IV. "Note on the Free Vibrations of an infinitely long Cylindrical Shell." By LORD RAYLEIGH, Sec. R.S. Received February 26, 1889.

In a recent memoir* Mr. Love has considered this question among others; but he has not discussed his result [equation (95)], except in its application to a rather special case involving the existence of a free edge. When the cylinder is regarded as infinitely long, the problem is naturally of a simpler character; and I have thought that it might be worth while to express more fully the frequency equation, as applicable to all vibrations, independent of the thickness of the shell, which are periodic with respect both to the length and the circumference of the cylinder.

In order to prevent misunderstanding, it may be well to premise that the vibrations, whose frequency is to be determined, do not include the gravest of which a thin shell is capable. If the middle surface be simply bent, the potential energy of deformation is of a higher order of magnitude than in the contrary case, and according to the present method of treatment the frequency of vibration will appear to be zero. It is known, however, that the only possible modes of bending of a cylindrical shell are such as are not periodic along the length, or rather have the wave-length in this direction infinitely long.† When the middle surface is stretched, as well as bent, the potential energy of bending may be neglected, except in certain very special cases.

Taking cylindrical co-ordinates (r, ϕ, z), and denoting the displacements parallel to z, ϕ, r by u, v, w respectively, we have for the principal elongations and shear at any point (a, ϕ, z)‡—

$$\sigma_1 = \frac{du}{dz}, \qquad \sigma_2 = \frac{w}{a} + \frac{1}{a}\frac{dv}{d\phi}, \qquad \varpi = \frac{1}{a}\frac{du}{d\phi} + \frac{dv}{dz} \quad \ldots\ldots (1);$$

and the energy per unit of area is expressed by

$$2nh\left\{\sigma_1^2 + \sigma_2^2 + \tfrac{1}{2}\varpi^2 + \frac{m-n}{m+n}(\sigma_1+\sigma_2)^2\right\} \quad \ldots\ldots\ldots (2),$$

where $2h$ denotes the thickness of the shell, and m, n are the elastic constants of Thomson and Tait's notation.

* "On the small Free Vibrations and Deformation of a thin Elastic Shell," 'Phil. Trans.,' A, vol. 179 (1888), p. 491.

† "On the Bending and Vibration of thin Elastic Shells, especially of Cylindrical Form," 'Roy. Soc. Proc.,' *supra*, p. 105.

‡ See a paper on the Infinitesimal Bending of Surfaces of Revolution ('London Math. Soc. Proc.,' vol. 13, p. 4, Nov. 1881), and those already cited.

The functions u, v, w are to be assumed proportional to the sines, or cosines, of μz and $s\phi$. These may be combined in various ways, but a sufficient example is

$$u = \mathrm{U}\cos s\phi \cos \mu z, \quad v = \mathrm{V}\sin s\phi \sin \mu z, \quad w = \mathrm{W}\cos s\phi \sin \mu z \ldots (3);$$

so that

$$\sigma_1 = -\mu \mathrm{U}\cos s\phi \sin \mu z \ldots (4),$$

$$\sigma_2 = (\mathrm{W}+s\mathrm{V})\cos s\phi \sin \mu z \ldots (5),$$

$$\varpi = (-s\mathrm{U}+\mu\mathrm{V})\sin s\phi \cos \mu z \ldots (6),$$

unity being written for convenience in place of a. The energy per unit area is thus

$$2nh\Big[\cos^2 s\phi \sin^2 \mu z\Big\{\mu^2\mathrm{U}^2+(\mathrm{W}+s\mathrm{V})^2+\frac{m-n}{m+n}(\mathrm{W}+s\mathrm{V}-\mu\mathrm{U})^2\Big\} + \sin^2 s\phi \cos^2 \mu z\,(-s\mathrm{U}+\mu\mathrm{V})^2\Big] \ldots (7).$$

Again, the kinetic energy per unit area is, if ρ be the volume density,

$$\rho h\left[\left(\frac{d\mathrm{U}}{dt}\right)^2 \cos^2 s\phi \cos^2 \mu z+\left(\frac{d\mathrm{V}}{dt}\right)^2 \sin^2 s\phi \sin^2 \mu z+\left(\frac{d\mathrm{W}}{dt}\right)^2 \cos^2 s\phi \sin^2 \mu z\right] \ldots (8).$$

In the integration of these expressions with respect to ϕ and z, the mean value of each $\sin^2$ or $\cos^2$ is $\frac{1}{2}$.* We may then apply Lagrange's method. If the type of vibration be $\cos pt$, and $p^2\rho/n = k^2$, the resulting equations may be written

$$\{2(\mathrm{M}+1)\mu^2+s^2-k^2\}\mathrm{U}-(2\mathrm{M}+1)\mu s\mathrm{V}-2\mathrm{M}\mu\mathrm{W} = 0 \ldots (9),$$

$$-(2\mathrm{M}+1)\mu s\mathrm{U}+\{\mu^2+2(\mathrm{M}+1)s^2-k^2\}\mathrm{V}+2(\mathrm{M}+1)s\mathrm{W} = 0 \ldots (10),$$

$$-2\mathrm{M}\mu\mathrm{U}+2(\mathrm{M}+1)s\mathrm{V}+\{2(\mathrm{M}+1)-k^2\}\mathrm{W} = 0 \ldots (11),$$

where

$$\mathrm{M} = \frac{m-n}{m+n} \ldots (12).$$

The frequency equation is that expressing the evanescence of the determinant of this triad of equations.

We will consider for a moment the simple case which arises when $\mu = 0$, that is, when the displacements are independent of z. The three equations reduce to

* In the physical problem the range of integration for ϕ is from 0 to 2π; but mathematically we are not confined to one revolution. We may conceive the shell to consist of several superposed convolutions, and then s is not limited to be a whole number.

$$(s^2-k^2)\mathrm{U} = 0 \ldots\ldots\ldots\ldots\ldots\ldots (13),$$

$$\{2(\mathrm{M}+1)s^2-k^2\}\mathrm{V}+2(\mathrm{M}+1)s\mathrm{W} = 0 \ldots\ldots\ldots (14),$$

$$2(\mathrm{M}+1)s\mathrm{V}+\{2(\mathrm{M}+1)-k^2\}\mathrm{W} = 0 \ldots\ldots\ldots (15);$$

and they may be satisfied in two ways. First let $\mathrm{V} = \mathrm{W} = 0$; then U may be finite, provided

$$s^2-k^2 = 0 \ldots\ldots\ldots\ldots\ldots\ldots (16).$$

The corresponding type for U is

$$\mathrm{U} = \cos s\phi \cos pt \ldots\ldots\ldots\ldots\ldots\ldots (17),$$

where

$$p^2 = \frac{ns^2}{\rho a^2} \ldots\ldots\ldots\ldots\ldots\ldots (18),$$

a being restored, as can be done at any moment by consideration of dimensions. In this motion the material is sheared without extension, every generating line of the cylinder moving along its own length. The frequency depends upon the circumferential wave-length, and not upon the curvature of the cylinder.

The second kind of vibrations are those in which $\mathrm{U} = 0$, so that the motion is strictly in two dimensions. The elimination of the ratio V/W from (14), (15) gives

$$k^2\{k^2-2(\mathrm{M}+1)(1+s^2)\} = 0 \ldots\ldots\ldots\ldots (19),$$

as the frequency equation. The first root is $k^2 = 0$, indicating infinitely slow motion. These are the flexural vibrations already referred to, and the corresponding relation between V and W is by (14)

$$s\mathrm{V}+\mathrm{W} = 0 \ldots\ldots\ldots\ldots\ldots\ldots (20),$$

giving by (4), (5), (6),

$$\sigma_1 = \sigma_2 = \varpi = 0.$$

The other root of (19) gives on restoration of a,

$$k^2a^2 = \frac{4m}{m+n}(1+s^2) \ldots\ldots\ldots\ldots\ldots (21),$$

or

$$p^2 = \frac{4mn}{m+n}\frac{1+s^2}{a^2\rho} \ldots\ldots\ldots\ldots\ldots (22);$$

while the relation between V and W is

$$-\mathrm{V}+s\mathrm{W} = 0 \ldots\ldots\ldots\ldots\ldots\ldots (23).$$

It will be observed that when s is very large, the flexural vibrations tend to become exclusively normal, and the extensional vibrations to become exclusively tangential, as might have been expected from the theory of plane plates.

Returning now to the general case, the determinant of (9), (10), (11) gives on reduction

$$[k^2-\mu^2-s^2]\{k^2[k^2-2(\mathrm{M}+1)\,(\mu^2+s^2+1)]+4(2\mathrm{M}+1)\mu^2\}$$
$$+4(2\mathrm{M}+1)\mu^2s^2=0 \quad \ldots\ldots\ldots\ldots\ldots \quad (24).$$

If $\mu=0$, we have the three solutions already considered,

$$k^2=0, \qquad k^2=s^2, \qquad k^2=2(\mathrm{M}+1)\,(s^2+1).$$

If $s=0$, that is, if the deformation be symmetrical about the axis, we have

$$k^2=\mu^2, \quad \text{or} \quad k^2[k^2-2(\mathrm{M}+1)\,(\mu^2+1)]+4(2\mathrm{M}+1)\mu^2=0 \;\ldots\; (25).$$

Corresponding to the first root we have $\mathrm{U}=0$, $\mathrm{W}=0$, as is readily proved on reference to the original equations with $s=0$. The vibrations are the purely torsional ones represented by

$$v=\sin\mu z\cos pt \quad \ldots\ldots\ldots\ldots\ldots \quad (26),$$

where

$$p^2=\frac{n\mu^2}{\rho} \quad \ldots\ldots\ldots\ldots\ldots\ldots (27).$$

The frequency depends upon the wave-length parallel to the axis, and not upon the radius of the cylinder.

The remaining roots of (25) correspond to motions for which $\mathrm{V}=0$, or which take place in planes through the axis. The general character of these vibrations may be illustrated by the case where μ is small, or the wave-length a large multiple of the radius of the cylinder. We find approximately from the quadratic (on restoration of a)

$$\frac{k^2a^2}{\mathrm{M}+1}=2+\frac{2\mathrm{M}^2\mu^2a^2}{(\mathrm{M}+1)^2} \quad \ldots\ldots\ldots\ldots\ldots (28),$$

or

$$k^2=\frac{2(2\mathrm{M}+1)\mu^2}{(\mathrm{M}+1)} \quad \ldots\ldots\ldots\ldots\ldots (29).$$

The vibrations of (28) are nearly purely radial. If we suppose that μ vanishes, we fall back upon

$$k^2a^2=2(\mathrm{M}+1),$$

or $$p^2 = \frac{4mn}{m+n}\frac{1}{a^2\rho} \quad \ldots\ldots\ldots\ldots\ldots\ldots (30),*$$

as may be seen from (22), by putting $s = 0$.

On the other hand, the vibrations of (29) are nearly purely axial. In terms of m and n,

$$p^2 = \frac{n\mu^2}{\rho}\frac{3m-n}{m} \quad \ldots\ldots\ldots\ldots\ldots\ldots (31).$$

Now, if q denote Young's modulus,

$$q = \frac{n(3m-n)}{m} \quad \ldots\ldots\ldots\ldots\ldots\ldots (32);$$

so that $$p^2 = \frac{q\mu^2}{\rho} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots (33).$$

This is the ordinary formula for the longitudinal vibrations of a rod, the fact that the section is here a thin annulus not influencing the result to this order of approximation.

Another extreme case worthy of notice occurs when s is very great. Equation (24) then reduces to

$$k^2[k^2-\mu^2-s^2][k^2-2(\mathrm{M}+1)(\mu^2+s^2)] = 0 \quad \ldots\ldots (34);$$

so that k^2 becomes a function of μ and s only through (μ^2+s^2), as might have been expected from the theory of plane plates. The first root relates to flexural vibrations; the second to vibrations of shearing, as in (18); the third to vibrations involving extension of the middle surface, analogous to those in (22).

It is scarcely necessary to add, in conclusion, that the most general deformation of the middle surface can be expressed by means of a series of such as are periodic with respect to z and ϕ, so that the problem considered is really the most general small motion of an infinite cylindrical shell.

[Another particular case worth notice arises when $s = 1$, so that (24) assumes the form

$$k^2(k^2-\mu^2-1)[k^2-2(\mathrm{M}+1)(\mu^2+2)] + 4\mu^2(k^2-\mu^2)(2\mathrm{M}+1) = 0 \quad \ldots\ldots (35).$$

As we have already seen, if μ be zero, one of the values of k^2 vanishes. If μ be small, the corresponding value of k^2 is of the order μ^4. Equation (35) gives in this case

$$k^2 = \frac{2\mathrm{M}+1}{\mathrm{M}+1}\mu^4 \quad \ldots\ldots\ldots\ldots\ldots (36);$$

* This equation is given, in a slightly different form, by Love (*loc. cit.*, p. 523).

or in terms of p, q, and with restoration of a,

$$p^2 = \frac{q\mu^4 a^2}{2\rho} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (37).$$

This agrees with the usual formula* for the transverse vibrations of rods.—Added April 3.]

Presents, March 14, 1889.

Transactions.

Bologna :—Reale Accademia delle Scienze dell' Istituto. Memorie. Ser. 4. Tomo VIII. 4to. *Bologna* 1887. The Academy.

Bordeaux :—Société des Sciences Physiques et Naturelles. Mémoires. Sér. 3. Tome III. No. 2. 8vo. *Paris* 1887; Observations Pluviométriques et Thermométriques faites dans le Département de la Gironde, 1886–87. (Appendice au Tome III. des Mémoires.) 8vo. *Bordeaux* 1887. The Society.

Brussels :—Société Royale Malacologique de Belgique. Annales. Tome XXII. 8vo. *Bruxelles* [1888]; Procès-Verbaux des Séances. Année 1888. 8vo. *Bruxelles.* The Society.

Buenos Aires :—Museo Nacional. Anales. Tomo III. Entrega 15. 4to. *Buenos Aires* 1888. The Museum.

Cambridge, Mass. :—Harvard University. Bulletin. No. 42. 8vo. *Cambridge* 1889. The University.

Cape Town :—South African Philosophical Society. Transactions. Vol. IV. Parts 1–2. 8vo. *Cape Town* 1887–88. The Society.

Catania :—Accademia Gioenia de Scienze Naturali. Bullettino Mensile. 1889. Fasc. 3. 8vo. *Catania.* The Academy.

Frankfort-on-Oder :—Naturwissenschaftlicher Verein. Monatliche Mittheilungen aus dem Gesammtgebiete der Naturwissenschaften. Jahrg. VI. Nr. 4–9. 8vo. [*Frankfurt*] 1888-89; Societatum Litterae. 1888. Nos. 6–10. 8vo. [*Frankfurt.*] The Verein.

Geneva :—Société de Physique et d'Histoire Naturelle. Mémoires. Tome XXX. Partie 1. 4to. *Genève* 1888. The Society.

Kew :—Royal Gardens. Bulletin of Miscellaneous Information. Nos. 25–27. 8vo. *London* 1889. The Director.

Klausenburg :—Erdélyi Muzeum. Értesitő (Szak I) 1888. Évfolyam 13. 8vo. *Kolozsvárt*; Értesitő (Szak II) 1888. Évfolyam 13. *Kolozsvárt.* The Museum.

London :—Photographic Society of Great Britain. Journal and Transactions. Vol. XIII. No. 5. 8vo. *London* 1889. The Society.

* 'Theory of Sound,' § 181.

P/Soc/R

PROCEEDINGS

OF THE

ROYAL SOCIETY OF LONDON.

From November 15, 1888, *to April* 11, 1889.

VOL. XLV.

LONDON:
HARRISON AND SONS, ST. MARTIN'S LANE,
Printers in Ordinary to Her Majesty.
MDCCCLXXXIX.

Q
41
L718
V.45

LONDON:
HARRISON AND SONS, PRINTERS IN ORDINARY TO HER MAJESTY,
ST. MARTIN'S LANE.

6510
17/11/90

CONTENTS.

VOL. XLV.

No. 273.—*November* 15, 1888.

Page

Combustion in dried Oxygen. By H. Brereton Baker, M.A., Dulwich College, late Scholar of Balliol College, Oxford 1

On the Mechanical Conditions of a Swarm of Meteorites, and on Theories of Cosmogony. By G. H. Darwin, LL.D., F.R.S., Fellow of Trinity College and Plumian Professor in the University of Cambridge..... 3

On the Secretion of Saliva, chiefly on the Secretion of Salts in it. By J. N. Langley, M.A., F.R.S., Fellow of Trinity College, and H. M. Fletcher, B.A., Trinity College, Cambridge 16

Observations upon the Electromotive Changes in the Mammalian Spinal Cord following Electrical Excitation of the Cortex Cerebri. Preliminary Notice. By Francis Gotch, M.A. Oxon., B.A., B.Sc. Lond., and Victor Horsley, B.S., F.R.S., Professor of Pathology, University College, London (Plate 1) 18

List of Presents..... 26

November 22, 1888.

On the Specific Heats of Gases at Constant Volume. (Preliminary Note.) By J. Joly, M.A., B.E..... 33

Report of Researches on Silicon Compounds and their Derivatives. Part I. By J. Emerson Reynolds, M.D., F.R.S., Professor of Chemistry, University of Dublin 37

Preliminary Note on a Silico-organic Compound of a new Type. By J. Emerson Reynolds, M.D., F.R.S., Professor of Chemistry, University of Dublin 39

On the Magnetisation of Iron and other Magnetic Metals in very strong Fields. By J. A. Ewing, B.Sc., F.R.S., Professor of Engineering in University College, Dundee, and William Low 40

The Waves on a rotating Liquid Spheroid of finite Ellipticity. By G. H. Bryan, B.A. 42

List of Presents..... 45

November 30, 1888.

ANNIVERSARY MEETING.

Page

Report of Auditors 47

List of Fellows deceased since last Anniversary 47

———————— elected 48

Address of the President 48

Election of Council and Officers 58

Financial Statement 60–63

Trust Funds 64–68

Table showing Progress and present State of Society with regard to Fellows 69

Account of the appropriation of the sum of £4,000 (the Government Grant) annually voted by Parliament to the Royal Society, to be employed in aiding the Advancement of Science 69

Account of Grants from the Donation Fund 72

Report of the Kew Committee 73

No. 274.—*December* 6, 1888.

Description of the Skull of an extinct Carnivorous Marsupial of the size of a Leopard (*Thylacopardus australis*, Ow.), from a recently opened Cave near the "Wellington Cave" locality, New South Wales. By Sir Richard Owen, K.C.B., F.R.S., &c. 99

The Pectoral Group of Muscles. By Bertram C. A. Windle, M.A., M.D. (Dub.), Professor of Anatomy in the Queen's College, Birmingham 99

Some Observations on the Amount of Light Reflected and Transmitted by certain kinds of Glass. By Sir John Conroy, Bart., M.A., Bedford Lecturer of Balliol College and Millard Lecturer of Trinity College, Oxford 101

The Specific Resistance and other Properties of Sulphur. By James Monckman, D.Sc. 102

List of Presents 102

December 13, 1888.

Spectrum Analysis of Cadmium. By A. Grünwald, Professor of Mathematics in the Imp. Roy. German Polytechnic University at Prague 105

On the Bending and Vibration of thin Elastic Shells, especially of Cylindrical Form. By Lord Rayleigh, M.A., D.C.L., Sec. R.S. 105

An Investigation of a Case of gradual Chemical Change. By W. H. Pendlebury and M. Seward 124

Determination of the Viscosity of Water. By A. Mallock 126

List of Presents 133

December 20, 1888.

Page

Co-relations and their Measurement, chiefly from Anthropometric Data. By Francis Galton, F.R.S. 135

On the Maximum Discharge through a Pipe of Circular Section when the effective Head is due only to the Pipe's Inclination. By Henry Hennessy, F.R.S., Professor of Applied Mathematics in the Royal College of Science for Ireland 145

Preliminary Account of the Morphology of the Sporophyte of *Splachnum luteum*. By J. R. Vaizey, M.A., of Peterhouse, Cambridge 148

A Contribution to the Knowledge of Protection against Infectious Diseases. By Alfred Lingard, M.B., M.S. Durh., Diplomate in Public Health, Cambridge 151

List of Presents 153

No. 275.—*January* 10, 1889.

Appendix to the Bakerian Lecture, Session 1887–88. By J. Norman Lockyer, F.R.S. 157

List of Presents 262

No. 276.—*January* 17, 1889.

A Method of Detecting Dissolved Chemical Compounds and their Combining Proportions. By G. Gore, F.R.S. 265

Relative Amounts of Voltaic Energy of Electrolytes. By G. Gore, F.R.S. 268

The Resistance of Electrolytes to the Passage of very rapidly alternating Currents, with some Investigations on the Times of Vibration of Electrical Systems. By J. J. Thomson, M.A., F.R.S., Cavendish Professor of Experimental Physics, Cambridge 269

List of Presents 290

January 24, 1889.

On the Influence of Carbonic Anhydride and other Gases on the Development of Micro-organisms. By Percy F. Frankland, Ph.D., B.Sc. (Lond.), F.I.C., Assoc. Roy. Sch. of Mines, Professor of Chemistry in University College, Dundee 292

The Spinal Curvature in an Aboriginal Australian. By D. J. Cunningham, M.D., Trinity College, Dublin 301

List of Presents 303

January 31, 1889.

On *Isoëtes lacustris*, Linn. By J. Bretland Farmer, B.A., F.L.S. 306

On Auto-infection in Cardiac Disease. By L. C. Wooldridge, M.D., D.Sc., Assistant Physician to Guy's Hospital 309

List of Presents 312

No. 277.—*February* 7, 1889.

Page

Second Series of Results of the Harmonic Analysis of Tidal Observations. By G. H. Darwin, LL.D., F.R.S., Fellow of Trinity College, and Plumian Professor in the University of Cambridge 315

The Principles of training Rivers through Tidal Estuaries, as illustrated by Investigations into the Methods of Improving the Navigation Channels of the Estuary of the Seine. By Leveson Francis Vernon-Harcourt, M.A., M.Inst.C.E. 315

Note on the Spectrum of the Rings of Saturn. By J. Norman Lockyer, F.R.S. 315

List of Presents 316

February 14, 1889.

Magnetisation of Iron at High Temperatures (Preliminary Notice). By J. Hopkinson, F.R.S. 318

On a Series of Salts of a Base containing Chromium and Urea.—No. 2. By W. J. Sell, M.A., F.I.C. With Crystallographic Determinations by Professor W. J. Lewis, Cambridge 321

Effect of Floor-deafening on the Sanitary Condition of Dwelling Houses. By Miss Etta Johnstone, University College, Dundee, and Thos. Carnelley, Professor of Chemistry in the University of Aberdeen 346

On the comparative Action of Hydroxylamine and Nitrites upon Blood-pressure. By T. Lauder Brunton, M.D., F.R.S., and T. Jessop Bokenham 352

On the Total Solar Eclipse of August 29, 1886. By Captain L. Darwin, R.E., Arthur Schuster, Ph.D., F.R.S., and E. Walter Maunder 354

On the Determination of the Photometric Intensity of the Coronal Light during the Solar Eclipse of August 28–29, 1886. By W. de W. Abney, Capt. R.E., F.R.S., and T. E. Thorpe, F.R.S. Professor of Chemistry in the Normal School of Science, South Kensington 354

List of Presents 355

February 21, 1889.

The Influence of Bile on the Digestion of Starch. I.—Its Influence on Pancreatin Digestion in the Pig. By Sidney Martin, M.D. (Lond.), B.Sc., British Medical Association Scholar, and Assistant Physician to the City of London Hospital for Diseases of the Chest, Victoria Park, and Dawson Williams, M.D. (Lond.), Assistant Physician to the East London Hospital for Children, Shadwell 358

The Innervation of the Renal Blood Vessels. By J. Rose Bradford, M.B., D.Sc., George Henry Lewes Student 362

The Innervation of the Pulmonary Vessels. By J. Rose Bradford, M.B., D.Sc., George Henry Lewes Student, and H. Percy Dean, M.B., B.S., B.Sc. 369

List of Presents 377

February 28, 1889.

Page

On the Spectra of Meteor-swarms (Group III). By J. Norman Lockyer, F.R.S. 380

On the Magnetic Action of Displacement-currents in a Dielectric. By Silvanus P. Thompson, D.Sc., B.A. 392

List of Presents 393

An Investigation of a Case of gradual Chemical Change : the Interaction of Hydrogen Chloride and Chlorate in presence of Potassium Iodide. By W. H. Pendlebury, B.A., late Scholar of Christ's Church, Oxford, Assistant Master of Dover College, and Margaret Seward, late Tutor of Somerville Hall, Oxford, Science Lecturer of Holloway College 396

No. 278.—*March* 7, 1889.

List of Candidates 424

On the Composition of Water. By Lord Rayleigh, Sec. R.S. 425

On the Wave-length of the principal Line in the Spectrum of the Aurora. By William Huggins, D.C.L., LL.D., F.R.S. 430

On the Cranial Nerves of Elasmobranch Fishes. Preliminary Communication. By J. C. Ewart, M.D., Regius Professor of Natural History, University of Edinburgh 436

List of Presents 436

March 14, 1889.

On the Organisation of the Fossil Plants of the Coal-measures. Part XVI. By W. C. Williamson, LL.D., F.R.S., Professor of Botany in the Owens College, Manchester 438

A Method of examining Rate of Chemical Change in Aqueous Solutions. By G. Gore, F.R.S. 440

Relative Amounts of Voltaic Energy of dissolved Chemical Compounds. By G. Gore, F.R.S. 442

Note on the Free Vibrations of an infinitely long Cylindrical Shell. By Lord Rayleigh, Sec. R.S. 443

List of Presents 448

March 21, 1889.

On the Velocity of Transmission through Sea-water of Disturbances of large Amplitude caused by Explosions. By Richard Threlfall, M.A., Professor of Physics, and John Frederick Adair, M.A., Demonstrator of Physics, University of Sydney 450

An Experimental Investigation of the Circumstances under which a Change of the Velocity in the Propagation of the Ignition of an Explosive Gaseous Mixture takes placed in closed and open Vessels. Part I. Chronographic Measurements. By Frederick J. Smith, M.A., Millard Lecturer, Exptl. Mech., Trin. Coll., Oxford 451

Page

On an Effect of Light upon Magnetism. By Shelford Bidwell, M.A., F.R.S. 453

Recalescence of Iron. By J. Hopkinson, F.R.S. 455

Electrical Resistance of Iron at a High Temperature. By J. Hopkinson, F.R.S. 457

List of Presents 458

March 28, 1889.

The Structural Arrangement of the Mineral Matters in Sedimentary and Crystalline Pearls. By George Harley, M.D., F.R.S. 460

On the descending Degenerations which follow Lesions of the Gyrus marginalis and Gyrus fornicatus in Monkeys. By E. P. France. With an Introduction by Professor Schäfer, F.R.S. (from the Physiological Laboratory, University College, London) 460

On certain Ternary Alloys. I. Alloys of Lead, Tin, and Zinc. By C. R. Alder Wright, D.Sc., F.R.S., Lecturer on Chemistry and Physics, and C. Thompson, F.C.S., F.I.C., Demonstrator of Chemistry in St. Mary's Hospital Medical School 461

The Diurnal Variation of Terrestrial Magnetism. By Arthur Schuster, F.R.S., Professor of Physics, with an Appendix by H. Lamb, F.R.S., Professor of Mathematics, Owens College, Manchester 481

On the Conditions for effective Scour in Drain-pipes of Circular Section. By Henry Hennessy, F.R.S., Professor of Applied Mathematics and Mechanism in the Royal College of Science for Ireland 486

List of Presents 486

The Spinal Curvature in an Aboriginal Australian. By D. J. Cunningham, M.D. (Edin. and Dubl.), Professor of Anatomy in the University of Dublin 487

The Principles of training Rivers through Tidal Estuaries, as illustrated by Investigations into the Methods of improving the Navigation Channels of the Estuary of the Seine. By Leveson Francis Vernon-Harcourt, M.A., M.Inst.C.E. (Plates 2—4) 504

On the Cranial Nerves of Elasmobranch Fishes. Preliminary Communication. By J. C. Ewart, M.D., Regius Professor of Natural History, University of Edinburgh 524

No. 279.—*April* 4, 1889.

On the Magnetic Inclination, Force, and Declination in the Caribee Islands, West Indies. By T. E. Thorpe, Ph.D., F.R.S. 538

Experiments on the Resistance of Electrolytic Cells. By Capt. H. R. Sankey, R.E. 541

The Ferment Action of Bacteria. By T. Lauder Brunton, M.D., F.R.S., and A. Macfadyen, M.A., B.Sc. 544

Page

On the Limit of Solar and Stellar Light in the Ultra-violet Part of the Spectrum. By William Huggins, D.C.L., LL.D., F.R.S. 544

List of Presents 544

April 11, 1889.

Bakerian Lecture.—A Magnetic Survey of the British Isles for the Epoch January 1, 1886. By A. W. Rücker, M.A., F.R.S., and T. E. Thorpe, B.Sc., Ph.D., F.R.S. 546

Experiments on the Nutritive Value of Wheat Meal. By A. Wynter Blyth 549

List of Presents 554

Second Series of Results of the Harmonic Analysis of Tidal Observations. Collected by G. H. Darwin, LL.D., F.R.S., Fellow of Trinity College and Plumian Professor in the University of Cambridge 556

The Structural Arrangement of the Mineral Matters in Sedimentary and Crystalline Pearls. By George Harley, M.D., F.R.S. 612

Obituary Notice :—

Dr. Parkinson i

Index v