — encounter, 415, 428
 — length, 410
 — making resistance, 337, 341
 — spectra, 409, 415
 Waves, combination of, 413
 —, deep sea, 410, 418
 —, energy of, 412
 —, shallow water, 418
 —, size of, 406
 —, slope of, 427
 Weddle's Rule, 9
 Weight, curve, 243
 — of drags, 182
 —, materials, 32, 36, 78
 —, suspended, 71, 91, 99, 100
 Wetted surface, area of, 45
 Wind pressure formula, 50
 Wolf, H.M.S., strength experiments, 244
 Work in pumping liquids, 89
 Yawing, 420
 Zones, seasonal, 206