index to current technical literature. The issue of a distinctly European edition of the magazine was commenced last month, and we are confident that it will meet with as much success here as it has in the United States.

THE additions to the Zoological Society's Gardens during the past week include a Macaque Monkey (*Macacus cynomolgus*) from India, presented by Mr. F. Greswolde-Williams; a Suakin Gazelle (*Gazella brookii*) from Abyssinia, presented by Dr. L. de Gebert; two Ring-necked Parrakeets (*Palæornis torquatus*) from India, presented by Mrs. G. F. Cooper; a Macaque Monkey (*Macacus cynomolgus, albino*) from Manilla, presented by Mr. James Coombs; two Double-spurred Francolins (*Francolinus bicalcaratus*) from West Africa, four Rosy Bullfinches (*Erythrospiza githaginea*), bred in England, presented by Mr. E. G. B. Meade-Waldo; two Herring Gulls (*Larus argentatus*), British, presented by Mr. T. Hope Robinson; two Rhomb-marked Snakes (*Trimerorhinus rhombeatus*), two —— Snakes (*Chlorophis hoplogaster*), a Puff Adder (*Bitis arietans*) from South Africa, presented by Mr. J. E. Matcham; a Ring-tailed Lemur (*Lemur catta*, ♀) from Madagascar, a Macaque Monkey (*Macacus cynomolgus*) from India, deposited; six Rosy-faced Love Birds (*Agapornis roseicollis*) from South Africa, a Malaccan Parrakeet (*Palæornis longicauda*) from Malacca, four Siskins (*Chrysomitris spinus*), four Lesser Redpolls (*Linota rufescens*), British, a Bridled Wallaby (*Onychogale frenata*) from Australia, a Loggerhead Turtle (*Thalassochelys caretta*) from the Mediterranean, purchased.

OUR ASTRONOMICAL COLUMN.

THE NOVEMBER METEOR SWARMS.—Up to the present time we have not received any news that the Leonids were more abundant this year than last. Indeed, bad weather seems to have universally prevailed about the time of observation. At the Paris Observatory five observers only noted twenty meteors, while M. Hansky, at the Meudon Observatory, saw in all seven, four of which were Leonids. M. Janssen, in consequence of the exceedingly bad weather experienced in Western Europe, telegraphed to San Francisco to inquire whether a more brilliant display had been noted there. The answer he received was to the effect that nothing more than the ordinary shower was observed. Perhaps, however, observers may be (or may have been) more fortunate with the Andromedes, which are expected between the 23rd and 27th of this month. This swarm is also of considerable strength, and should be more than usually active Its period of revolution being six and a half years, and the last maximum having occurred on November 23, 1892, we expect the shower this month to be above the ordinary yearly display. There are several points about the Andromedes that are of peculiar interest. One of these is that the orbit in which they move is very similar to that of the comet Biela; in fact, the bodies which produce the phenomena of shooting stars may be none other than the component parts of this comet. In the years 1872 and 1885 the maximum display occurred on the 27th of the month, but at the following expected shower it took place on the 23rd. This difference is explained, according to Bredichin, by the perturbatory effects due to the proximity of the planet Jupiter, thus causing the node to recede 4°. The radiant point of this swarm (25° + 43°) has a large northern declination, which renders it always above the horizon. The meteors themselves are different from the Leonids in that they move more slowly, and are of a yellowish tinge.

In the note under this heading, that appeared last week, it should have been mentioned that the observations recorded were made by Dr. W. J. S. Lockyer at the Solar Physics Observatory, South Kensington.

In another part of this journal Mr. Denning summarises the results of this year's Leonid display.

CURRENT ASTRONOMICAL ARTICLES.—M. Gaston Armelin contributes an interesting article on that curious variable Mira Ceti to *La Nature* for November (No. 1274). After a brief historical summary the writer describes some theories current to-day, and points out the variations in the time of maxima observed of late years, and their consequent suggested explanations.—The bulletin of the *Société Astronomique de France* for the same month contains, among other interesting matter, a drawing of comet Perrine as observed at the observatory of Juvisy. M. Camille Flammarion deals with the Leonid swarm of meteors. The number contains several contributions of planetary notes.—In the October number of *Himmel und Erde*, a brief account is given of the present state of the proposed large Potsdam refractor. There seems to have been some difficulty about the optical parts, so that it has been decided to assume that the aperture will be 80 cm., and commence at once with the construction of the instrument and a suitable dome. This instrument when finished will be then the largest in Europe, the aperture being nearly thirty-two inches. This article contains the results of many investigations on the absorption properties of different thicknesses and kinds of glass.

COMET PERRINE (OCTOBER 16).—This comet is gradually becoming fainter, but a continuation of the ephemeris for the current week will perhaps prove useful :—

12h. Berlin M.T.

1897.	R.A. h. m. s.	Decl. ° ′	log *r*.	log Δ.	Br.
Nov. 25	18 16 49	+59 24·6			
26	15 45	58 44·8	0·1376	0·0278	0·7
27	14 47	58 6·4			
28	13 54	57 29·3	0·1366	0·0370	0·7
29	13 6	56 53·4			
30	12 23	56 18·8	0·1357	0·0459	0·7
Dec. 1	11 43	55 45·5			
2	11 7	55 13·5	0·1351	0·0546	0·7
3	18 10 34	+54 42·4			

REV. DR. SEARLE has resigned the directorship of the astronomical observatory of the Catholic University of America. His place will be taken by Mr. Alfred Doolittle.

THEORY OF THE MOTION OF THE MOON.[1]

OF the lunar theories hitherto completed the two greatest are undoubtedly those of Hansen and Delaunay. The former has for its chief object the formation of tables: the inconvenience of slowly converging series is avoided by using numerical values throughout; and the problem solved is the one actually presented by nature, every known cause of disturbance being allowed for. It suffers, however, under the disadvantage that there are no means of correcting the results for any change in the values of the constants that observation may demand. This drawback was avoided by Delaunay, but only at the expense of still greater evils from the point of view of the making of an ephemeris; for owing to the slow convergence of certain series, twenty years' labour did not suffice to give sufficiently approximate results; moreover, the problem had to be considerably modified from the circumstances of nature, in order to achieve a result within even so long a time.

The memoir that Dr. Brown has lately presented to the Royal Astronomical Society, forms the first part of a fresh attempt to calculate the motion of our satellite. All Delaunay's modifications of the problem are adopted: that is to say, the sun and earth are supposed centrobaric, the mass of the moon is neglected, as is also the action of the planets, and the true mass of the sun is increased by that of the earth. The calculation of the effect of the attraction of the planets and of the protuberant parts of the earth's equator will follow when the modified problem is solved. The solution can also be easily modified so as to allow for the greater part of the effect of the remaining modifications, and the outstanding error Dr. Brown has shown to be insensible to observation; but it is, however, far larger than the minute fraction of a second to which his calculations are pushed.

Dr. Brown's theory resembles Delaunay's in being algebraical with, however, one important exception: the ratio of the mean motions is replaced by its numerical value. By this means the slowly converging series that occur in Delaunay's theory are avoided; and no admissible correction of the value of the above ratio can introduce any change in the results that would be sensible to observation. This modification in the form, combined

[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. (Reprinted from the *Memoirs* of the Royal Astronomical Society, vol. liii.)

with the use of a totally different method of calculation will, Dr. Brown estimates, cut down the twenty years occupied by Delaunay over the same problem to five.

One great advantage of an algebraical theory is the facility with which the work can be divided into sections, each consisting in the calculation of a group of terms multiplied by the same power of the eccentricities, inclination, and solar parallax, or, in the language of the lunar theory, having the same characteristic. Delaunay's theory unfortunately lost this advantage by its peculiar methods, and substituted another form of subdivision that enormously increased the total labour in the desire to present each step in a moderate compass. Adams appears to have been the first to clearly recognise the advantages of a subdivision such as Dr. Brown has employed, but it was Dr. Hill who actually laid the foundations of the present theory. In the first volume of the *American Journal* he published his famous "Researches in the Lunar Theory," where, after the lapse of more than a century, he revived Euler's idea of using rectangular coordinates. Confining his investigations to the case when the eccentricities, inclination, and solar parallax are supposed to vanish, he used axes rotating so that the axis of x points constantly to the sun, and then replaced x, y by the conjugate complex variables $u, s = x \pm y\sqrt{-1}$, and the time by another complex quantity $\zeta = e^{(n-n')t\sqrt{-1}}$, and the symbol of differentiation by D defined as $\zeta\frac{d}{d\zeta}$. He also used the symbol m to denote the ratio of the synodic month to the sidereal year, and k to denote the mass of the earth divided by the square of the difference of the mean motions of the moon and the sun. He then arrived at the differential equations,

$$(\mathrm{D} + m)^2u + \tfrac{1}{2}m^2u + \tfrac{3}{2}m^2s - \frac{ku}{(us)^{\frac{3}{2}}} = 0$$

$$(\mathrm{D} - m)^2s + \tfrac{1}{2}m^2s + \tfrac{3}{2}m^2u - \frac{ks}{(us)^{\frac{3}{2}}} = 0.$$

At this point arose a difficulty which, in a closely analogous form, is common to all lunar theories, the presence, that is to say, of the quantity denoting the mass of the earth divided by the cube of the distance. The practical convenience of a theory is perhaps in no way better tested than by examining the manner in which this difficulty is overcome, and it is certainly not too much to say that in this respect Dr. Hill's method has no rival. In a few brief steps he succeeds in eliminating the obnoxious quantity altogether, and he obtains two equations of the second degree in u, s and homogeneous in these variables except for a constant of integration, which may be looked upon as replacing k. These equations are easily solved numerically, and denoting the values of the variables with Dr. Hill's modifications of the general problem by the suffix zero, u_0 and its conjugate complex s_0 may be henceforth looked upon as known functions of the time. They are, in fact, capable of expression as infinite series of positive and negative odd powers of ζ. The coefficient of ζ in u_0 is denoted by a, which is a constant defining the linear dimensions of the orbit. By having recourse to one of the original equations containing k, the value of k/a^3, which is a mere number, may be found. This completes the investigation of the variation, as this class of inequalities is called.

It is at this point that Dr. Brown took up the subject. He replaced Dr. Hill's first pair of equations by the following set of three, the third of which determines z or the moon's coordinate perpendicular to the ecliptic, which in the particular case treated by Dr. Hill is zero

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

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

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

In these equations Ω_1 represents the part of the disturbing function neglected by Dr. Hill, every term of which is divisible by either the solar eccentricity or parallax. The quantity k can be eliminated from the first two of these equations in a manner analogous to the methods of Dr. Hill. It can be also eliminated from the third and either of the other two in an obvious manner. The resulting equations need not be written down here; following Dr. Brown, they will be alluded to as the homogeneous equations. There are thus two distinct sets of equations that can be used at any step in the work. In practice one set is used, and a single equation from the other set is used in addition, generally as a mere equation of verification, but in certain special cases for the actual solution when the equations of the first set are not well adapted for the purpose. Dr. Brown's procedure is as follows: let

$$u = u_0 + u_\mu + u_\lambda \qquad z = z_\mu' + z_\lambda$$

Where u_μ, z_μ denote the terms already calculated, u_λ, z_λ the new terms of characteristic λ to be calculated in the next step of the process of solution. Either u_λ or z_λ is always zero according as λ contains an odd or even power of the inclination. These values are then substituted in either set of differential equations, and the terms of order λ picked out. It can be readily seen that the right-hand side of the equations contain only known terms, and the unknown new terms occur in the first degree and multiplied by functions of u_0 s_0 only. If the first set of equations be used, the terms containing k/r^3 must be expanded by Taylor's Theorem into series proceeding according to powers of $u_\mu + u_\lambda$, $s_\mu + s_\lambda$, $z_\mu + z_\lambda$ with coefficients containing k, u_0, s_0 only. These coefficients are easily deducible from Dr. Hill's value of u_0, the method of special values being in general used. One remark, however, requires to be made. Every time a set of terms is calculated whose arguments are the same as the terms in u_0, there arises the opportunity of modifying the meaning of the linear constant a. It is otherwise evident that any solution remains a solution when a is replaced by a new constant a' defined by the relation $a/a' - 1$ = an arbitrary series of powers and products of the squares of the eccentricities, inclination, and solar parallax. The value of k is of course simultaneously modified also. Consequently we should be liable to have the values of such quantities as k/r_0^3 varying from time to time as the approximation proceeds. This would be obviously inconvenient, and Dr. Brown has used the power of modification at his disposal so that k/a^3 remains invariable throughout the solution, and therefore, since in Dr. Hill's papers it is a function of m only, it always remains so.

In the first set of equations therefore 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

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

where

$$\mathrm{M} = \tfrac{1}{2}m^2 + \tfrac{1}{2}\frac{k}{\rho_0^3}$$

$$\mathrm{N} = \tfrac{3}{2}m^2\zeta^{-2} + \tfrac{3}{2}\frac{ku_0^2\zeta^{-2}}{\rho_0^5}$$

the same form at every approximation. (A misprint in the algebraical value of N, on p. 63, should be noticed; the factor ζ^{-2} being there omitted. This is merely a printer's error, for the arithmetical value on p. 90 is correctly given. Indeed, were it otherwise, the discordance of the results from those of other theories would long ago have been noticed.)

When the new terms to be calculated have the same arguments as u_e or z_k, the principal elliptic or inclinational terms, a new term in the motion of the perigee or node (of order λ/e or λ/k) has to be calculated. The unknown term $c_{\lambda/e}$ appears multiplied by $2(\mathrm{D}+m)u_e$ in the first equation, and $g_{\lambda/k}$ appears multiplied by $2\mathrm{D}z_k$ in the second equation. These coefficients are independent of λ: since, however, λ must be of at least the third order for the point to arise, it does not properly enter into the part of the work already published.

A series with indeterminate coefficients is then assumed for u_λ or z_λ: and a number of simultaneous equations formed, from which the coefficients are found. The labour of forming the known terms in these equations increases rapidly with the characteristic; but the operations required are mere multiplication of series, and can to a great extent be left to a computer. The results are readily checked by computing independently the value when $\zeta = 1$.

The unknown terms enter at each step into the equations under the same algebraical form, or rather under one of two forms, according as the new terms belong to u or z. These forms unfortunately involve the symbol of differentiation D, so that the different sets of simultaneous equations have different arithmetical coefficients; but whenever more terms with an old set of arguments are being calculated, the arithmetical coefficients are the same as before, and it is only the right-hand sides which are different. This greatly facilitates the labour of solution; but the advantage is obviously one that is deferred to the later stages of the work, the only instances in the part of the work hitherto published being that the calculations of sections (v.) and (viii.) of chapter iv. are to some extent facilitated by the previous calculation of section (ii.) of the same chapter.

The ordinary method of approximation in the simultaneous equations proceeds by determining approximate values of the unknown quantities in order of magnitude, at first neglecting the smaller of these quantities in the equations of principal importance for determining the larger ones. It happens, from a well-known cause, that sometimes the coefficients of certain unknowns are small even in the equations of principal importance in determining them. Prof. Brown has, in these cases, found it best to defer their determination until he has found all the other quantities in terms of them.

After considerable experience of both sets of differential equations, Prof. Brown has come to the conclusion that the first set on the whole is the best adapted to the numerical work. An important exception, however, arises. The two coefficients of a term of long period are principally determined by two equations very nearly deducible, the one from the other, the determinant of the coefficient varying inversely as the square of the period. The difficulty is considerably lessened by using one equation derived from the homogeneous set.

The following table will give some idea of the extent of the calculations already performed. The terms have been calculated

Reference Number.	Characteristic.	Argument.	Number of Terms.	Approximate value in arc of the largest coefficient (1) including (2) excluding purely elliptic terms.		Value of unity in the last figure given in millionths of a second of arc.
				(1) "	(2) "	
1*	1	0	13	206265	1800	0·0002
2	e	$\pm l$	18	17000	3000	2
3	e'	$\pm l'$	21	350	350	0·4
4	α	D	9	80	80	0·05
5	k	F	11	9000	300	0·01
6	e^2	$\pm 2l$	21	240	170	3
7	e^2	0	11	340	100	3
8	ee'	$\pm (l + l')$	21	140	140	4
9	ee'	$\pm (l - l')$	22	100	100	4
10	e'^2	$\pm 2l'$	18	6	6	0·6
11	e'^2	0	10	2	2	0·6
12	k^2	± 2F	20	400	40	0·4
13	k^2	0	11	400	40	0·4
14	$e.\alpha$	D $\pm l$	19	12	12	0·6
15	$e'.\alpha$	D $\pm l'$	20	14	14	0·1
16	α^2	0	9	0·01	0·01	0·1
17	ke	F + l	10	15	15	0·06
18	ke	F − l	11	45	45	0·06
19	ke'	F + l'	10	1	1	0·01
20	ke'	F − l'	11	0·4	0·4	0·01
21	$k\alpha$	D + F	10	4	4	0·02

* Calculated by Dr. Hill.

in twenty-one groups, the order of calculation being indicated by the number in the first column. The second column gives the multiple of the eccentricities, inclination, and ratio of parallaxes that is common to each coefficient of the group. The third column gives the fundamental argument from which all the other arguments are derived by the addition or subtraction of multiples of twice the elongation, Delaunay's notation being used, The fourth column gives the number of terms calculated. The fifth column gives the approximate value in arc of the largest coefficient, and the sixth column the value of the largest coefficient indicating a disturbance from elliptic motion. The last column gives the value in arc of the last significant figure, and where, as often happens, the coefficients of a group have been calculated to a different number of decimal places, then the number given in this column corresponds to the coefficient calculated with least accuracy.

Dr. Brown gives as the approximate values of the constants in the third column of the above table

$$e = 0·11 \quad e' = 0·017 \quad k = 0·045 \quad \alpha = 0·0026$$

It will be seen that the terms calculated include all that ar algebraically of the second order. The ratio of the parallaxe is here considered as being of the first order. The terms depending on the square of this ratio, it will be noticed, are insensible to observation. This is fortunate, as the terms cannot be corrected for the neglected mass of the moon.

We think that the results selected for publication are a little too meagre. They consist of the actual solution itself, and one other set of terms whose calculation divides the labour of each section into two fairly equal halves. We hope that an appendix will be finally published in which the value of every auxiliary quantity will be given. Such an appendix might be of great use in other investigations. It would also be of immense value should there ever be a suspicion of error in Dr. Brown's own calculations, for it would then be far easier to establish the fact of such an error, should one ever creep in, and it would entail less labour to carry through the correction.

MARINE BIOLOGY AT THE BERMUDAS.

AN expedition of the biological department of New York University went to the Bermudas a few months ago to study the marine fauna, and to investigate the conditions offered for the establishment of a permanent biological station there. The party has now returned, and an account of the observations made is contributed by Prof. C. L. Bristol to *Science*, from which source the following particulars have been derived:—

The most attention was given to a search for the various forms and a careful survey of the general conditions subtending their abundance and collection, so that, taken as a whole, the work might prove a reconnaissance and furnish knowledge for future investigations. In this the expedition was fairly successful and would have been much more so but for a long spell of south-west wind which prevented off-shore work, excepting for a few days. Our work was confined mainly to the lee shores, and here we were greatly rewarded. Of corals the genera *Diploria*, *Meandrina*, *Astrea*, *Siderastrea*, *Porites*, *Isophyllia*, *Oculina* and *Mycedium* were found; of Gorgonians, *Rhipidogorgia* and *Gorgonia*. The Actinaria are very abundant and our collections are numerous. We found but few hydroids and a millespore coral. The Medusæ and Hydro-Medusæ are very abundant in the still waters of Harrington Sound. The Echinoderms are exceedingly interesting and abundant. The Holothuria are represented by the genera *Holothuria*, *Semperia*, *Stichopus*, the last being very abundant. The Asteroidea are few, and are represented by one species of *Asterias* and one of a new genus not yet determined; the Ophiuroidea by several genera. The Echinoidea are represented by *Cidaris*, *Diadema*, *Hipponæ*, *Echinometra*, *Toxopneustes*, *Mellita* and one new genus. The Crustacea are numerous and exceedingly interesting. Our collections will be studied by Dr. Rankin, who will report on them later.

The Mollusca of the archipelago number, according to Heilprin, about 170 marine forms and thirty terrestrial. Among the cephalopoda are *Octopus* and *Argonauta*. The naked *Aplysia* is fairly abundant, and numerous other naked molluscs are found in Harrington Sound.

The Annelids are not as numerous in the places we searched as we expected, but those we found are new to us and the genera are not yet determined. The sponges are very numerous in genera and plenty in individuals. The Tunicates are exceedingly numerous and offer a rich field for investigations. *Amphioxus* is reported, but we had no opportunity to search for it. The abundance and beauty of the Bermuda fishes is notorious. Dr. Bean is making a study of them, carrying on the work started by his colleague the late Dr. G. Brown Goode. Incidental to the main work of the expedition we undertook to furnish the Aquarium in New York with live specimens of some of these fishes, and thousands of visitors to that institution testify to their beauty and gracefulness. This part of the work was by no means the least interesting. We installed four large tanks and a pumping engine on White's Island, in the harbour of Hamilton, and acclimatised the fish before transferring them to the steamship On board the boat the fish were supplied with running water, thanks to the kindness of the Quebec Steamship Company, and no small part of our success was due to the generous and skilful aid given us by the Chief Engineer, Mr. Ritchie. Under these favourable conditions our loss was slight, and another season will be much less. It is interesting to note that our efforts to bring invertebrates alive failed in every