than when measured by the determination of electrical conductivity at a lower temperature.

THE additions to the Zoological Society's Gardens during the past week include a Macaque Monkey (*Macacus cynomolgus*) from India, presented by Mr. J. H. Higgins; two Maholi Galagos (*Galago maholi*) from South Africa, presented by the Hon. Gilbert Johnstone; two Common Badgers (*Meles taxus*), British, presented by Mr. A. Gorham; a Spring-bok (*Gazella euchore*, ♂), a Ring-hals Snake (*Sepedon haemachates*) from South Africa, four Spur-winged Geese (*Plectropterus gambensis*) from West Africa, presented by Mr. J. E. Matcham; two Lanner Falcons (*Falco lanarius*) European, presented by Sir H. H. Johnston, K.C.B.; a Yellow-fronted Amazon (*Chrysotis ochrocephala*) from Guiana, presented by Mrs. G. F. Cote; a Hunting Crow (*Cissa venatoria*) from India, a Black-necked Grackle (*Graculipica nigricollis*) from China, a Larger Rocket-tailed Drongo (*Dissemurus paradiseus*) from India, a Sacred Kingfisher (*Halcyon sancta*) from Australia, a Black Hangnest (*Cassidix orizivora*) from the Amazons, two Blackbirds (*Turdus merula*), European; a Brown Thrush (*Turdus leucomelas*) from South America, presented by Mr. Russell Humphreys; an Arabian Baboon (*Cynocephalus hamadryas*) from Arabia, three Barbary Partridges (*Caccabis petrosa*) from North Africa, three Western Pintailed Sand-Grouse (*Pterocles pyrenaica*), South European, a Grand Galago (*Galago crassicaudata*) from East Africa, three Black-headed Terrapins (*Damonia reevesi-unicolor*), three Reeve's Terrapins (*Damonia reevesi*) from China, a Home's Cinixys (*Cinixys homeana*), a Derbian Sternothere (*Sternothaerus derbianus*) from West Africa, three Reticulated Pythons (*Python reticulatus*) from the East Indies, deposited; four Crested Pigeons (*Ocyphaps lophotes*) from Australia, an Ostrich (*Struthio camelus*, ♂) from Senegal, a Sun Bittern (*Eurypyga helias*) from South America, a Scarlet Ibis (*Eudocimus ruber*) from Pará, purchased; a Japanese Deer (*Cervus sika*, ♂), born in the Gardens.

OUR ASTRONOMICAL COLUMN.

COMET 1899 *a* (SWIFT).—

Ephemeris for 12h. Berlin Mean Time.

1899.	R.A. h. m. s.	Decl. ° ′	Br.
July 13	... 14 13 3	... +13 50·7	... 0·06
15	... 12 26	... 12 59·9	
17	... 12 1	... 12 12·1	
19	... 11 45	... 11 26·9	... 0·05
21	... 11 36	... 10 44·1	
23	... 11 34	... 10 3·6	... 0·04
25	... 11 40	... 9 25·1	
27	... 11 53	... 8 48·3	
29	... 12 10	... 8 13·3	... 0·03
31	... 12 32	... 7 39·7	
August 2	... 14 12 59	... + 7 7·6	

TEMPEL'S COMET 1899 *c* (1873 II.).

Ephemeris for 12h. Paris Mean Time.

1899.	R.A. h. m. s.	Decl. ° ′ ″	Br.
July 13	... 20 31 7·6	... −14 25 22	
14	... 32 20·5	... 14 55 18	
15	... 33 33·2	... 15 25 46	... 3·418
16	... 34 45·7	... 15 56 42	
17	... 35 58·0	... 16 28 5	
18	... 37 10·2	... 16 59 51	
19	... 38 22·3	... 17 31 59	... 3·566
20	... 20 39 34·3	... −18 4 26	

The comet is still on the borders of Sagittarius and Capricornus, about 3° west of α and β Capricorni. M. L. Schulhoff points out in *Ast. Nach.* (No. 3574) that it is important to secure as many accurate observations of the comet as possible at observatories of different latitudes during this apparition, as by this means our knowledge of the mass of Jupiter may be considerably improved.

THE NEW ALLEGHENY OBSERVATORY.—A little over a year ago Mr. J. A. Brashear inaugurated a movement to provide for the erection of a new building and an adequate instrumental equipment for the Allegheny Observatory, and the fund, from numerous subscriptions received, has grown to such proportions that the plan shows every sign of success. Prof. F. L. O. Wadsworth, until recently a member of the staff of the Yerkes Observatory, has been appointed to the directorship, and the plans for the new building have been prepared by him. The largest instrument is to be a refracting telescope of 30 inches aperture, with object-glass by Brashear, and special provision is to be made for astrophysical investigations, which will form the principal work of the observatory.

LEEDS ASTRONOMICAL SOCIETY.—The *Journal and Transactions* for the year 1898, lately issued, maintains the excellent standard of former years. Among the many interesting papers mention may be made of "The movements of the moon," "Star temples in Egypt," "Astronomy as applied to navigation." The volume contains two plates, one showing four drawings of Jupiter and one of Saturn made by Mr. H. J. Townshend, and the other a portrait of Mr. T. J. Moore, who has charge of one of the micrometers from the Oxford Observatory, with which he is engaged in measuring the plates for the Astrographic Catalogue. Accompanying this is a very lucid description of the work and scope of the Astrographic Survey, by Mr. Moore.

THEORY OF THE MOTION OF THE MOON.[1]

THE second part of Dr. Brown's "Lunar Theory" contains the calculation of the terms of the third order in the eccentricities, inclination and ratio of the parallaxes. The first part (reviewed in NATURE, November 25, 1897) had already dealt with the general theory, the variation, and the terms of the first and second orders. It will be remembered that the differential equations to be solved are

$$(\mathrm{D}+m)^2u+\tfrac{1}{2}m^2u+\tfrac{3}{2}m^2s-\frac{ku}{(us+z^2)^{\frac{3}{2}}}=-\frac{\partial\Omega_1}{\partial s}$$

$$(\mathrm{D}-m)^2s+\tfrac{1}{2}m^2s+\tfrac{3}{2}m^2u-\frac{ks}{(us+z^2)^{\frac{3}{2}}}=-\frac{\partial\Omega_1}{\partial u}$$

$$(\mathrm{D}^2-m^2)z-\frac{kz}{(us+z^2)^{\frac{3}{2}}}=-\tfrac{1}{2}\frac{\partial\Omega_1}{\partial z}.$$

The notation is sufficiently familiar to render explanation unnecessary.

Dr. Brown's procedure is as follows :—Let

$$u=u_0+u_\mu+u_\lambda,\quad z=z_\mu+z_\lambda$$

where u_0 denotes the variational terms

$$u_\mu,\ z_\mu$$

the terms of the orders already calculated

$$u_\lambda,\ z_\lambda$$

the terms of the next order to be calculated.

Then expanding by Taylor's theorem the unknown terms enter in the form

$$\zeta^{-1}(\mathrm{D}+m)^2u_\lambda+\mathrm{M}\zeta^{-1}u_\lambda+\mathrm{N}\zeta s_\lambda,$$

and

$$\mathrm{D}^2z_\lambda-2\mathrm{M}z_\lambda,$$

M, N being functions of the known variational terms.

The unknown terms enter under the same form every time, but if a solution with indeterminate coefficients be assumed, the coefficients in the simultaneous equations that result will depend upon the period of the inequality under consideration, and therefore, from the point of view of numerical solution, entirely different nearly every time. All who have had the practical

[1] "Theory of the Motion of the Moon; containing a New Calculation of the Expressions for the Coordinates of the Moon in Terms of the Time." By Ernest W. Brown, M.A., Sc.D., F.R.S. (from the *Memoirs* of the Royal Astronomical Society, vol. liii.).

experience know how laborious is the solution of twenty simultaneous equations. Prof. Brown estimates the solution of the equations at half the labour of obtaining them, in addition

Reference number.	Characteristic.	Argument.	Number of terms.	Approximate value in arc of the largest coefficient.	Value of unity in the last figure given, in millionths of a second of arc.
1	1	0	13	206265″	0·0002
2	e	$\pm l$	18	17000	2
3	e'	$\pm l'$	21	350	0·4
4	α	D	9	80	0·05
5	k	F	11	9000	0·01
6	e^2	$\pm 2l$	21	240	3
7	e^2	0	11	340	3
8	ee'	$\pm(l+l')$	21	140	4
9	ee'	$\pm(l-l')$	22	100	4
10	e'^2	$\pm 2l'$	18	6	0·6
11	e'^2	0	10	2	0·6
12	k^2	± 2F	20	400	0·4
13	k^2	0	11	400	0·4
14	$e\alpha$	D$\pm l$	19	12	0·6
15	$e'\alpha$	D$\pm l'$	20	14	0·1
16	α^2	0	9	0·01	0·1
17	ke	F$+l$	10	15	0·06
18	ke	F$-l$	11	45	0·06
19	ke'	F$+l'$	10	1	0·01
20	ke'	F$-l'$	11	0·4	0·01
21	$k\alpha$	D$+$F	10	4	0·02
22	e^3	$\pm 3l$	17	11	27
23	e^3	$\pm l$	18	11	27
24	e^2e'	$\pm(2l+l')$	17	6	4
25	e^2e'	$\pm(2l-l')$	18	3	4
26	e^2e'	$\pm l'$	19	8	4
27	ee'^2	$\pm(l+2l')$	16	5	0·6
28	ee'^2	$\pm(l-2l')$	15	2	0·6
29	ee'^2	$\pm l$	17	1	0·6
30	e'^3	$\pm 3l'$	13	0·3	0·01
31	e'^3	l'	16	0·1	0·1
32	ek^2	$\pm(l+2$F$)$	15	11	4
33	ek^2	$\pm(l-2$F$)$	17	30	4
34	ek^2	$\pm l$	16	14	0·4
35	$e'k^2$	$\pm(l'+2$F$)$	15	2	0·07
36	$e'k^2$	$\pm(l'-2$F$)$	16	1	0·7
37	$e'k^2$	$\pm l'$	16	4	0·7
38	$e^2\alpha$	D$\pm 2l$	18	0·8	0·6
39	$e^2\alpha$	D	7	1·3	6
40	$ee'\alpha$	D$\pm(l+l')$	16	0·4	1
41	$ee'\alpha$	D$\pm(l-l')$	16	0·8	1
42	$e'^2\alpha$	D$\pm 2l'$	15	0·3	0·02
43	$e'^2\alpha$	D	8	0·4	0·2
44	$k^2\alpha$	D± 2F	16	0·5	0·1
45	$k^2\alpha$	D	8	3	0·1
46	$e\alpha^2$	$\pm l$	16	0·03	0·1
47	$e'\alpha^2$	$\pm l'$	16	0·002	0·02
48	α^3	D	8	0·001	0·03
49	k^3	3F	9	1	0·2
50	k^3	F	8	0·2	0·2
51	ke^2	F$+2l$	10	10	1
52	ke^2	F$-2l$	10	9	1
53	ke^2	F	10	4	1
54	kee'	F$+l+l'$	10	5	0·2
55	kee'	F$-l-l'$	10	3	0·2
56	kee'	F$+l-l'$	11	2	0·2
57	kee'	F$-l+l'$	11	4	0·2
58	ke'^2	F$+2l'$	10	0·8	0·03
59	ke'^2	F$-2l'$	10	0·08	0·3
60	ke'^2	F	10	0·4	0·03
61	$ke\alpha$	D$+$F$+l$	10	0·1	0·2
62	$ke\alpha$	D$+$F$-l$	10	0·2	0·2
63	$ke'\alpha$	D$+$F$+l'$	10	0·2	0·003
64	$ke'\alpha$	D$+$F$-l'$	10	0·5	0·003
65	$k\alpha^2$	F	8	0·004	0·06

to the fact that this portion of the work is peculiarly liable to numerical error. He may therefore be congratulated on having obtained an algebraical solution, reducing the operation of finding fresh terms to mere multiplication of series. The mathematical investigation is referred to as destined for publication elsewhere, and does not appear in the memoir. The underlying principle is that when in a differential equation of the nth order there are $n-1$ integrals known, when the right-hand member of the equation is zero, then a particular integral in the general case can be obtained. In the lunar theory the differential equation is, in effect, of the fourth order, and three integrals are known, two representing the elliptic inequality and the third a variation of the epoch.

For forming the right-hand sides of later stages, the quotient of each set of terms by the variation terms is required. As divisions are troublesome, these quotients are the quantities sought in the first instance: the new set of terms can then be obtained by a multiplication. The quotients referred to are given algebraically as the sum of four products, each product being that of two series. It is inconvenient, in the numerical application of the above method, that small coefficients often appear as differences of comparatively large numbers. Dr. Brown gives as an example a case where a coefficient 2 arises as the sum of separate coefficients

$$-6418 + 6496 + 316 - 392$$

from the above-mentioned four products.

Terms of long period require a special treatment, but the general methods apply to the other terms of the group. The loss of accuracy is reduced to that due to the first, instead of the second, order of the small divisor.

When the period is that of the elliptic inequality, a new part of the motion of the perigee has to be determined. Calling this new part $c_{\lambda/e}$ a new unknown term $\zeta^{-1}(\mathrm{D}+m).u_e\, c_{\lambda/e}$ appears, and is transposed to the right-hand side of the equation, so that the quantities A, which in other cases are completely known, now appear in the form $\mathrm{B}+c_{\lambda/e}b$, where B, b are known. Dr. Brown has already shown in the first part how $c_{\lambda/e}$ may be obtained before the coefficients of the inequalities are calculated. When this has been done, one of the equations becomes redundant. Another is already redundant, until the meaning of the arbitrary constant denoting the ellipticity is defined with further precision. Dr. Brown defines the arbitrary constant so that $\epsilon_0 - \epsilon_0' = 1$ to all orders; hence $\lambda_0 = \lambda_0'$. The other coefficients λ_ι, λ_ι' consist of three parts, one proportional to $c_{\lambda/e}$, and arising from the quantities b, a second arising from the quantities B, and a third proportional to λ_0. The two equations for which $\iota = 0$ then give a double determination of λ_0, and furnish a check upon the numerical accuracy. Many of the quantities that occur in this arrangement of the computations are of service at subsequent stages.

The treatment of the third coordinate follows the same lines, and only differs in being more simple.

The foregoing table exhibits the extent of the calculations already performed, and the results of the first part are for convenience included in it.

The decrease of accuracy of the terms in the twenty-second and twenty-third groups is due to the period of one term approximating to the synodic period. Even in these cases, the coefficients are given to less than one-thousandth part of the least quantity that could be detected by observation.

P. H. C.

INVESTIGATIONS OF DOUBLE CURRENTS IN THE BOSPHORUS AND ELSEWHERE.[1]

As my books and papers are published chiefly in the Russian language, they are not very well known in this country. A short account of some of my results may therefore not be without interest. I cannot, in the course of my address, make you familiar with all my works, and wish at the present moment only to draw your attention to the interesting phenomena of double currents in the Straits of Bosphorus, Gibraltar, Bab-el-Mandeb, Formosa, and La Pérouse.

The Strait of Bosphorus joins the Black Sea and the Marmora Sea. The Black Sea water has in it—roughly speaking—half the quantity of salt found in the water of the Mediterranean.

[1] Abridged from a paper by Vice-Admiral S. Makaroff in the *Proceedings* of the Royal Society of Edinburgh (vol. xxii. No. 4, 1899).