will be 2700 Å.U. If, however, the particles have diameters of only 1600 Å.U. and unit density the light pressure will be nineteen times greater than the gravitation attraction. For sizes still smaller the light pressure would decrease again, and for diameters less than 500 Å.U. gravity would once more preponderate.

If, then, the solar eruptions drive up into colder regions vapours which are condensed to liquid or solid particles, a sorting action will at once come into play. Particles above a certain diameter will be drawn back into the sun. Particles below a certain diameter will be repelled away with great force by light pressure, and particles of a certain critical diameter will remain suspended in space. The solar corona may perhaps be in part composed of solar dust of this critical diameter, as Arrhenius has suggested. Now, as regards that dust which is repelled by the sun, it is easy to calculate the time particles of certain sizes will take to travel to the earth's orbit and the velocities they will then possess. Taking the particles to have unit density and three sizes, viz. 1600, 5000, and 10,000 Å.U., and to be projected from the sun with velocities of 200 km. per sec., I find that the times required to travel to the earth's orbit will be respectively twenty-two hours, forty-two hours, and seventy-six hours. The velocities with which they will arrive will be 1700 km. per sec., 780 km. per sec., and 350 km. per sec. respectively.

These minute particles, composed, it may be, of carbon from the photosphere or metallic dust from the reversing layer or volcanic ash or other solar materials will in general carry electric charges. The high temperature will cause emission of electrons from the metallic particles, as also will the fierce ultra-violet radiation to which they are exposed. The metallic vapours will also be in a state of ionisation, and the free electrons emitted will condense round them gases or vapours from the chromosphere as they pass through it. Hence the particles which are repelled by light may be either positively or negatively electrified or neutral. Owing to the greater tendency of negative electrons to condense vapours and attach themselves to groups of molecules, the negatively charged particles may be less dense and smaller than those positively charged. It should be noted, however, that isolated molecules or electrons are far too small in diameter to be repelled by light. It is only groups of molecules of at least 500 Å.U. in diameter which can be repelled. Hence these dust particles will travel outwards from the sun with very different velocities. Some will come with great velocity and others with small speed.

In short, we may say that the sun, like a good housemaid, dislikes dust, especially dust of a certain degree of fineness, and pushes it away from it with great force. The moment that this electrified dust enters the earth's magnetic field with high velocity forces will be brought to bear on it tending to separate the negatively and the positively charged particles. If H is the magnetic force of the earth and v the particle's velocity, and e its charge, then the separating force is Hev where H is that component of magnetic force at right angles to the direction of v and the separating force is also at right angles to the plane of H and v.

(To be continued.)

Obituary.

Sir Ernest Shackleton, C.V.O.

THE sudden death of Sir Ernest Shackleton on board the *Quest* at South Georgia on January 5 stopped the career of the most brilliant of Antarctic explorers just on the threshold of the South Polar regions which he was entering for the fifth time with his third expedition. That such a courageous and indomitable explorer should die a natural death after a lifetime of hair-breadth escapes from perils of ice, of starvation, of shipwreck, and of war is a grim stroke of Nature's irony. Great as his loss is to geographical exploration, we cannot but recognise his end as happy, for his life was arrested in the full course of the enthusiastic pursuit of a great and crowning adventure. The sympathy of all who appreciate high-hearted deeds will flow towards his wife, to whose co-operation much of his success was due; towards his shipmates, who have nobly resolved to carry on the voyage; and towards Mr. John Q. Rowett, whose friendship for Shackleton made him undertake the main financial burden of the expedition.

Ernest Henry Shackleton was born at Kilkee, in Ireland, in 1874, removed to London with his father while still a schoolboy, and at an early age insisted on going to sea instead of following his father's profession of medicine. After voyages to South America and other parts of the world, he entered the service of the Union Castle Co., where he was during the stirring days of the Boer War. He had become an officer of the Royal Naval Reserve before the plans of the Antarctic expedition on the *Discovery* fired him with the desire for exploration. His application for a post on the expedition was refused, persisted in, and finally accepted, and he had a strenuous time on board as junior watch-keeping officer. The expedition sailed in August, 1901, and from the outset Shackleton was eager to undertake every piece of voluntary work. He assisted in the chemical and oceanographical observations, assumed the editorship of the *South Polar Times*, and read up the history of polar exploration. When Capt. Scott was making up his party for the great southern journey of 1902–3 he included Shackleton, who thus took part in establishing the "farthest south" of lat. 82° 17′ S., and saw the great range of mountains bordering the Ice Barrier on the west and stretching far to the southward. On the return journey Shackleton broke down from an illness which was probably scurvy, but he struggled on to

the end without giving in, and only last year he refuted with the utmost indignation a published statement that he had been dragged on a sledge by his comrades on that occasion. He was much distressed at the decision that he should return home by the relief ship, and it may well be that this fact was the germ of the determination to return to the Antarctic with an expedition of his own. Shackleton had more than recovered by the time he reached England, and his health never gave way again.

In 1904 he became secretary of the Royal Scottish Geographical Society and took up his residence in Edinburgh after his marriage to Emily, daughter of the late Mr. Charles Dorman. It is scarcely too much to say that the breezy energy of the new secretary electrified the society. Unheard-of innovations were installed, unprecedented expenses undertaken, and a harvest of new members justified every reform. At the general election of 1906 he appeared as the Unionist candidate for Dundee and conducted a vivacious though unsuccessful campaign.

After this, secretarial duties proved too commonplace, and for a time Shackleton found a freer vent for his energies in business life, taking part in one of the great shipbuilding and engineering works on the Clyde. But all the time unseen lines of force were holding his ambition true to the south, and silently but solidly he laid his plans. He bought an old whaler, the *Nimrod*, raised a considerable sum of money under his personal guarantee of repayment if the expedition proved a success, and, profiting by the mistakes of the *Discovery* expedition, he had all his provisions prepared, packed, and stowed under his personal inspection. He had no committee and no orders, but held himself free to carry out his own plans in his own way at his own risk. He decided to base his transport on ponies and motor haulage, methods never used before in polar exploration, and although the motor broke down at an early stage, the ponies brought the expedition to a point on the barrier beyond that reached in the *Discovery* expedition, and but for the loss in a crevasse of the last pony, the South Pole would have been reached. An ascent to the plateau was found by the Beardmore Glacier, and when it was clear that the provisions could not carry the party all the way and back, Shackleton turned in lat. 88° 23′ S. Had he pushed on for another day before turning he would have met the fate which afterwards befell Scott, and, indeed, he very narrowly missed it. On this expedition there were many innovations in food, in lighting, and for the first time it carried a kinematograph into the polar regions.

On his return in 1909 the recognition of the epoch-making advances in methods and results was widespread, if not universal, and the splendid achievement of David and Mawson in reaching first the summit of Mount Erebus and then the Magnetic Pole, together with the biological, meteorological, and geological work of all the parties, gave the expedition, as a whole, high scientific value Shackleton received a shower of gold medals from the geographical societies of the world and the honour of knighthood. He passed a strenuous year or two lecturing in Europe and America to pay off the debts of the expedition and the expense of the scientific reports.

The attainment of the South Pole by Amundsen and Scott in 1912 turned Shackleton's attention to the project of crossing the Antarctic continent by landing on the shores of the Weddell Sea and marching *via* the Pole to his old quarters on the Ross Sea. Again his word was sufficient security for the advance of funds, and again the plan was his own. The war broke out after his start in the first week of August, 1914, and he at once placed ships, stores, and men at the disposal of the Government for military service. The offer was declined, and the expedition sailed. The Ross Sea party carried out its programme and laid a chain of *depôts* from Macmurdo Strait to the Beardmore Glacier, but the men were imprisoned at their winter quarters by the drifting away of their ship, the *Aurora*. Meanwhile, Shackleton, in the *Endurance*, had carried the exploration of Coats Land farther south than its discoverer, Bruce, or his German follower, Filchner; but just when a landing was almost in sight the ship was caught and drifted northward fast in the ice step by step with the *Aurora* on the other side of the world.

The *Endurance* was crushed and sank, but Shackleton and his party kept up their courage through a dreadful year of inaction. Where reckless daring was the only course everyone knew that he would dare all; but it was a revelation to most of us to find that when safety lay in caution he could command the eager spirits of his companions to patience. When a landing was made on Elephant Island he at once decided to make for South Georgia, 800 miles away, in a little open boat with a few volunteers, and seek help for the others, who remained under the charge of Frank Wild. He made the almost impossible voyage, well knowing that if he survived and the party on Elephant Island perished he would be charged with deserting them and seeking his own safety, and to face this possibility was a greater test of courage than the Southern Ocean itself. He succeeded after three failures in bringing every man who sailed in the *Endurance* back alive to South America in August, 1916.

Hurrying to New Zealand, he found that the authorities who had repaired and equipped the *Aurora* to rescue his Ross Island party refused to allow him to take charge of his own ship to look for his own men; but he felt his responsibility so keenly that with an almost unbelievable magnanimity he accepted the situation and shipped as a common sailor on the relief voyage. Never was a case where failure was so nobly retrieved, and the failure had occurred only because the forces of Nature are stronger than the resources of the most heroic man.

For two years Shackleton served in the army as officer in charge of the supplies for the British force operating in the White Sea and Northern Russia. Then for another feverish spell he threw all his energies into lecturing on his last expedition to enable

him to repay the advances which had been made to him. Once out of debt, he found the call of the ice irresistible. He meditated a dash to the unknown centre of the Beaufort Sea in the Arctic regions, and had gone far to mature his plans when circumstances barred the way, and he resolved on one more Antarctic voyage.

This time the munificence of friends secured him freedom from financial worries. His plan was sound; the Enderby Quadrant which he was to explore was practically unknown; his old comrades rallied to him from the ends of the earth; but the ship was small though stout, and he was forty-seven years old, though a boy at heart. He sailed in the *Quest* in September, 1921, had a grievous buffeting on the voyage to Madeira, a long and trying delay for refitting in the heat of Rio de Janeiro, again a stormy voyage to South Georgia, and then the sudden seizure in the midst of apparent health, and the career of the most Elizabethan of modern explorers had an end as abrupt as the clash of "the blind Fury with the abhorred shears."

Shackleton lived like a mighty rushing wind, and the very strength of his nature made him enemies as well as friends. He resented injustice and slights, but they only spurred him on to show by new achievements how baseless they were. He endeared himself to his friends, and was adored by his ship-mates, who saw in "the Boss" a kindly but unquestionable authority. He loved applause and gloried in the limelight; but he was applauded for feats that no one else was able to accomplish. The labourer is worthy of his hire, and no one has a right to quarrel with a good workman if he likes to take some of his pay in the form of praise and publicity.

Shackleton's most characteristic quality was neither courage nor resolution, both of which he shared with other heroes of exploration. It was his instinctive judgment. Whenever he had to make a decision between two courses of action, no matter how suddenly the necessity arose nor how quickly it had to be met, he invariably did the right thing. Again and again the wrong decision would have meant certain death or irremediable disaster. This power of decision was not an effort of reason, but an apparently instinctive impulse which can perhaps be accounted for by a peculiar balance of perception. Indeed, it is to the balancing of contradictory qualities that much of Shackleton's success was due. His mind was not essentially scientific, though he valued science and made most generous provision for it in his expeditions. He was both impulsive and cautious, yet he was never irresolute. He revelled in poetry and seemed to breathe the air of romance, but at the same time he was a methodical organiser and a keen business man. His imagination was amazingly fertile, and it seems as if in planning an expedition he imaged to himself everything that could possibly happen in any set of circumstances and then set himself to work to provide for each contingency. Whatever may have been its secret, his personality was his greatest power, and it marked him out as a commanding figure He might well have been a Drake or a Ralegh; in no time and in no conditions could he have been commonplace. The greatness of his loss may be judged by the things he did and the way he did them.

HUGH ROBERT MILL.

SIR WILLIAM CHRISTIE, K.C.B., F.R.S.

WILLIAM HENRY MAHONEY CHRISTIE was the youngest son of Samuel Hunter Christie, professor of mathematics in the Royal Military Academy at Woolwich and secretary of the Royal Society from 1837 to 1854. He was born in 1845, the same year as George Darwin and two years later than David Gill. Educated at King's College School and Trinity College, Cambridge, he was fourth wrangler in 1868, and in the following year was elected to a fellowship of his college. On the recommendation of Airy, Christie was, in the autumn of 1870, appointed chief assistant at the Royal Observatory, Greenwich. At that time the activity of the Observatory was largely concentrated on its traditional duty of the regular observation of sun, moon, planets, and fundamental stars, the stars being regarded as points of reference for the planets, and especially the moon, and serving also for the determination of time. The observations were made with the transit circle erected by Airy in 1850. Christie made a careful study of (1) the most suitable value of the refraction constant at Greenwich, (2) the corrections to be applied for a well-established and persistent difference between the zenith distances of stars when observed by reflection from mercury and when observed directly, and (3) the value of the latitude at Greenwich—data required to deduce the declinations of stars free from systematic errors. In this involved and somewhat indeterminate problem his judgment was correct, as is shown by the smallness of the systematic corrections applicable to the Greenwich catalogues of 1880, 1890, and 1900 to bring them into accord with the mean of other observatories.

The extension of the field of work of the Observatory was pressed on Airy by Warren de la Rue, who advocated continuous observations of sun spots, and by Huggins, who advocated spectroscopic observations of sun and stars. In a letter to Airy in May, 1872, Huggins writes: "I understand Mr. Christie, who is zealous in the matter, to say that you would be agreeable to this course." Government sanction was obtained, and Mr. E. W. Maunder was appointed assistant for photographic and spectroscopic observations. Christie was in sympathy with both these extensions of the activity of the Observatory. The photo-heliographic work was carried through very successfully, and arrangements made with the Solar Physics Committee, and later with the Cape and Kodaikanal Observatories, resulted in a uniform and continuous series of photographs of the sun being taken day by day, which were afterwards measured and discussed at Greenwich with reference to the positions and areas of sun spots.

The spectroscopic observations for velocity in the line of sight were not successful. It was not until the introduction of photography by Vogel that any reliance could be placed on line of sight determina-