it would need nothing more to imbue the whole pen with the idea that there was some cause for fear. Then they would all make a rush, and their terror and the momentarily recurring incentives to, and aggravations of, it in the shape of collisions would only subside when the sheep had broken out and were in the open, clear of one another and of their troughs and hurdles.

If this is the explanation of the panic, then it is easy to understand why folded sheep are so much more likely to suffer than those lying in open fields. The heavy, oppressive atmosphere accompanying the thick darkness, the susceptibility of sheep to atmospheric disturbance, and their nervous and timid dispositions would all tend to increase the fright the sheep experienced. The cause of the panic being a cloud rolling along so low down as (apparently) to touch the ground, the tops of the hills and the high-lying ground would naturally be most affected; and this is observed to be the case, although locally the usual direction followed by thunderstorms has indicated a line along which sheep stampeded on nearly every farm.

The Work and Discoveries of Joule.[1]

By SIR DUGALD CLERK, K.B.E., F.R.S.

THE greatest generalisation in the early history of physical science was made late in the seventeenth century by Sir Isaac Newton when he enunciated the laws of motion and deduced from them the existence in space of attraction between planets and the sun. Mechanical science has been built up on Newton's fundamental propositions and discoveries. The discovery by Joule in the middle of the nineteenth century of the mechanical equivalent of heat and his suggestion and determination of the existence of an absolute zero, together with the adaptation of Carnot's cycle of 1824 to the theory of heat as a mode of motion, provide generalisations of equal importance to Newton's law of gravitation, and from them fundamental thermodynamic laws are deduced: the equivalence of energy in different forms, conservation of energy and dissipation of energy. Joule's discovery, in fact, called the modern science of thermodynamics into existence.

Manchester has been the home of many highly distinguished men—great scientific men, great inventors, and great masters of industry and business—but it is fortunate indeed in its connection with two of the greatest discoverers in the history of the world, Dalton and Joule. Joule read his first paper before the Manchester Literary and Philosophical Society in the year 1841 upon the subject of "The Electric Origin of the Heat of Combustion." He contributed a long series of papers from that year until 1879, a period of thirty-eight years, and he dealt with a great variety of subjects, including experimental investigations on the phenomena of the voltaic current, the determination of the specific heat of bodies, heat and constitution of elastic fluids, mirage, freezing point of thermometers, galvanometers, dip circle, solar photographs, duty of electro-magnetic engines, magnetic storms, polarisation of platinum plates, mercurial air-pumps, and telescopic oscillations.

The debt of the practical engineer to Joule and his great associates is very real, but the science of thermodynamics did not supply the fundamental laws from which heat-engines were invented and developed. The steam-engine had been developed by Newcomen, Smeaton, and James Watt long before the birth of the science of thermodynamics. What is true of the steam-engine is true also of the hot-air engine and the internal-combustion engine; all the known types of heat-engine at present in use were invented before the year 1850, and practical experimental examples of both hot-air and internal-combustion engines were then in operative existence. Thermodynamics supplied the laws of the conversion of heat into mechanical work by which these engines are governed; it explained the relative perfection of engines already in existence, but it did not create these engines. It performed the very important service of dispelling the errors of thought which hindered the future advance of heat-engines Such errors as to the theory of the regenerator and the theory of compression and expansion in all steam and internal-combustion engines, held by the most eminent engineers and scientific men so late as from 1845 to 1853, were rendered impossible by the splendid work of Joule, Kelvin, Rankine, and their Continental colleagues. The knowledge of thermodynamics has thus an increasing effect upon instructed engineers of the present generation. It is quite obvious that although the origin of heat-engines cannot be ascribed to Joule's work, yet the improvement and final development towards a maximum conversion of heat into mechanical work are rendered possible to the engineer of to-day by his great discoveries. Engineers and engine-designers are most grateful to Joule, and look back on his achievements as those of the utmost intellectual and practical importance.

Giant and Dwarf Stars.[2]

THE amount of light received from a star determines its *apparent magnitude* (m), the ratio for two stars differing by one magnitude being 2·512. The *absolute magnitude* (M) is what the apparent magnitude would be if the star were at the standard distance of 10 parsecs, which corresponds to a parallax of 0·1″. If π is the parallax of a star in seconds of arc,

$$M = m + 5 + 5 \log \pi.$$

In this equation m is not difficult to measure, and hence if π or M is determined the other can be found.

Russell took all stars for which fairly accurate values of π were available, and from the above equation computed M. Then, plotting M as ordinate and type of spectrum as abscissa, he found that (1) all white stars are far brighter than the sun; (2) range of brightness increases with redness; (3) all faint stars are red; and (4) all red stars are very bright or very faint.

Adams and Kohlschütter found that the relative intensity of selected lines in the spectrum of a star depended on the absolute magnitude from measurements on the spectrum. M being determined, the

[1] Abstract of the first Joule Memorial Lecture delivered on Tuesday, December 14, 1920, to the Manchester Literary and Philosophical Society.

[2] Abstract of a lecture delivered before the Royal Society of Victoria, Melbourne, on October 14, 1920, by Dr. J. M. Baldwin, Government Astronomer.

equation gives π, and thus the parallax can be measured spectroscopically. This work brought out very clearly the division of the red stars into a very bright group and a very faint group, with no stars of intermediate brightness.

The absolute magnitude depends on mass, density, and surface brightness. The only information as to mass is obtained from binary stars, and for these the total range in mass is only from nineteen times that of the sun to one-quarter that of the sun.

The surface brightness for stars with similar spectra must be nearly equal, and thus the average red star of the bright group, which gives out 1000 times as much light as the average red star of the faint group, must have 1000 times the surface and 30,000 times the volume of the latter. Hence the terms "giant" and "dwarf." If the masses are equal the densities will be in the ratio 30,000 to 1.

For special classes of stars the relative surface brightness can be obtained, and it is found that the very white stars give out 500 times as much light per unit-surface as the very red stars. For the giant stars the density increases from the red stars to the white, while for the dwarf stars the density increases from the white stars to the red. As the giant stars contract and get hotter the increase in surface brightness nearly balances the decrease in surface, and the stars remain nearly constant in brightness, as is actually found to be the case. After a limiting density is reached cooling follows further contraction, and both the surface brightness and surface decrease together, and a rapid diminution of light is the result. This also is confirmed by observation.

University and Educational Intelligence.

LONDON.—Among the proceedings of the Senate on January 19 are the following:—

Miss Philippa Chicheley Esdaile, D.Sc. (Manchester), has been appointed as from February 1 to the University readership in biology tenable in the Household and Social Science Department of King's College for Women. Miss Esdaile has held a zoological research studentship and an honorary research fellowship in the University of Manchester, where she has also been assistant demonstrator in the Zoological Department. In 1914 Miss Esdaile was elected to a research fellowship at University College, Reading, and from 1915 to 1920 she was acting head of the Department of Zoology at Bedford College during the absence on war service of Dr. Marett Tims. Since last August she has been senior lecturer on zoology at Birkbeck College. She is the author of various publications, especially on salmon-scale research.

The following doctorates were conferred:—*Ph.D. in Philosophy:* Mr. N. K. Datta, an internal student, of University College, for a thesis entitled "The Vedanta: Its Place as a System of Metaphysics." *D.Sc. in Mathematics:* Mr. S. R. U. Saveer, an external student, for a thesis entitled "On the Instability of the Pear-shaped Figure of Equilibrium of a Rotating Mass of Homogeneous Liquid."

A resolution was adopted expressing the gratification with which the Senate had heard of the anonymous donation of 20,000*l.* made to the authorities of the Middlesex Hospital Medical School for the endowment of the University chair of physiology there tenable.

A LECTURE on "Agricultural Botany" will be given by Prof. R. Biffen at King's College, Strand, W.C.2, on Saturday morning, February 5, at 11 o'clock, in connection with the London County Council's lectures for teachers. The chair will be taken by Sir A. Daniel Hall.

THE War Work Council of the Y.M.C.A. in the United States of America has recently made a grant of 1,960,000 dollars for the fund out of which it provides scholarships and other educational assistance for ex-Service men. The grant makes the funds available for this purpose amount to 6,100,000 dollars. Free scholarship awards representing an expenditure of 2,367,895 dollars have been given to 38,582 former Service men, and in all the sum of 5,050,000 dollars has been apportioned to scholarships.

A COURSE of nine public lectures on "Problems of Modern Science," to be given on Wednesdays at 5.15 p.m., began at King's College on January 19 with a lecture by Prof. J. W. Nicholson on Mathematics. The other subjects and lecturers in the course are as follows:—January 26, Astronomy, Prof. J. B. Dale; February 2, Physics, Prof. O. W. Richardson; February 9, Chemistry, Prof. S. Smiles; February 16, Geology, Prof. W. T. Gordon; February 23, Biology, Prof. A. Dendy; March 2, Botany, Dr. R. Ruggles Gates; March 9, Physiology, Prof. W. D. Halliburton; and March 16, Anatomy, Prof. E. Barclay-Smith. The lectures are free, and cards of admission can be obtained from the Lecture Secretary, King's College, Strand, W.C.2. A stamped addressed envelope should be enclosed.

WITH commendable promptness the Association of Science Teachers has published a new edition of the "Book List" which was issued about a year ago. Sections on zoology, natural history, and astronomy have been added in the present volume, in which the old list has been extended and revised in many ways. The compilation should be of great assistance to those who are responsible for the selection of science books for use in class, for reference by both pupils and teachers, or for general school libraries. Its special value lies in the fact that the books included are in every case recommended by teachers who are exceptionally well qualified to judge of their suitability. "Book List, 1920," may be obtained at the price of 2*s.* from the Hon. Secretary, Association of Science Teachers, 10 Gresley Road, London, N.19.

FIGURES compiled by the U.S. Bureau of Education showing the public expenditure on education and the incomes of the various colleges, etc., in the United States are issued in *School Life* for December 1 last. The figures for 1918 and previous years are taken from the annual report of the Commissioner of Education; those for 1919 and 1920 are estimated. Throughout the period investigated, from 1870 onwards, the yearly increase in expenditure on education has grown successively larger. In 1870 the charge for elementary schools was 2 dollars per head of the population; it is now 9.50 dollars per head. The income of colleges, universities, and technical schools for 1920 was two and one-third times as much as it was in 1910 and thirty-six times what it was in 1870. The total sum which it is estimated was spent on education in the United States during 1920 is 1,224,000,000 dollars; this sum is approximately half the world's expenditure for educational purposes, although the people served represent only one-seventeenth of the world's population.

PART I. of the Indian Bureau of Education Publication entitled "Selections from Educational Records" has been received. It consists of reprints of a number of documents relating to education in India for the period 1781–1839, which illustrate the gradual growth of the feeling of responsibility for Indian education in the minds of Englishmen. The records which have been utilised come mainly from the Government of India, though a few have been