

## CONTENTS

*Foreword, by R.A. Caflisch*

xvii

### CHAPTER I

#### THE EQUATIONS OF MOTION

ART.		PAGE
1, 2.	Fundamental property of a fluid . . . . .	1
3.	The two plans of investigation . . . . .	1
4-9.	'Eulerian' form of the equations of motion. Dynamical equations. Equation of continuity. Physical equations. Surface conditions .	2
10.	Equation of energy . . . . .	8
10 a.	Transfer of momentum . . . . .	10
11.	Impulsive generation of motion . . . . .	10
12.	Equations referred to moving axes . . . . .	12
13, 14.	'Lagrangian' form of the equations of motion and of the equation of continuity . . . . .	12
15, 16.	Weber's transformation . . . . .	14
16 a.	Equations in polar co-ordinates . . . . .	15

### CHAPTER II

#### INTEGRATION OF THE EQUATIONS IN SPECIAL CASES

17.	Velocity-potential. Lagrange's theorem . . . . .	17
18, 19.	Physical and kinematical relations of $\phi$ . . . . .	18
20.	Integration of the equations when a velocity-potential exists. Pressure- equation . . . . .	19
21-23.	Steady motion. Deduction of the pressure-equation from the principle of energy. Limiting velocity . . . . .	20
24.	Efflux of liquids; vena contracta . . . . .	23
24 a, 25.	Efflux of gases . . . . .	25
26-29.	Examples of rotating fluid; uniform rotation; Rankine's 'combined vortex'; electromagnetic rotation . . . . .	28

### CHAPTER III

#### IRROTATIONAL MOTION

30.	Analysis of the differential motion of a fluid element into strain and rotation . . . . .	31
31, 32.	'Flow' and 'circulation.' Stokes' theorem . . . . .	33
33.	Constancy of circulation in a moving circuit . . . . .	35
34, 35.	Irrotational motion in simply-connected spaces; single-valued velocity- potential . . . . .	37

ART.		PAGE
36–39.	Incompressible fluids; tubes of flow. $\phi$ cannot be a maximum or minimum. The velocity cannot be a maximum. Mean value of $\phi$ over a spherical surface . . . . .	38
40, 41.	Conditions of determinateness of $\phi$ . . . . .	41
42–46.	Green's theorem; dynamical interpretation; formula for kinetic energy. Kelvin's theorem of minimum energy . . . . .	43
47, 48.	Multiply-connected regions; 'circuits' and 'barriers' . . . . .	49
49–51.	Irrotational motion in multiply-connected spaces; many-valued velocity-potential; cyclic constants . . . . .	50
52.	Case of incompressible fluids. Conditions of determinateness of $\phi$ . . . . .	53
53–55.	Kelvin's extension of Green's theorem; dynamical interpretation; energy of an irrotationally moving liquid in a cyclic space . . . . .	54
56–58.	'Sources' and 'sinks'; double sources. Irrotational motion of a liquid in terms of surface-distributions of sources . . . . .	57

## CHAPTER IV

## MOTION OF A LIQUID IN TWO DIMENSIONS

59.	Lagrange's stream-function . . . . .	62
60, 60 a.	Relations between stream- and velocity-functions. Two-dimensional sources. Electrical analogies . . . . .	63
61.	Kinetic energy . . . . .	66
62.	Connection with the theory of the complex variable . . . . .	66
63, 64.	Simple types of motion, cyclic and acyclic. Image of a source in a circular barrier. Potential of a row of sources . . . . .	68
65, 66.	Inverse relations. Confocal curves. Flow from an open channel . . . . .	72
67.	General formulae; Fourier method . . . . .	75
68.	Motion of a circular cylinder, without circulation; stream-lines . . . . .	76
69.	Motion of a cylinder with circulation; 'lift.' Trochoidal path under a constant force . . . . .	78
70.	Note on more general problems. Transformation methods; Kutta's problem . . . . .	80
71.	Inverse methods. Motion due to the translation of a cylinder; case of an elliptic section. Flow past an oblique lamina; couple due to fluid pressure . . . . .	83
72.	Motion due to a rotating boundary. Rotating prismatic vessels of various sections. Rotating elliptic cylinder in infinite fluid; general case with circulation . . . . .	86
72 a.	Representation of the effect at a distance of a moving cylinder by a double source . . . . .	90
72 b.	Blasius' expressions for the forces on a fixed cylinder surrounded by an irrotationally moving liquid. Applications; Joukowski's theorem; forces due to a simple source . . . . .	91
73.	Free stream-lines. Schwarz' method of conformal transformation . . . . .	94
74–78.	Examples. Two-dimensional form of Borda's mouthpiece; fluid issuing from a rectilinear aperture; coefficient of contraction. Impact of a stream on a lamina, direct and oblique; resistance. Bobileff's problem . . . . .	96
79.	Discontinuous motions . . . . .	105
80.	Flow on a curved stratum . . . . .	108

## Contents

ix

### CHAPTER V

#### IRROTATIONAL MOTION OF A LIQUID: PROBLEMS IN THREE DIMENSIONS

ART.		PAGE
81, 82.	Spherical harmonics. Maxwell's theory of poles . . . . .	110
83.	Laplace's equation in polar co-ordinates . . . . .	112
84, 85.	Zonal harmonics. Hypergeometric series . . . . .	113
86.	Tesseral and sectorial harmonics . . . . .	116
87, 88.	Conjugate property of surface harmonics. Expansions . . . . .	118
89.	Symbolical solutions of Laplace's equation. Definite integral forms . . . . .	119
90, 91.	Hydrodynamical applications. Impulsive pressures over a spherical surface. Prescribed normal velocity. Energy of motion generated . . . . .	120
91 a.	Examples. Collapse of a bubble. Expansion of a cavity due to internal pressure . . . . .	122
92, 93.	Motion of a sphere in an infinite liquid; inertia coefficient. Effect of a concentric rigid boundary . . . . .	123
94-96.	Stokes' stream-function. Formulæ in spherical harmonics. Stream-lines of a sphere. Images of a simple and a double source in a fluid sphere. Forces on the sphere . . . . .	125
97.	Rankine's inverse method . . . . .	130
98, 99.	Motion of two spheres in a liquid. Kinematical formulæ. Inertia coefficients . . . . .	130
100, 101.	Cylindrical harmonics. Solutions of Laplace's equation in terms of Bessel's functions. Expansion of an arbitrary function . . . . .	134
102.	Hydrodynamical examples. Flow through a circular aperture. Inertia coefficient of a circular disk . . . . .	137
103-106.	Ellipsoidal harmonics for an oblate ellipsoid. Translation and rotation of an oblate ellipsoid in a liquid . . . . .	139
107-109.	Harmonics for a planetary ellipsoid. Flow through a circular aperture. Stream-lines of a circular disk. Translation and rotation of a planetary ellipsoid . . . . .	142
110.	Motion of a fluid in an ellipsoidal vessel . . . . .	146
111.	General orthogonal co-ordinates. Transformation of $\nabla^2\phi$ . . . . .	148
112.	General ellipsoidal co-ordinates; confocal quadrics . . . . .	149
113.	Flow through an elliptic aperture . . . . .	150
114, 115.	Translation and rotation of an ellipsoid in liquid; inertia coefficients . . . . .	152
116.	References to other problems . . . . .	156
	APPENDIX: The hydrodynamical equations referred to general orthogonal co-ordinates . . . . .	156

### CHAPTER VI

#### ON THE MOTION OF SOLIDS THROUGH A LIQUID: DYNAMICAL THEORY

117, 118.	Kinematical formulæ for the case of a single body . . . . .	160
119.	Theory of the 'impulse' . . . . .	161
120.	Dynamical equations relative to axes fixed in the body . . . . .	162
121, 121 a.	Kinetic energy; coefficients of inertia. Representation of the fluid motion at a distance by a double source . . . . .	163
122, 123.	Components of impulse. Reciprocal formulæ . . . . .	166

ART.		PAGE
124.	Expressions for the hydrodynamic forces. The three permanent translations; stability . . . . .	168
125.	The possible modes of steady motion. Motion due to an impulsive couple . . . . .	170
126.	Types of hydrokinetic symmetry . . . . .	172
127–129.	Motion of a solid of revolution. Stability of motion parallel to the axis. Influence of rotation. Other types of steady motion . . . . .	174
130.	Motion of a ‘helicoid’ . . . . .	179
131.	Inertia coefficients of a fluid contained in a rigid envelope . . . . .	180
132–134.	Case of a perforated solid with cyclic motion through the apertures. Steady motion of a ring; condition for stability . . . . .	180
134 a.	The hydrodynamic forces on a cylinder moving in two dimensions . . . . .	184
135, 136.	Lagrange’s equations of motion in generalized co-ordinates. Hamiltonian principle. Adaptation to hydrodynamics . . . . .	187
137, 138.	Examples. Motion of a sphere near a rigid boundary. Motion of two spheres in the line of centres . . . . .	190
139–141.	Modification of Lagrange’s equations in the case of cyclic motion; ignorance of co-ordinates. Equations of a gyrostatic system . . . . .	192
142, 143.	Kineto-statics. Hydrodynamic forces on a solid immersed in a non-uniform stream . . . . .	197
144.	Note on the intuitive extension of dynamic principles . . . . .	201

## CHAPTER VII

## VORTEX MOTION

145.	‘Vortex-lines’ and ‘vortex-filaments’; kinematical properties . . . . .	202
146.	Persistence of vortices; Kelvin’s proof. Equations of Cauchy, Stokes, and Helmholtz. Motion in a fixed ellipsoidal envelope, with uniform vorticity . . . . .	203
147.	Conditions of determinateness . . . . .	207
148, 149.	Velocity in terms of expansion and vorticity; electromagnetic analogy. Velocities due to an isolated vortex . . . . .	208
150.	Velocity-potential due to a vortex . . . . .	211
151.	Vortex-sheets . . . . .	212
152, 153.	Impulse and energy of a vortex-system . . . . .	214
154, 155.	Rectilinear vortices. Stream-lines of a vortex-pair. Other examples . . . . .	219
156.	Investigation of the stability of a row of vortices, and of a double row. Kármán’s ‘vortex-street’ . . . . .	224
157.	Kirchhoff’s theorems on systems of parallel vortices . . . . .	229
158, 159.	Stability of a columnar vortex of finite section; Kirchhoff’s elliptic vortex . . . . .	230
159 a.	Motion of a solid in a liquid of uniform vorticity . . . . .	233
160.	Vortices in a curved stratum of fluid . . . . .	236
161–163.	Circular vortices; potential- and stream-function of an isolated circular vortex; stream-lines. Impulse and energy. Velocity of translation of a vortex-ring . . . . .	236
164.	Mutual influence of vortex-rings. Image of a vortex-ring in a sphere . . . . .	242
165.	General conditions for steady motion of a fluid. Cylindrical and spherical vortices . . . . .	243
166.	References . . . . .	246
166 a.	Bjerknes’ theorems . . . . .	247
167.	Clebsch’s transformation of the hydrodynamical equations . . . . .	248

## Contents

xi

### CHAPTER VIII

#### TIDAL WAVES

ART.		PAGE
168.	General theory of small oscillations; normal modes; forced oscillations .	250
169–174.	Free waves in uniform canal; effect of initial conditions; measuring of the approximations; energy . . . . .	254
175.	Artifice of steady motion . . . . .	261
176.	Superposition of wave-systems; reflection . . . . .	262
177–179.	Effect of disturbing forces; free and forced oscillations in a finite canal .	263
180–184.	Canal theory of the tides. Disturbing potentials. Tides in an equatorial canal, and in a canal parallel to the equator; semi-diurnal and diurnal tides. Canal coincident with a meridian; change of mean level; fortnightly tide. Equatorial canal of finite length; lag of the tide . . . . .	267
185, 186.	Waves in a canal of variable section. Examples of free and forced oscillations; exaggeration of tides in shallow seas and estuaries .	273
187, 188.	Waves of finite amplitude; change of type in a progressive wave. Tides of the second order . . . . .	278
189, 190.	Wave motion in two horizontal dimensions; general equations. Oscillations of a rectangular basin . . . . .	282
191, 192.	Oscillations of a circular basin; Bessel's functions; contour lines. Elliptic basin; approximation to slowest mode . . . . .	284
193.	Case of variable depth. Circular basin . . . . .	291
194–197.	Propagation of disturbances from a centre; Bessel's function of the second kind. Waves due to a local periodic pressure. General formula for diverging waves. Examples of a transient local disturbance . .	293
198–201.	Oscillations of a spherical sheet of water; free and forced waves. Effect of the mutual gravitation of the water. Reference to the case of a sea bounded by meridians and parallels . . . . .	301
202, 203.	Equations of motion of a dynamical system referred to rotating axes .	307
204–205 a.	Small oscillations of a rotating system; stability 'ordinary' and 'secular.' Effect of a <i>small</i> degree of rotation on types and frequencies of normal modes . . . . .	309
205 b.	Approximate calculation of frequencies . . . . .	313
206.	Forced oscillations . . . . .	316
207, 208.	Hydrodynamical examples; tidal oscillations of a rotating plane sheet of water; waves in a straight canal . . . . .	317
209–211.	Rotating circular basin of uniform depth; free and forced oscillations .	320
212.	Circular basin of variable depth . . . . .	326
212 a.	Examples of approximate procedure . . . . .	328
213, 214.	Tidal oscillations on a rotating globe. Laplace's kinetic theory . .	330
215–217.	Symmetrical oscillations. Tides of long period . . . . .	333
218–221.	Diurnal and semi-diurnal tides. Discussion of Laplace's solution . .	340
222, 223.	Hough's investigations; extracts and results . . . . .	347
223 a.	References to further researches . . . . .	352
224.	Modifications of the kinetic theory due to the actual configuration of the ocean; question of phase . . . . .	353
225, 226.	Stability of the ocean. Remarks on the general theory of kinetic stability .	355
	APPENDIX: On Tide-generating Forces . . . . .	358

## CHAPTER IX

## SURFACE WAVES

ART.		PAGE
227.	The two-dimensional problem ; surface conditions . . . . .	363
228.	Standing waves ; lines of motion . . . . .	364
229, 230.	Progressive waves ; orbits of particles. Wave-velocity ; numerical tables. Energy of a simple-harmonic wave-train . . . . .	366
231.	Oscillations of superposed fluids . . . . .	370
232.	Instability of the boundary of two currents . . . . .	373
233, 234.	Artifice of steady motion . . . . .	375
235.	Waves in a heterogeneous liquid . . . . .	378
236, 237.	Group-velocity. Transmission of energy . . . . .	380
238–240.	The Cauchy-Poisson wave-problem ; waves due to an initial local elevation, or to a local impulse. . . . .	384
241.	Kelvin's approximate formula for the effect of a local disturbance in a linear medium. Graphical constructions . . . . .	395
242–246.	Surface-disturbance of a stream. Case of finite depth. Effect of inequalities in its bed . . . . .	398
247.	Waves due to a submerged cylinder . . . . .	410
248, 249.	General theory of waves due to a travelling disturbance. Wave-resistance . . . . .	413
250.	Waves of finite height ; waves of permanent type. Limiting form . . . . .	417
251.	Gerstner's rotational waves . . . . .	421
252, 253.	Solitary waves. Oscillatory waves of Korteweg and De Vries . . . . .	423
254.	Helmholtz' dynamical condition for waves of permanent type . . . . .	427
255, 256.	Wave-propagation in two horizontal dimensions. Effect of a local disturbance. Effect of a travelling pressure-disturbance ; wave-patterns . . . . .	429
256 a, 256 b.	Travelling disturbances of other types. Ship-waves. Wave-resistance. Effect of finite depth on the wave-pattern . . . . .	437
257–259.	Standing waves in limited masses of water. Transverse oscillation in canals of triangular, and semi-circular section . . . . .	440
260, 261.	Longitudinal oscillations ; canal of triangular section ; edge-waves . . . . .	445
262–264.	Oscillations of a liquid globe, lines of motion. Ocean of uniform depth on a spherical nucleus . . . . .	450
265.	Capillarity. Surface-condition . . . . .	455
266.	Capillary waves. Group-velocity . . . . .	456
267, 268.	Waves under gravity and capillarity. Minimum wave-velocity. Waves on the boundary of two currents . . . . .	458
269.	Waves due to a local disturbance. Effect of a travelling disturbance ; waves and ripples . . . . .	462
270–272.	Surface-disturbance of a stream ; formal investigation. Fish-line problem. Wave-patterns . . . . .	464
273, 274	Vibrations of a cylindrical column of liquid. Instability of a jet . . . . .	471
275	Oscillations of a liquid globe, and of a bubble . . . . .	473

*Contents*

xiii

CHAPTER X

WAVES OF EXPANSION

ART.		PAGE
276–280.	Plane waves; velocity of sound; energy of a wave-system . . . .	476
281–284.	Plane waves of finite amplitude; methods of Riemann and Earnshaw. Condition for permanence of type; Rankine's investigations. Waves of approximate discontinuity . . . . .	481
285, 286.	Spherical waves. Solution in terms of initial conditions . . . . .	489
287, 288.	General equation of sound-waves. Equation of energy. Determinateness of solutions . . . . .	492
289.	Simple-harmonic vibrations. Simple and double sources. Emission of energy . . . . .	496
290.	Helmholtz' adaptation of Green's theorem. Velocity-potential in terms of surface-distributions of sources. Kirchhoff's formula . . . . .	498
291.	Periodic disturbing forces . . . . .	501
292.	Applications of spherical harmonics. General formulae . . . . .	503
293.	Vibrations of air in a spherical vessel. Vibrations of a spherical stratum	506
294.	Propagation of waves outwards from a spherical surface; attenuation due to lateral motion . . . . .	508
295.	Influence of the air on the oscillations of a ball-pendulum; correction for inertia; damping . . . . .	510
296–298.	Scattering of sound-waves by a spherical obstacle. Impact of waves on a movable sphere; case of synchronism . . . . .	511
299, 300.	Diffraction when the wave-length is relatively large: by a flat disk, by an aperture in a plane screen, and by an obstacle of any form . . . . .	517
301.	Solution of the equation of sound in spherical harmonics. Conditions at a wave-front . . . . .	521
302.	Sound-waves in two dimensions. Effect of a transient source; comparison with the one- and three-dimensional cases . . . . .	524
303, 304.	Simple-harmonic vibrations; solutions in Bessel functions. Oscillating cylinder. Scattering of waves by a cylindrical obstacle . . . . .	527
305.	Approximate theory of diffraction of long waves in two dimensions. Diffraction by a flat blade, and by an aperture in a thin screen . . . . .	531
306, 307.	Reflection and transmission of sound-waves by a grating . . . . .	533
308.	Diffraction by a semi-infinite screen . . . . .	538
309, 310.	Waves propagated vertically in the atmosphere; 'isothermal' and 'con- vective' hypotheses . . . . .	541
311, 311a, 312.	Theory of long atmospheric waves . . . . .	547
313.	General equations of vibration of a gas under constant forces. . . . .	554
314, 315.	Oscillations of an atmosphere on a non-rotating globe . . . . .	556
316.	Atmosphere tides on a rotating globe. Possibility of resonance . . . . .	558

## CHAPTER XI

## VISCOSITY

ART.		PAGE
317, 318.	Theory of dissipative forces. One degree of freedom; free and forced oscillations. Effect of friction on phase . . . . .	562
319.	Application to tides in equatorial canal; tidal lag and tidal friction . . . . .	565
320.	Equations of dissipative systems in general; frictional and gyrostatic terms. Dissipation function . . . . .	567
321.	Oscillations of a dissipative system about a configuration of absolute equilibrium . . . . .	568
322.	Effect of gyrostatic terms. Example of two degrees of freedom; disturbing forces of long period . . . . .	570
323–325.	Viscosity of fluids; specification of stress; formulae of transformation . . . . .	571
326, 327.	The stresses as linear functions of rates of strain. Coefficient of viscosity. Boundary-conditions; question of slipping . . . . .	574
328.	Dynamical equations. The modified Helmholtz equations; diffusion of vorticity . . . . .	576
329.	Dissipation of energy by viscosity . . . . .	579
330, 330 a.	Flow of a liquid between parallel planes. Hele Shaw's experiments. Theory of lubrication; example . . . . .	581
331, 332.	Flow through a pipe of circular section; Poiseuille's laws; question of slipping. Other forms of section . . . . .	585
333, 334.	Cases of steady rotation. Practical limitations . . . . .	587
334 a.	Examples of variable motion. Diffusion of a vortex. Effect of surface-forces on deep water . . . . .	590
335, 336.	Slow steady motion; general solution in spherical harmonics; formulae for the stresses . . . . .	594
337.	Rectilinear motion of a sphere; resistance; terminal velocity; stream-lines. Case of a liquid sphere; and of a solid sphere, with slipping . . . . .	597
338.	Method of Stokes; solutions in terms of the stream-function . . . . .	602
339.	Steady motion of an ellipsoid . . . . .	604
340, 341.	Steady motion in a constant field of force . . . . .	605
342.	Steady motion of a sphere; Oseen's criticism, and solution . . . . .	608
343, 343 a.	Steady motion of a cylinder, treated by Oseen's method. References to other investigations . . . . .	614
344.	Dissipation of energy in steady motion; theorems of Helmholtz and Korteweg. Rayleigh's extension . . . . .	617
345–347.	Problems of periodic motion. Laminar motion, diffusion of vorticity. Oscillating plane. Periodic tidal force; feeble influence of viscosity in rapid motions . . . . .	619
348–351.	Effect of viscosity on water-waves. Generation of waves by wind. Calming effect of oil on waves . . . . .	623
352, 353.	Periodic motion with a spherical boundary; general solution in spherical harmonics . . . . .	632
354.	Applications; decay of motion in a spherical vessel; torsional oscillations of a hollow sphere containing liquid . . . . .	637
355.	Effect of viscosity on the oscillations of a liquid globe . . . . .	639
356.	Effect on the rotational oscillations of a sphere, and on the vibrations of a pendulum . . . . .	641
357.	Notes on two-dimensional problems . . . . .	644



## Contents

XV

ART.	PAGE
358. Viscosity in gases; dissipation function . . . . .	645
359, 360. Damping of plane waves of sound by viscosity; combined effect of viscosity and thermal conduction . . . . .	646
360 a. Waves of permanent type, as affected by viscosity alone . . . . .	650
360 b. Absorption of sound by porous bodies . . . . .	652
361. Effect of viscosity on diverging waves . . . . .	654
362, 363. Effect on the scattering of waves by a spherical obstacle, fixed or free . . . . .	657
364. Damping of sound-waves in a spherical vessel . . . . .	661
365, 366. Turbulent motion. Reynolds' experiments; critical velocities of water in a pipe; law of resistance. Inferences from theory of dimensions . . . . .	663
366 a. Motion between rotating cylinders . . . . .	667
366 b. Coefficient of turbulence; 'eddy' or 'molar' viscosity . . . . .	668
366 c. Turbulence in the atmosphere; variation of wind with height . . . . .	669
367, 368. Theoretical investigations of Rayleigh and Kelvin . . . . .	670
369. Statistical method of Reynolds . . . . .	674
370. Resistance of fluids. Criticism of the discontinuous solutions of Kirchhoff and Rayleigh . . . . .	678
370 a. Kármán's formula for resistance . . . . .	680
370 b. Lift due to circulation . . . . .	681
371. Dimensional formulae. Relations between model and full-scale . . . . .	682
371 a, b, c. The boundary layer. Note on the theory of the aerofoil . . . . .	684
371 d, e, f, g. Influence of compressibility. Failure of stream-line flow at high speeds . . . . .	691

## CHAPTER XII

### ROTATING MASSES OF LIQUID

372. Forms of relative equilibrium. General theorems . . . . .	697
373. Formulae relating to attraction of ellipsoids. Potential energy of an ellipsoidal mass . . . . .	700
374. Maclaurin's ellipsoids. Relations between eccentricity, angular velocity and angular momentum; numerical tables . . . . .	701
375. Jacobi's ellipsoids. Linear series of ellipsoidal forms of equilibrium. Numerical results . . . . .	704
376. Other special forms of relative equilibrium. Rotating annulus . . . . .	707
377. General problem of relative equilibrium; Poincaré's investigation. Linear series of equilibrium forms; limiting forms and forms of bifurcation. Exchange of stabilities . . . . .	710
378–380. Application to a rotating system. Secular stability of Maclaurin's and Jacobi's ellipsoids. The pear-shaped figure of equilibrium . . . . .	713
381. Small oscillations of a rotating ellipsoidal mass; Poincaré's method. References . . . . .	717
382. Dirichlet's investigations; references. Finite gravitational oscillations of a liquid ellipsoid without rotation. Oscillations of a rotating ellipsoid of revolution . . . . .	719
383. Dedekind's ellipsoid. The irrotational ellipsoid. Rotating elliptic cylinder . . . . .	721
384. Free and forced oscillations of a rotating ellipsoidal shell containing liquid. Precession . . . . .	724
385. Precession of a liquid ellipsoid . . . . .	728
LIST OF AUTHORS CITED . . . . .	731
INDEX . . . . .	734