to research he made important contributions to the development of instrumental facilities at Victoria and was one of the first successfully to aluminize a large astronomical mirror. He took a major part in the planning of a new telescope and Coudé spectrograph soon to be in operation at Victoria.

Numerous responsibilities and honours came to McKellar as his qualities were recognized. He was a member of the International Astronomical Union continuously from 1938, and was President of the Commission on Comets from 1948 to 1952. He was elected a Fellow of the Royal Astronomical Society in 1948. He was President of the Astronomical Society of the Pacific from 1956 to 1958 and was President of the Royal Astronomical Society of Canada at the time of his death. He served as associate editor of the *Astrophysical Journal* and foreign correspondent of the *Annales d'Astrophysique*, and contributed papers to handbooks and international symposia. He was elected to the Royal Society of Canada in 1942 and was created M.B.E. in 1947, in recognition of his war services.

Not the least of McKellar's contributions to Canadian astronomy is the stimulating and inspiring example of his life. His quiet devotion to his work, to his family, and to his community, will long be remembered. For the past fifteen years he lived under the shadow of an incurable illness. Yet such were his spirit and fortitude that only the most intimate friends knew he was seriously ill. Normal activities were continued when he might have assumed lighter duties. He completed a full day's work at the Observatory on May 2, just four days before his death.

In 1938 Andrew McKellar married Mary Belgrave Crouch of Victoria. Mrs McKellar and two children, Andrew Robert, and Mary Barbara, survive him.

R. M. PETRIE.

FREDERICK JOHN MARRIAN STRATTON

Frederick John Marrian Stratton was born in Birmingham on 1881, October 16. He was educated at King Edward's Grammar School, and at Mason College, in what subsequently became the University of Birmingham. He then went to Gonville and Caius College, Cambridge, with which he was associated for the rest of his life. He was Third Wrangler in the Mathematical Tripos of 1904, the year in which Eddington was Senior Wrangler; Isaac Newton Student in 1905, Smith's Prize-man in 1906, and was elected a Fellow of Caius in the same year. His first paper was published in volume 46 of the Society's *Notices*, in 1906, and it deals with planetary inversion; it is an essay of entirely

mathematical character and enquires whether tidal forces can produce substantial changes in the obliquities of the orbits of planets. But at about this time Stratton went out to the Observatory and commenced a career in practical astronomy. In Sir Robert Ball's report on the Cambridge Observatory (1906 February) we read that "Mr F. J. M. Stratton, B.A., Caius College, Isaac Newton Student of the University, has recently joined the Observatory as an honorary member of the staff and has undertaken researches on the proper motion of faint stars by photography". These researches culminated in the publication in 1908 of a *Memoir* of the Society, "Proper Motions of Faint Stars in the Pleiades", which Stratton concludes by saying that "In this piece of work I should like to acknowledge myself his (Mr A. R. Hinks') pupil". Only 14·6 years were available, between the old plates taken at Greenwich and Oxford, and the second epoch plates which were specially taken for the work with the Sheepshanks telescope; and now, of course, much longer time intervals, and therefore much more accurate proper motions, are to be had. But Stratton did not pursue the subject, nor his first mathematical interests, because he found himself more strongly attracted by solar physics and expecially by stellar spectroscopy than by mathematical theory and astronomy, and in his next papers he turned to latitude drift in sunspots, to the Hartmann Cornu formula in the reduction of spectrograms, and finally in 1912 to a study which was perhaps his greatest interest, the spectra of novae, for in this year he published two papers, one alone, and one jointly with Newall, on Nova Geminorum. The following year (1913) he was appointed by Newall as the assistant director of the Solar Physics Observatory, on its removal from South Kensington to Cambridge.

However, the first Great War broke out shortly afterwards, and it was to Stratton a complete interruption of his astronomical work. He retained throughout his life a great interest in military matters, and in the 1914–18 war he had a most distinguished career on active service, rising to the rank of Lieutenant Colonel and winning the coveted Distinguished Service Order.

The war over, he became a Tutor in Caius, relinquishing his post at the Solar Physics Observatory, but not his interest in astrophysics, to do so. His interest in Caius was immense. He knew something about an amazing number of men who had been at the College in his own time, and on his travels, which were extensive, he would be certain to know of the Caius men in every outpost of Empire such as Singapore or Rangoon, and would try to bring them together. Immediately after the first war there were a number of ex-servicemen in the College and during this period there occurred the episode of the Jesus Gun, when

a number of Caius men, mostly ex-officers, organized an elaborate operation which consisted of removing a German gun which the War Office had given to Jesus College, and bringing it to Caius. After this affair was over, Stratton, as Senior Tutor, gated the entire college. As it was the second Friday of the month, he went up to London to attend a meeting of the Society, and he let it be known that if an undergraduate left the college, he would have to resign. Such was his hold in the college that all the men remained loyally within it, contenting themselves with crowding to the windows and exchanging taunts with the Jesus men outside.

Stratton's position in Caius had great importance for astronomy. In the beginning of the century astronomy was still the only physical science to be fully organized in a professional manner with a professional career attached to it, and observatories were the only fully fledged scientific institutions. Astronomy figured prominently in the mathematical tripos; there was no difficulty about finding recruits to the astronomical profession, and Dyson had only to offer a post to last year's Senior Wrangler to be sure of getting him to join the staff at Greenwich. But in the twenties and thirties things had begun to change; other careers in mathematics and physics began to present themselves, and since the number of men of very great talent is always limited, it required the zeal of someone alike vitally interested in astronomy and well placed to influence young people, to ensure that astronomy as a professional career was kept as a possibility before the eyes of the right young men. No one is better placed than a Cambridge tutor, but no one will succeed in this important work unless he has a sympathetic touch with young people, and this Stratton had. Stratton succeeded ultimately in scooping the offices of Astronomer Royal, Astronomer Royal for Scotland and H.M. Astronomer at the Cape for his College; and our profession awaits the day when another tutor will do the same.

While Tutor, he found time to write *Astronomical Physics*, the first book to treat the subject in what was then the modern way, that is to say with full reference to Saha's theory and the correct classification of spectrum lines according to ionization; in a word with a degree of rationalization not possible to earlier writers.

He also took a great interest in eclipses. The expeditions appealed to his military sense; he used to say that preparing for an eclipse was like preparing for a battle, because one made the best dispositions that one could before the event, and then awaited the outcome. Unlike Dyson, he was not always lucky with the weather. Perhaps his most important eclipse expedition was undertaken with C. R. Davidson. Together they observed the eclipse of 1926 January 14 in Sumatra. At this eclipse

Davidson and Stratton obtained excellent spectra of the chromosphere down to 3066Å, and, by subsequently identifying the lines with particular multiplets, gave a definitive answer to the question of the identification of the lines in the chromospheric spectrum, which had been a vexed question in earlier decades. They also conducted observations of the intensity of the Balmer lines as far as $m = 28$ and of the Balmer continuum and observations of the distribution of intensity in the corona; and furthermore they measured accurately the wavelengths of lines in the coronal spectrum. The work is reported in the *Memoirs* of the Society, volume 64.

During this period, when he was still Senior Tutor at Caius, Stratton contributed a scholarly article on Novae to the *Handbuch der Astrophysik* and delivered the Halley Lecture at Oxford. But this period of his life was about to come to an end, for in 1928 Newall retired from the Chair of Astrophysics at Cambridge, and Stratton was elected to succeed him as Professor of Astrophysics and Director of the Solar Physics Observatory.

He threw himself into the affairs of the Observatory with his customary energy, and set about bringing the publications of the Annals up to date, organizing the solar work and, as ever, encouraging the young men of Cambridge to come out to the Observatory and start practical work.

He led an immensely busy life, concerning himself with all sorts of affairs without any secretarial help whatever. He used to carry round with him a slip of paper on which he wrote a memorandum of everything he had undertaken to do, however trivial or however important; and he would cross off the items when the business was discharged, and, I suppose, start a new piece of paper when he came to the bottom of the old one. His light burnt nightly in his rooms in Caius into the early hours of the morning, but he would be up betimes, often with guests to breakfast. In his tutorial days the guests were undergraduates, but I think these rather gave way to older people when Stratton became Professor. In the midst of this he suffered a setback. Some rooms in the College caught fire in the early morning. Stratton rushed out of his rooms to direct operations and fell over one of those hoops which were employed to keep people off the grass.* He fell heavily on his chest and developed a complaint which compelled him to spend the winter in Jamaica in order to recuperate. It was said that Eddington composed a puzzle every week and sent it to Stratton to help him to pass the time. When he came back

* A contemporary undergraduate ballad about the fire described Stratton's unique position in Caius admirably, when it related how the whole College turned out

"From Professor Colonel Stratton
To the Porters and the Waiters"

to England he went very slowly for a while, cycling out to the Observatory along the Madingley road with what must have been the minimum speed to achieve equilibrium.

In 1934 his interest in Novae was rewarded by the appearance of Nova Herculis, and Stratton organized the forces of the Observatory in order to secure as many spectra of this object as possible, despite the Cambridge weather; and indeed so zealously did the observers snatch every opportunity to observe through a gap in the clouds that there were few nights when nothing was done. To stimulate interest in observing matters, Stratton used to conduct a competition at the Observatory tea club, to guess whether any observations would be secured in the coming night. Two points were awarded for a correct affirmative and one for a correct negative, the criterion being at least one stellar spectrum being secured with the spectrograph on the Newall telescope.

Stratton was a hard worker for the organization of science. He was general secretary of the British Association from 1930 to 1935 and general secretary of the International Astronomical Union from 1925 to 1935. He was the only person who attended all the meetings of the I.A.U. from its first meeting in Rome in 1922 up to its tenth meeting in Moscow in 1958. At the Zurich meeting in 1948, Stratton addressed the Union assembled at the official banquet in English, French and German, and proceeded to follow this feat with a few words of welcome in a dozen different languages. He carried his interest in international co-operation into great practical effect, and assisted wherever he could astronomers who were the victims of political persecution in their own country. At the time of his death he was still Chairman of Commission 38 of the I.A.U. (Exchange of Astronomers), having been especially pressed by the I.A.U. Executive to continue in office for a third term, against all current practice.

Stratton was short, and rotund. He was known as Tubby Stratton to generations of Caius undergraduates, and as Chubby to everyone else. But chubby or no, he was a Colonel and a D.S.O. and he held the College in his hand. I have seen him silence a noisy Hall with a single word. In those days, as at present, there was insufficient room for all the College to dine at once, and there was a First Hall with no dons present as well as a Second Hall for the more senior undergraduates and the dons. Someone in First Hall discovered that the College silver was soft and amused himself by twisting one of the College forks. Stratton walked in alone on the dons' dais on the following night, waving the twisted fork in the air. The undergraduates started to cheer him: but Stratton barked "Quiet!" and quiet there was.

He was a bachelor, and a Unitarian. While the latter fact was generally known, few of his friends knew, what was said at his funeral service, that he had been so active a Unitarian as to have been Chairman of the Cambridge Church for more than fifty years. He was a man of tremendous principle. Everything that he did was a result of principle. He never was heard to speak evil of anyone at all.

He was elected a Fellow of the Royal Society in 1947. He was elected a Fellow of the Royal Astronomical Society in 1905, and was Treasurer from 1923 to 1927, President from 1933 to 1935 and Foreign Secretary from 1945 to 1955.

R.v.d.R. WOOLLEY

Summaries of Original Papers published in Monthly Notices, Volume 121

On Mr King-Hele's theory of the effect of the Earth's oblateness on the orbit of a close satellite, by P. J. Message (p. 1).—The relations are obtained between α and Ω, the parameters defining King-Hele's plane II, and the osculating inclination and longitude of node. The secular motion of the node is thereby obtained in terms of mean osculating elements in a form comparable to that arising in Brouwer's treatment of the canonical equations. A modification is made to King-Hele's theory which removes the singularities in the Je terms of $d\Omega/d\psi$, and it is also found that there are no terms of order Je^2 in α or Ω.

A southern hemisphere survey of the radiants of sporadic meteors, by A. A. Weiss and J. W. Smith (p. 5).—A further survey of sporadic meteor activity, from December 1956 to August 1958, has been made with 67 Mc/s narrow-beam equipment operated at a limiting line density close to 10^{11} electrons/cm. Analysis of the echo rates suggests that the sporadic radiant distribution may be sharply divided into two components. One component is concentrated towards the apex and corresponds to a distribution of orbits uniform in heliocentric co-ordinates except for a moderate preponderance of direct over retrograde orbits. The other component lies close to the plane of the ecliptic, with radiants strongly concentrated in two regions centred on longitudes $\pm 68°$ from the apex. No change is apparent in the radiant distribution as the limiting sensitivity is lowered from the 3rd to the 7th visual magnitude.

Absolute measures of stellar radiation, by R. V. Willstrop (p. 17).—Observations at the Cambridge Observatories showed that the broad-band V and B photometric systems may be reproduced by observations in narrow bands about 200Å broad centred at 5410Å and at 4390Å respectively. At the Royal Observatory, Cape of Good Hope, measurements were made of the radiation flux outside the Earth's atmosphere in four narrow ($\sim$200Å) wavelength bands from stars of known magnitude and colour index, by comparing bright stars with an artificial star, composed of a calibrated lamp and blue filter. A 4-inch refractor was used, with interference filters and a d.c. photometer The results are given in Table 1. They are in good agreement with some other recent measurements. Systematic errors are discussed in detail.

Narrow-band visual magnitudes were measured for 221 stars, and compared with broad-band visual magnitudes determined by Johnson, by Hogg and by Eggen, and with early and recent Cape results. When linear colour equations are removed the standard deviations of the residuals are between $\pm 0^{m}{\cdot}014$ and $\pm 0^{m}{\cdot}036$. The internal random errors of the best individual series are believed

to be $\pm 0^m.010$ (narrow-band) $\pm 0^m.007$ (Johnson) and $\pm 0^m.007$ (Cape). It follows that the large differences usually found between similar broad-band visual magnitudes cannot be explained by differences of band-width and equivalent wave-length combined with differences of stellar spectra.

There is good agreement between the present narrow-band colour indices and gradients on the Greenwich system measured at Mt Stromlo. The relation between absolute and Greenwich gradients was found to be $\phi = G_G + 1.11$, in excellent agreement with the best previous results.

The photo-detachment of H^-, by T. L. John (p. 41).—The photo-detachment cross section of H^- is calculated numerically using exchange free waves. The improvement got by using exchange wave functions is shown by making a comparison with experimental results.

Collision broadening and shift in the λ6573 line of calcium, by W. R. Hindmarsh (p. 48).—The collision broadening and shift of the line Ca 6573Å due to an external pressure of helium have been measured. The half-intensity damping width of the line was found to be $1.42 \pm 0.07 \times 10^{-20}$ cm^{-1} per atom per cc of helium, and the shift $0.19 \pm 0.05 \times 10^{-20}$ cm^{-1} per atom per cc of helium towards the violet. The ratio of broadening to shift is 7·5. This result is shown to be consistent with the hypothesis that short-range repulsive forces between calcium and helium atoms are predominantly responsible for the broadening and shift. No deduction about collision broadening and shift in stellar atmospheres can be made from these laboratory results, but it is suggested that a study of more highly excited lines may yield astrophysically relevant results.

The magnesium b *lines in late-type stars*, by T. J. Deeming (p. 52).—The absorption lines of Mg I at λ 5167–84Å have been measured photo-electrically in 539 Go–K5 stars. The results show an increasing absorption with advancing spectral type and a negative absolute luminosity effect. No significant differences are found between the strong and weak line groups of Miss Roman, or between weak-CN and strong-CN stars. High velocity class III stars have slightly stronger Mg than normal. It is suggested that the Mg b lines can be used as a good criterion of the MK luminosity class for stars with $B-V$ between 0·70 and 1·30, and as a fairly good criterion of MK spectral type between G8 and K5.

The abundance of oxygen in the planetary nebula NGC 7027, A. Burgess and M. J. Seaton (p. 76).—The abundances of O^0, O^+ and O^{+2} are determined from [O I], [O II] and [O III] forbidden lines and the abundances of O^{+3}, O^{+4} and O^{+5} from O III, O IV and O V recombination lines. In the recombination calculations cascade from all upper levels is taken into account. It is found that O^{+3} is the most abundant oxygen ion and that the abundance of O^{+5} is small. The chemical abundance ratio is found to be $N(O)/N(H) = 1.2 \times 10^{-3}$.

Variable stars in NGC 2257, J. B. Alexander (p. 97).—From the blink-comparison of plates taken at the Radcliffe Observatory over a period of

about six years, 28 variables have been discovered in the globular cluster NGC 2257 which is on the outskirts of the Large Magellanic Cloud. Visual estimates of the brightness of these variables have been made on a step basis relative to a sequence. For six variables with a large amplitude of light-variation, periods ranging from 0·51 to 0·69 days have been derived, and the light-curves obtained are like those of Bailey *a* and *b* type RR Lyrae variables in the Galaxy. It has not been possible from the available material to work out the periods of the many variables with a much smaller range of light-variation, but at least some of these stars have the gradual rise to maximum found in Bailey *c* type variables.

A catalogue of Hα*-emission regions in the southern Milky Way*, A. W. Rodgers, C. T. Campbell and J. B. Whiteoak (p. 103).—In connection with an Hα atlas of the Southern Milky Way being produced at Mount Stromlo, a catalogue has been made of the H II regions distributed about the galactic equator within galactic latitude limits $\pm 15°$, and extending from galactic longitude 190° to 12°. The results of this survey have been compared with those of previous surveys overlapping the region investigated.

The spectrum of the Cygnus (19N4A) *and Cassiopeia* (23N5A) *radio sources below* 30 *Mc/s*, A. C. B. Lovell and H. W. Wells (p. 111).—The 250ft. steerable radio telescope and the 220ft telescope at Jodrell Bank have been used as an interferometer to measure the ratio of the intensities of the Cygnus and Cassiopeia radio sources from 16·0 to 26·0 Mc/s. The ratio remains constant at 0·53. The results are compared with previous measurements. The amount of absorption to be expected in H II regions is calculated and it is shown that the difference in H II content along the lines of sight to Cassiopeia and Cygnus cannot be greater than that contained in a cloud of extent 4 parsecs and electron density less than 3 electrons per cc, which is well below the value normally assumed for an average H II cloud.

Informational considerations in the design of astronomical spectrographs, E. H. Linfoot (p. 115).—The problem of designing spectrographs so as to maximize their information rate on random low-contrast spectral distributions is considered. In Section 2 it is shown how spectrographs can be discussed within the general framework of Fourier optics. In Section 3 the effects of optical aberrations, of photographic spread and granularity, and of variation of slit width are briefly considered and the implications of the band-limitedness of optical images in the problem of allowing for instrumental bandwidth are pointed out. An approximate expression for the information rate is obtained in the special case of an aberration-free spectrograph.

The new I.A.U. system of galactic coordinates (1958 *revision*), by A. Blaauw, C. S. Gum, J. L. Pawsey and G. Westerhout (p. 123).—The definition of a new system of galactic coordinates was recently announced by Sub-Commission 33b on behalf of the I.A.U. The present paper is the first of a series of five, which together form the final report of the Sub-Commission. It summarizes

the observational evidence, given in detail in the other papers, relevant to setting up the new system, it discusses various considerations which were taken into account, and it concludes with a definition of the new system.

A 21-cm determination of the principal plane of the Galaxy, by C. S. Gum, F. J. Kerr and G. Westerhout (p. 132).—Observations at 21 cm have shown that the neutral hydrogen layer is exceedingly flat over the region of the Galaxy within 7 kpc from the centre. The mean plane of the hydrogen in this region must have an important dynamical significance, and may be regarded as the principal plane of the Galaxy.

The position of this plane has been determined, using data from two extensive surveys of the Milky Way by the Leiden and Sydney groups. A number of least squares solutions have been made for the position of the plane. Besides the main series of solutions incorporating all the points, various partial solutions were made for restricted regions of the Galaxy, to obtain additional information about the flatness of the hydrogen layer and the reliability of the observations. Close agreement was obtained between the best solutions, indicating that the region of the Galaxy within 7 kpc from the centre is indistinguishable from a plane.

The finally-adopted solution has the following elements and overall probable errors, expressed in terms of Ohlsson's coordinate system:

l_0[1], the longitude of the north pole of the plane, $347° \pm 5°$
Δ, the deviation of this pole from Ohlsson's pole, $1°{\cdot}50 \pm 0°{\cdot}12$
z_0, the height of the Sun above the plane, 4 pc $\pm$ 12.

Radio data relevant to the choice of a galactic coordinate system, by C. S. Gum and J. L. Pawsey (p. 150).—Radio observations relating to the determination of the directions towards the galactic pole and centre are collected and studied. The most important evidence on the direction of the pole is based on 21-cm hydrogen line observations; the derived direction is confirmed by observations in the radio continuum. The direction towards the galactic centre is deduced from various continuum and hydrogen line observations, the most precise information being derived from the position of the radio source Sagittarius A which is assumed to be associated with the galactic nucleus and at the galactic centre.

The outstanding physical result of this study is the extreme flatness of the disk of neutral hydrogen in its central parts; a new point is the large-scale association between the sources of the radio continuum and the 21-cm line radiation. The significance of the results is discussed.

Optical determinations of the galactic pole, by A. Blaauw (p. 164).—A discussion is given of two new determinations of the galactic pole, based on recent surveys of distant OB stars and Cepheids (Table I). It is shown that, within the observational uncertainty, the plane defined by all optical objects observed between 1000 and 4000 pc from the Sun is parallel to the plane defined by the neutral hydrogen.

It is concluded, however, that the optical objects should not be used in the determination of a new galactic pole because (i) they represent a very limited sample of the Galaxy, (ii) they are not free from the influence of observational selection (absorption), (iii) they are partly situated in the outer distorted regions of the Galaxy and (iv) they are closely related to the neutral hydrogen and therefore not really independent.

The position of the galactic centre, by J. H. Oort and G. W. Rougoor (p. 171).—The direction to the radio source Sagittarius A is found to be within 0°·03 of the direction to the galactic centre as determined from a number of precise optical and radio observations, including the recently discovered rapidly rotating disk of neutral hydrogen around the centre. This, together with the fact that the source is unique among the known sources, makes it highly probable that Sgr A is situated at the centre. Additional evidence comes from the observation of 21-cm absorption lines, which indicate that the distance of Sgr A is equal to or greater than the distance to the galactic centre.

The variation of meteor heights with velocity and magnitude, by J. S. Greenhow and J. E. Hall (p. 174).—The variation of the heights of occurrence of meteors, with velocity and magnitude, are compared with the theoretical predictions. The photographic observations are shown to be in good agreement with theory over the range of zenithal visual magnitudes from -3 to $+3$ and for velocities of 13 to 70 km/sec. Very large departures from the predicted heights are found for radio echo observations of $+6$ magnitude meteors. Reasons for these departures are discussed.

The importance of initial trail radius on the apparent height and number distributions of meteor echoes, by J. S. Greenhow and J. E. Hall (p. 183).—Some simultaneous radio echo observations of meteors at wavelengths of 8 m and 17 m are described. It is shown that very many more echoes from faint $+6$ mag. meteors are observed at 17 m than at the shorter wavelength, and this effect is attributed to an attenuation in echo amplitude due to the large initial radii of the ionized trails. The initial radius is found to increase from 1 m to 3 m between the heights of 90 and 115 km. It is estimated that radio echo equipments of moderate sensitivity detect only 1·5 per cent of $+6$ mag. meteors at a wavelength of 4 m, 8 per cent of 8 m, rising to 40 per cent at 17 m. The influence of this large attenuation in echo amplitude on metre wave radio echo observations of meteor height, mass, and velocity distributions is considered.

Magneto-hydrostatics of stellar atmospheres, I. The stability of the axially symmetric case, by M. J. Laird (p. 197).—The equation governing a small perturbation in a rotating stellar atmosphere under gravity with an axially symmetric magnetic field, whose lines of force are confined to the meridional planes, is set up. A sufficient condition for stability is found to be that a certain quadratic form is positive definite.

Magneto-hydrostatics of stellar atmospheres, II. The axially symmetric equilibrium configurations, by H. Bondi (p. 201).—It is shown how the equation of hydro-

static equilibrium may be reduced to a form suitable for calculation in the axially symmetric case, full account being taken of gas pressure, gravity, and magnetic forces. The nature of the solution is discussed, and a specially simple case is worked out in detail.

Magneto-hydrostatics of stellar atmospheres, III. The axially symmetric equilibrium configurations (continued), by M. J. Laird (p. 208).—In paper II, Bondi showed how the fundamental equation may be reduced to a form suitable for calculation in the axially symmetric case under certain assumptions. In the first part of this paper a more general method of effecting this reduction is given, with an example. In the second part, this method is extended to the case when the star is rotating, under more restricted assumptions about the structure of the atmosphere.

Electron impact excitation of positive ions: application to Ca^+ $4s$–$4p$ *and* $3d$–$4p$, by H. van Regemorter (p. 213).—A review is given of different approximate methods for computing cross sections for transitions in positive ions produced by electron impact. It is shown that it is necessary to take into account the distortion by the ion field, and, for strong optically allowed transitions, one must allow for strong coupling effects.

Applications to the $4s-4p$ and $4p-3d$ transitions in singly ionized calcium shows that the neglect of strong coupling effects overestimates the cross sections. However, our results, computed with a Coulomb distorted wave approximation, with allowance for strong coupling effects, are much bigger than those of Jefferies, the reason being that he considered only one value ($l = 1$) of the angular momentum of the incident electron, whereas the main contribution is shown to occur for $l = 4$.

The Bethe approximation, with allowance for Coulomb distortion, implies in fact two different approximations: the weak coupling approximation and the "long range approximation". It is possible to make corrections for strong coupling effects and, for strong allowed transitions such as $4s-4p$ and $4p-3d$ in Ca^+, this method gives good results in a very simple way.

Photometry in the Magellanic Clouds, III. The cluster NGC 1783, by Allan R. Sandage and Olin J. Eggen (p. 232).—Photometry is reported of the cluster NGC 1783 in the Large Magellanic Cloud. The 74-inch Radcliffe reflector at Pretoria, South Africa, was used. NGC 1783 had previously been suspected as being a "normal" globular cluster similar to the halo clusters in our Galaxy but the $(V, B-V)$-diagram shows that this is not the case. The red giant sequence has a much more gradual slope than that of halo clusters, and the giant sequence extends to an extremely red terminal point at $(B-V)_0 = +2{\cdot}4$. The diagram, although dissimilar to globulars in our Galaxy, is almost identical with the $(V, B-V)$-diagram of NGC 361 and NGC 419 obtained by Arp in the SMC and to the diagram of NGC 1978 obtained by Hodge in the LMC.

A composite diagram is shown which compares the $(V, B-V)$-diagram of M3, M92, NGC 6356, and NGC 1783. The position and slope of the giant branch of 1783 suggests that its cluster stars may be very rich in heavy elements,

similar to NGC 6356. But this appears to be contradicted by the extreme redness of the giant branch. Spectrograms of the cluster or of its individual stars would appear to be necessary to settle the question. If clusters similar to the known clusters in our Galaxy are not found in the Magellanic Clouds, then the quest for the cosmic distance scale is made more difficult because of the inapplicability of the principle of uniformity to the stellar contents of galaxies.

The formation of population I stars, part II. The formation of molecular hydrogen in interstellar matter, by W. H. McCrea and D. McNally (p. 238).—This paper is essentially an investigation of the possibility of molecule-formation (chiefly H_2) by surface-reactions on interstellar dust-grains. The process has often been mentioned but here we seek to derive as precise an expression as possible for the rate of formation in terms of the properties of the grains. The effect upon the rate of a collision between interstellar clouds is also considered. The case of interstellar CH is discussed; it seems that some of the difficulties encountered by Bates and Spitzer may be overcome if we recognize the possibility of the enhanced production of CH in the conditions produced by a collision between clouds. If this is accepted, it indicates that the type of process here considered does actually take place with a fairly high efficiency. The case of H_2 is then considered. An efficiency comparable to that inferred in the case of CH would give a proportion of H_2 in ordinary interstellar matter in satisfactory agreement with Kahn's estimate of the amount required to cool the matter after heating by cloud-collisions. Such an efficiency would also explain why free atomic hydrogen would not be found with a density more than the order 100 atom cm^{-3}. If H_2 is produced at the inferred rate, then if an ordinary interstellar cloud is compressed by a factor about 100 the material will mostly take the form of H_2. This is of much significance for the process of star formation. Moreover, this significance is likely to remain, even if the process of H_2-formation has about the lowest efficiency that could be admitted.

Note on the transference of angular momentum within the Galaxy through the agency of a magnetic field, by F. Hoyle and J. G. Ireland (p. 253).—It is shown that, under favourable conditions, the conventional picture of the orientation of the magnetic field in the spiral arms of the Galaxy can explain the outward motion of gas at a radial speed of order 50 km sec^{-1} within the central regions of the Galaxy. Such a motion cannot arise, however, unless at a greater distance from the galactic centre there is a corresponding inward motion. The failure to observe such an inward motion casts doubt on the correctness of the conventional picture of the magnetic field.

Note on the brightness fluctuation in the solar granulation, by J. Gaustad and M. Schwarzschild (p. 260).—On photographs of the solar granulation obtained with a balloon-borne telescope, Blackwell, Dewhirst and Dollfus measured a r.m.s. brightness fluctuation of 4·6 per cent. From this measurement they deduced a true r.m.s. brightness fluctuation of 18 per cent. This deduction was based on an accurate measurement of the contrast transmission function of their instrument, but on an approximate application of this transmission function to

the granulation. This note aims to show that, using the same observed r.m.s. brightness fluctuation, the same measured instrumental transmission function, and the same value of 1·4 seconds of arc for the average granule diameter, a more detailed analysis gives a true r.m.s. brightness fluctuation not of 18 per cent, but of only about 7 per cent. The overestimate by Blackwell *et al.* appears to have resulted from their identifying the granule diameter with a wave-length rather than half a wave-length.

The Scorpio-Centaurus association. 1. Radial velocities of 120 bright stars, by William Buscombe and Pamela M. Morris (p. 263).—Newly determined radial velocities are given for 2 stars of spectral type O, 104 of type B and 14 of type A, all brighter than magnitude 7·0. They are part of a programme covering the region of the Scorpio-Centaurus moving stream, between galactic longitudes 200° and 300°. Each star has been classified on the revised Yerkes luminosity system.

At least three spectrograms of each star have been measured, except in a few cases where previous results were merely confirmed. For 39 stars the statistical reliability of previously published mean velocities is increased. Eighteen new velocities are announced, of which nine are constant and nine variable. Observations have been resumed on 64 stars previously known to have variable velocity, including 5 double-lined binaries.

Revised orbital elements are derived for the spectroscopic binaries HD 79351 and 81188, and velocity curves are presented for five separate cycles of the pulsating star θ Ophiuchi. Two of these stars are members of the association.

The emission spectrum of the night side of Venus, by B. Warner (p. 279).—The measurements given by Kozyrev of features in the spectrum of the night side of Venus are examined. The existence of nitrogen bands is confirmed and evidence is presented identifying emission lines of neutral and ionized oxygen.

The determination of the incident flux of radio-meteors, by T. R. Kaiser (p. 284).—The observed rate of radio-meteors depends on a number of factors which include: (i) the incident flux and distribution in magnitude of the meteors, (ii) the radiant co-ordinates, (iii) the variation in ionization along a meteor trail, (iv) the nature of the radio reflection process and (v) the parameters of the radio-echo equipment. The present work represents a considerable simplification over previous attempts to relate the radio echo rate to the actual flux of meteoroids. Simple formulae are derived relating these two quantities which, when used together with suitable graphical representation of the directional properties of the aerial system and of the reflection geometry, enable the incident flux of shower meteors to be deduced from the observed rate. The fact that the variation with time of the shower rate obtained with a fixed aerial beam may be predicted is relevant in connection with a method for shower radiant determination. Limitations due to the approximations in the theory, and to the simplified ablation theory on which it is based, are discussed.

Oscillator strengths of neutral atoms of the iron-group, by C. W. Allen (p. 299).—Measurements from various sources of the relative oscillator strengths of

multiplets in Sc, Ti, V, Cr, Mn, Fe, Co, Ni have all been reduced to a consistent absolute scale. This makes it possible to compare experimental accuracy, make certain corrections, and tabulate mean measurements. The measurements are then compared with calculations based mainly on an elaboration of the *f*-sum rule. The character of the results differs for three sets of multiplets as follows:—

(*a*) For the transition types A, E, F, G, H, which involve non-equivalent electrons only, the log (observed/calculated) intensity is almost independent of excitation potential or wave-length. The scatter is probably due to unsuitability of the designations or to the interaction of terms. When absolute *f*-value measurements (for Cr, Mn, Fe, Co, Ni only) are used to convert these multiplets to a measured absolute scale, all atoms are within a factor 3 of the calculated scale. The high (obs./calc.) value in Mn is discussed. There is only a small systematic difference between observation and calculation.

(*b*) For the transition types B, C, which involve equivalent electrons, the scatter of the results is much larger. Multiplets with an upper excitation potential less than 4 eV have *f*-values below the calculations, while above 4 eV values agree with the calculated absolute scale.

(*c*) Measured values of multiplets violating *LS*-coupling vary erratically between zero and an empirically calculated value.

Recommended corrections for putting the mean values onto the best absolute scale are given.

The photoelectric light curve of FU Arae, by G. G. Cillié and E. M. Lindsay (p. 333).—Photoelectric light curves have been obtained in blue and yellow light for the star FU Arae using the 60-inch Rockefeller reflector of the Boyden Observatory. There are two equal fairly flat topped maxima. Primary minimum is much deeper than secondary; the latter occurs at 0·5 phase. The light elements are Min. = JD 2426869·490 + 0^{d}·864500957*E*.

The brightest stars in the Magellanic Clouds, by M. W. Feast, A. D. Thackeray and A. J. Wesselink (p. 337).—Spectroscopic and photoelectric observations of individual members of the Magellanic Clouds are presented (Sections 1–7). Table II includes spectral classifications of 50 Small Cloud objects and 105 Large Cloud objects; of these 93 have been observed photoelectrically (mostly in 3 colours), and 112 have measured radial velocities. Table III also lists 103 stars proved spectroscopically to be foreground galactic stars.

In Section 8 the observed colours of Cloud stars are compared with intrinsic colours of galactic supergiants by Johnson (O to A3) and Feinstein (A0 to K5). With the exception of Johnson's dip at A3 the least reddened Cloud stars agree well with these colours. Cloud stars are subject to a small amount of reddening ($\bar{E}_{B-V}$ = 0·10) apparently arising partly in the Clouds and partly in the Galaxy. The Cloud reddening is greater for stars involved in nebulosity.

In Section 9 the HR diagram shows stars at A0 to A3 brighter visually than the early B and O supergiants. Bolometrically, however, the brightest star ($M_{b} \sim -11$) cover this whole range of spectral types; these brightest stars all tend to show P Cyg characteristics in their spectra and are probably at the limit

of stability for massive stars (mass ~ 100⊙). Some peculiar emission-line stars resembling Eta Car are slightly less luminous. The few red super-supergiants (visually among the brightest Large Cloud members) are probably very rare objects. Photographically, the 18th brightest known LMC member has $B = 10{\cdot}70$.

In Section 10, a detailed spectroscopic comparison between Cloud stars and galactic standards is made (together with a comparison of the gas in the Large and Small Cloud). Most of the small pecularities noted can be attributed to very high luminosity (e.g. narrowness of the H lines) and lack of suitable galactic standards. In particular, no outstanding pecularities are found in the 10 long-period Cloud Cepheids which have been studied. A list of 26 elements (including La II) identified in Cloud spectra is given.

In Section 11, a discussion of the *UBV* photometry shows that the reddening and intrinisic lines reinforce the essential similarity of stars (and dust) in both Clouds and the Galaxy.

In Sections 12 and 13 evidence is presented that interstellar lines due to Cloud and galactic gas occur in spectra of stars in both Clouds. Stars showing Cloud interstellar lines tend to be involved in nebulosity; our stars of type earlier than B1 are all involved in nebulosity, as in the Galaxy. The W stars and red super-supergiants also appear to be associated with nebulous regions.

In Sections 14 and 15 foreground stars are briefly discussed. Details of the photometric evidence for foreground galactic absorption are presented, and spectra of 3 peculiar galactic stars are described.

An analysis of the radial velocities of galaxies in the Virgo cluster, by Sidney van den Bergh (p. 387).—It is found that the radial velocities in the Virgo cluster do not deviate significantly from a Gaussian distribution. However, reasonable assumptions regarding the mass to luminosity ratios of galaxies indicate that there is no equipartition of energy between the cluster members. Stable binary and multiple systems appear to exist within the cluster. The velocity differences of members of close pairs may indicate mass to light ratios smaller than those obtained from the virial theorem.

Note on magnetic instabilities in stellar structure, by T. G. Cowling (p. 393).—A particular model of a magnetic star, found by Prendergast to be unstable if the magnetic field is sufficiently great, is shown to be unstable for all magnitudes of the field. The bearing of this result on the general problem of magnetic instabilities is discussed, and it is indicated that such instabilities lead to a readjustment in the field rather than to an explosion of the star as a whole.

Computing precise star co-ordinates, by A. J. Wickens and Harold E. Jones (p. 399).—The Geodetic Survey of Canada has found it feasible to use the IBM 650 computer to determine precise apparent star co-ordinates without the use of precomputed tables or punch cards of Besselian or Independent Star Numbers and Annual Variation, etc. Corrections for precession, proper motion, nutation, aberration and parallax are applied to the positions from the basic catalogues. Newcomb's precession constants are used; nutation is computed

using the formulae of the Improved Lunar Ephemeris; aberration is computed following the method described by Porter and Sadler. The resulting programme requires an average of about ten seconds per star and will preserve the accuracy of FK3 star co-ordinates for many years from the catalogue epoch.

The radio telescope for 7·9 metres wavelength at the Mullard Observatory, by C. H. Costain and F. G. Smith (p. 405).—This pencil-beam radio telescope, which uses the principle of aperture synthesis, has a resolution of $0{\cdot}8° \times 0{\cdot}8°$ at a wavelength of 7·9 m. A survey of the sky between R.A. 05^h and 17^h, Dec. + 10° to + 50°, has proved the performance of the instrument. The map of this region, which is presented in this paper, shows detail of the spur of radio emission at galactic longitude $l' = 0°$; it also shows some discrete sources, including the Coma cluster.

The radio spectrum of the Andromeda nebula, by J. E. Baldwin and C. H. Costain (p. 413).—Some new observations of the Andromeda nebula have been made at frequencies of 38 and 178 Mc/s. At 178 Mc/s both fan-beam and interferometric measurements have allowed a number of point sources superimposed on the nebula to be distinguished; a comparison of the number of these sources with those found in neighbouring areas of sky suggests that they are not related to the nebula.

By comparing the observations at 38 and 178 Mc/s with those previously made at Jodrell Bank at 408 Mc/s it has been possible to show that all parts of the nebula have a similar spectrum, the brightness temperature varying at $\nu^{-2.5\pm0.1}$, a figure close to that for the Galaxy.

The solar red-shift, by L. A. Higgs (p. 421).—The centre-to-limb increase in wave-length of three medium strength iron lines in the solar spectrum has been determined, using micrometer measurements of grating spectra. The observations were made at solar latitudes of approximately ± 55°, and at radial distances from the centre between 85 and 100 per cent of the radius of the disk. The limb-effect curve obtained, after corrections for scattering of light, is in good agreement with the curve obtained recently at Oxford (5) for solar equatorial regions.

The absolute wave-lengths in the solar spectrum of the lines used in this investigation and the vacuum arc wave-lengths of the three iron lines were determined using the method of circular channels. The centre red-shifts of the three lines, together with the limb-effect curve, give a red-shift at the extreme limb substantially exceeding the shift required by the principle of equivalence.

It is shown that the line profiles of the solar lines in the grating spectra are affected by the apparatus function of the spectrograph. Allowing for this, the solar lines at the centre appeared to be symmetric but an unexplained asymmetry at the extreme limb was discovered. This indicates that wave-length measurements alone are insufficient for a determination of the nature of limb effect.

Radio echo measurements of the orbits of faint sporadic meteors, by J. G. Davies and J. C. Gill (p. 437).—A survey has been made of the orbits of faint sporadic meteors. The results show that, in addition to meteors moving in orbits similar

to those of the comets, there are many in orbits of very short period. The more eccentric of these orbits are concentrated towards the plane of the ecliptic, but some are nearly circular and have inclinations near 60°. The differences between these results and those previously published for bright meteors are discussed, and a qualitative explanation is given in terms of the action on near-parabolic orbits of solar radiation and the major planets.

Spectra of a bright coronal prominence associated with a Class 3 flare, by Ian Elliot, M. A. Ellison and John H. Reid (p. 463).—Photographs and spectra are described of a prominence which formed in the corona following a Class 3 flare at the limb. Line profiles have been obtained which are Gaussian in shape. On the assumption that the line broadening is of purely thermal origin a kinetic temperature $\sim 10^5$ °K is indicated for the $H\alpha$ line. The line-widths of H and K require temperatures $\sim 10^6$ °K. It is concluded that these great line-widths must arise largely from non-thermal processes occurring within the prominence. Some possible mechanisms are discussed.

Radiative recombination of He, by A. Burgess and M. J. Seaton (p. 471).—Recombination coefficients for

$$He^+ + e \rightarrow He(n^{2S+1}L) + h\nu$$

are tabulated for $T = 0$, 1×10^4 and 2×10^4. Hydrogenic data are used for $L \geqslant 2$, but allowance is made for the non-hydrogenic character of the He nS and nP states.

The relativistic model of the steady-state universe, by W. B. Bonnor (p. 475).—It is shown that in the relativistic and Newtonian versions of the steady-state universe the motion of the cosmic matter is indeterminate. The reason is that for matter with equation of state $p + \rho = 0$ both the inertial and passive gravitational mass densities vanish. The conclusion is that these versions are of doubtful value in the prediction of cosmological observations.

Solar intensity and limb darkening between 8·6 and 13μ, by F. Saiedy (p. 483).—The intensities of the centre of the solar disk at 8·63μ and 12·02μ have been measured by a technique previously described for 11·10μ. The emission temperatures obtained were 5160 °K at 8·63μ and 5050 °K at 12·02μ against the earlier value of 5036 °K at 11·10μ. The results are a few per cent greater than values calculated from model solar atmospheres.

Limb darkening measurements have been made out to 0·91 of the solar radius (solar image diameter 17 mm) at 8·63, 11·10, 12·02 and 12·95μ, and are in good agreement with those of Pierce *et al.* at 8·3 and 10·2μ.

The combined measurements of solar intensity and limb darkening have been used to study the wavelength variation of the photospheric opacity. The results show less variation with wavelength than predicted theoretically. They also indicate that the free-free component of H^- opacity calculated by Chandrasekhar and Breen is 40 per cent too high, which is approximately in agreement with the recent calculations of T. Ohmura and H. Ohmura.

On tidal torque and eccentricity of a satellite's orbit, by Gordon W. Groves (p. 497).—It has long been known, by a simple and general argument, that tidal dissipation within the Earth must slow its rotation, slow the Moon's orbital motion and increase the Moon's mean distance. A hypothesis is made whereby it can be shown, under almost as general conditions, that tidal dissipation must also increase the eccentricity of the Moon's orbit. The exact rate of increase is not determined. However, it is shown that if the Moon were at one time quite close to the Earth the eccentricity would have been at most about 2×10^{-6}; i.e., the orbit would have been nearly circular. This agrees nicely with Darwin's idea that the Moon originated near the Earth. At the stage where, according to Darwin, the Earth and Moon each present the same face toward each other and revolve with a period of 55 present days, the eccentricity will be about 0·2 to 0·4.

Stellar rotation in galactic open clusters, by P. J. Treanor, S. J. (p. 503).—A survey of existing determinations of stellar rotational velocities reveals severe limitations on the use of this material due to the inhomogeneities in the methods of measurement and in the selection of the objects that have been measured. To secure information concerning a more homogeneous population, measurements of rotation have been made for 58 members of the Hyades cluster, 63 members of Praesepe, and for 10 members of the ζ-Persei association. A number of stars measured by Slettebak were included and good scale agreement is found with these. The results for the Hyades stars are systematically higher than those found by Struve.

The small rotational velocities of the 16 metallic line stars in Hyades and Praesepe confirm previous measures on stars of this type.

The variation of rotational velocity in the main sequence is investigated by a new analysis of the measures of Herbig and Spalding, of Slettebak, and of Slettebak and Howard, together with the present material. This analysis, based on a colour *vs.* rotational velocity diagram of equal groups of stars, reveals a sudden fall in rotation near F6 in the results of Herbig and Spalding. The other results are not inconsistent with this finding. The early-type stars show a large scatter. The rotations of the Hyades and Praesepe stars are in mutual agreement and tend to be somewhat larger than those of the general field in the neighbourhood of spectral type Fo.

Micrometer measurement of high dispersion spectra, by A. D. Petford (p. 519).—A position-sensitive germanium photocell has been used as the basis of a setting device for measuring spectra, and has given a great reduction in the time of measurement, and some increase in precision, compared with visual measurement.

The rotation of a barred galaxy under gravitational forces, by S. Aarseth (p.525).—A simple geometrical model of a barred spiral with central nucleus is considered. The problem of rotation about an axis normal to the bar axis is discussed, and it is found that a certain density distribution in the bar will make the system remain stable for a time of order 3×10^9 years. When the ratio of

the diameter of the nucleus to the total length of the bar is 1 : 3, this situation requires the ratio of total bar mass to central mass to equal 0·54. If the latter is taken to be 5×10^{10} ⊙ the period of rotation is $1{\cdot}5 \times 10^{8}$ years.

Four standard sequences in the Southern hemisphere, by Bart J. and Priscilla F. Bok (p. 531).—The four photo-electric sequences are in Tables V to IX for the stars shown in Plates I to IV. The centres are for Selected Areas 141, 193 and 158 and for the van Wijk Sequence in the Large Magellanic Cloud. The basic material is from Boyden Station (1950–51) and from Mount Stromlo Observatory (1957–59). All results are reduced to the Johnson-Morgan *UBV* system.

Radio emission from the Cygnus Loop, by D. S. Mathewson, M. I. Large and C. G. T. Haslam (p. 543).—The Cygnus Loop, an expanding system of bright nebulosities about 3° of arc in extent, is thought to be the remnant of a supernova type II and probably represents the nearest of the Class I radio sources. The high resolution and sensitivity of the 250ft paraboloid at 408 Mc/s made possible a detailed study of the radio emission within this type of object and its relation to the optical features. The radio emission was found to be most intense in the optically faint southern region, the position of maximum emission being $20^{h}\ 48^{m}\ 21^{s}$, +29° 40′ (1950). The radio source associated with the bright nebulosity NGC 6992–5 was resolved from the main body of emission and although very similar in size and shape to the optical feature it was displaced towards the centre of expansion by about 12′ of arc. An attempt was made to estimate the relative contributions of the thermal and non-thermal components of the radio emission by measuring the spectral index at several points in the Cygnus Loop by combining the 408 Mc/s survey with a lower resolution 158 Mc/s survey using the 250ft paraboloid.

Dynamical calculations relating to the origin of the solar system, by R. A. Lyttleton (p. 551).—The dynamical aspects of certain hypotheses for the formation of planets are shown to be capable of close representation by a restricted three-body system, and accurate machine integrations of the equations of motion have been carried out on such a basis to test the hypotheses. It is first shown that the collisional and tidal mechanisms as applied to the Sun could not result in any particles going into orbital motion outside the Sun at however small a distance. The calculations also show that in a two-body collision of stars only a negligible quantity of material is likely to escape from both stars and be available for capture by the Sun; the amount could rise to planetary order only if the relative speed of the colliding stars when widely separated were several hundred kms per sec. Rotational break-up of a companion star to the Sun might fulfil such a condition.

The rotational instability of a primitive planet growing gradually from a disk of material in motion round the Sun would probably result in disruption into two main pieces with high mass-ratio and separating with hyperbolic speed. The motion of small particles formed in the stream of material drawn out between the separating main masses can also be investigated by means of a restricted three-body analogy, and in this way it is shown that satellite orbits

are possible as a result of the great elongation that the last Jacobi figure possesses together with the high relative velocity of the separating pieces. It is suggested that the rotational stability of the great planets has been reached in this way and by the same means their principal satellites produced. The smaller main pieces resulting from the break-up would have sufficient terminal speed to escape entirely from the solar system.

Rock creep: A correction, by Harold Jeffreys and Stuart Crampin (p. 571).—A mistake in the previous discussion of the modified Lomnitz law of creep is corrected. The index in the law is changed from 0·17 to 0·25. The other effects of creep are rediscussed and some are calculated that had not been calculated with the former index. The results are qualitatively similar to those found previously and no contradiction with the data is found.

Summary of Contents of Geophysical Journal Vol. 3, Nos. 3 and 4

Thickness of the Earth's crust in Antarctica and the surrounding oceans, by F. F. Evison, C. E. Ingham, R. H. Orr and J. H. Le Fort (p. 289).—Love waves and Rayleigh waves from eight earthquakes recorded at Hallett Station, Scott Base and Mirny have been analysed and the dispersion compared with that predicted by theory for simple model crusts. The average thickness of the crust in eastern Antarctica is found to be about 35 km, as is typical of continents, whereas Marie Byrd Land with an average thickness of about 25 km cannot be regarded as truly continental. Love wave dispersion indicates that the thickness of the solid crust in the oceanic regions surrounding Antarctica varies from about 5 km to 10 km, the smaller values being associated with the deeper basins. It is shown that the determination of oceanic crustal thickness from Rayleigh wave dispersion is in general subject to large uncertainties, nor can one usually rely on values of the thickness of unconsolidated bottom sediments obtained by this means.

Focal mechanisms of some earthquakes of the year 1950, by A. R. Ritsema (p. 307).

A theory of polar geomagnetic storms, by J. H. Piddington (p. 314).—This is the third of a series of papers outlining a hydromagnetic theory of geomagnetic storms. The first two dealt with the storm-time variations *Dst* in terms of isotropically propagating hydromagnetic compression (first phase) and rarefaction (main phase) of the geomagnetic field and its plasma.

The three phases of the longitude-dependent disturbance *Ds*, the first phase or *Sc*, the main phase and the preliminary reverse are all accounted for in terms of hydromagnetic waves whose Poynting fluxes are directed along the magnetic lines of force. These disturbances originate from "electromagnetic friction" between the solar wind and geomagnetic lines of force near 06 and 18 h local time. These lines of force are bent out of their meridian planes and cause two pairs of "twist" waves to reach the Earth, being focused into relatively confined regions at high latitudes. These twists are stable or force-free and result in space-charge accumulations in the lower ionosphere where the resultant Hall current accounts for the observed disturbances.

During the main phase the twists are maintained by a deformation of the geomagnetic field which was described in the first two papers (the geomagnetic "tail"). Thus the tail theory accounts for both *Dst* and *Ds* main phase. It is difficult to see how any ring-current theory or other theory dependent on

trapped corpuscular radiation could account for the asymmetric features of a storm.

The mechanism also provides the beginning of a theory of aurorae.

World-wide characteristics of geomagnetic micropulsations, by J. A. Jacobs and K. Sinno (p. 333).—A detailed investigation is carried out on geomagnetic micropulsations recorded by rapid-run magnetograms during the International Geophysical Year from 17 observatories as widely distributed geographically as possible. A number of well-defined cases (14 *Pt*'s and 3 *Pc*'s) are investigated in detail. Diurnal and world-wide characteristics are derived and the equivalent overhead current systems which may give rise to the micropulsations are constructed.

Many of the examples of *Pt*'s can be divided into two groups: *viz.* Pt^- which is a *Pt* associated with a negative bay in the auroral zone and Pt^+ which is a *Pt* either associated with a positive bay or one which appears with no bay in the auroral zone. Although both groups of *Pt*'s with their associated bays, have different characteristics, there are many points of similarity. Both classes have more or less coherent, synchronous wave forms over a wide area, i.e. they have the same period at different stations, where they are either nearly in or out of phase.

It is found that *Pc*'s consist of two different wave bands, both occurring during the daylight hours. The first band contains shorter period *Pc*'s (15–30)s with maximum amplitudes of a few gammas in moderate latitudes. They are not synchronous over wide areas. The second band contains longer period *Pc*'s (30–90s) with maximum amplitudes in the polar regions, amounting, on occasions, to as much as a few tens of gammas. They are well synchronized round the world.

Attention is drawn to the occurrence of long period, continuous, pulsations (called *LPc*'s) which have a longer period than *Pc*'s and usually appear simultaneously with *Pc*'s in polar regions.

The characteristics of micropulsations found in this investigation may throw some light on their origin. In this regard, a tentative discussion is given of hydromagnetic oscillations in the outer atmosphere which are excited by solar corpuscular streams.

Note on cusps in seismic travel-times, by K. E. Bullen (p. 354).—When there is triplication in travel-time curves, it is often assumed that the cusps in the curves are necessarily associated with large wave amplitudes. Models which give a good representation of various types of seismic velocity variation are here set up to show that there are important cases in which this assumption does not apply. The analysis, which is facilitated by use of the variable $\alpha = 2d\log r/d\log\eta$, shows fairly directly that $d\Delta/dp$, where Δ and p are the angular length and parameter of ray, is sometimes discontinuous, sometimes continuous at a cusp.

Note on the paper of A. H. Cook, "The external gravity field of a rotating spheriod to the order of e^3", by Walter D. Lambert (p. 360).—A. H. Cook published in the

September 1959 number of this Journal an article entitled "The External Gravity Field of a Rotating Spheroid to the order of e^3". Cook's formulas for the potential of such a spheroid stop with the term in $P_6(\sin\phi)$, which is given, as indicated, by the title, to an accuracy of e^3. This note states, without proof, formulas for the coefficients of $P_{2n}(\sin\phi)$ with no limit on n and no limit to the formal numerical accuracy of such coefficients.

Some of Cook's other formulas may be simplified by a slight change in notation.

The palaeomagnetic poles for the lower Jurassic of Europe, by K. M. Creer, E. Irving and S. K. Runcorn (p. 367).

Microseisms at Scott Base, by T. Hatherton (p. 381).—The seasonal variation of the pack ice surrounding the Antarctic continent has a great effect on the levels of microseismic activity at Scott Base. Microseismic storms are in general of two types, one with periods 1–3·5 s, the other with periods 4–10 s. The short-period activity is due to events within the Ross Sea and is at a maximum during January and February when the Ross Sea is clear of ice. The long-period activity has a maximum during March and April and this is thought to be due to swell from peripheral cyclones penetrating the Ross Sea and creating microseisms after passing the continental shelf.

It is found that the microseisms of any period (T) have a limiting amplitude (A_{max}) and that for the short-period microseisms $A_{max} \propto T^{4.2}$ while for the long-period microseisms $A_{max} \propto T^{6.0}$. The difference between these two relationships can be satisfactorily explained on the basis of frequency-selective decay of the waves causing the long-period microseisms as these waves travel from the cyclone area to the continental shelf. The fourth-power relationship between maximum amplitude and period is similar to that obtained for single storms in America by Romney. It is suggested that this relationship might provide a useful test for a quantitative theory of microseisms, such as the standing wave theory, or alternatively that it can be used to investigate transmission and absorption processes in the crust.

The data appear to confirm the requirement of sea roughness for the generation of microseisms, the half-period relationship between microseism and sea wave periods, and the role of the continental shelf and other crustal features as barriers to microseisms of periods less than $7\frac{1}{2}$ s.

Reflexion and refraction of plane elastic waves at a plane boundary between aeolotropic media, by M. J. P. Musgrave (p. 406).—General equations in stress and displacement are set down and their implications qualitatively discussed.

Detailed results are presented for the slownesses, amplitudes and energy fluxes of body waves generated by the incidence of a body wave upon a range of differently oriented boundaries in hexagonal media.

Results for ice and beryl show that assumption of isotropy preserves the qualitative form of the reflexion characteristics; in contrast, the variations caused by changing the orientation of the boundary in zinc are too great to be adequately represented in terms of isotropic constants.

The time term approach to refraction seismology, by P. L. Willmore and A. M. Bancroft (p. 419).—In all seismic refraction surveys, the problem is to determine the constants in a system of equations of the type

$$t_{ij} = a_i + b_j + \Delta_{ij}/v$$

where a_i and b_j are "time terms" which are characteristic of the shot-point and seismograph station respectively, Δ_{ij} is the distance between the shot point and the seismograph, t_{ij} is the time of propagation of a refracted wave and v is the velocity of propagation of seismic waves in an underlying marker layer. It is shown that the equations can be solved for interpenetrating networks of shot-points and seismographs provided that certain general conditions are satisfied. Factors which determine the uncertainties of the final solution are discussed and methods of correcting for the effects of steeply dipping boundaries are included.

The revision of earthquake epicentres, focal depths and origin-times using a high-speed computer, by B. A. Bolt (p. 433).—A program for an automatic computer has been developed to revise rapidly, provisional foci and origin-times of normal and deep-focus earthquakes. For each earthquake, up to 300 equations of condition found from *P*, *pP* and *PKP* observations are solved by least squares to give a correction to the trial location. Special attention is given to the weighting of observations and factors affecting convergence.

Features of the program are that the theoretical travel-time tables are stored in complete form, and after each iteration a list of stations with corresponding distances, azimuths, and residuals as well as the root-mean-square error is printed. Applications to a 1954 hydrogen bomb explosion and a number of earthquakes are described. The results suggest that the program may be useful to research organizations requiring either regular or special location of epicentres.

Experimental investigation on the properties of Stoneley waves, by R. J. Donato (p. 441).

Palaeomagnetic directions and pole positions. Part II, Pole numbers 2/1 *to* 2/41 *and* 1/71 (*m* 1), by E. Irving (p. 444).

Geophysics in Australia, by J. C. Jaeger and R. F. Thyer (p. 450).

Reports of Meetings

Geophysical Discussion of the Royal Astronomical Society, 1960 April 22, on papers received during the session (p. 374).

XII General Assembly of the International Union of Geodesy and Geophysics, Helsinki, 1960 July 26 to August 6 (p. 462).

Book Reviews

Palaeomagnetism and Stratigraphic Correlation, by A. N. Khramov (p. 377).

Introduction to Geophysical Prospecting, by M. B. Dobrin (p. 378).

Handbook of Geophysics, revised edition, by multiple authors of Geophysics Directorate, United States Air Force (p. 476).