The magnitude S represents the "maximum gradient of gravity in the horizontal surface," *i.e.*, the maximum amount by which the vertical force of gravity is increased as we proceed from the origin through unit distance in any direction in the horizontal surface, and is obviously the resultant of U_{13} and U_{23}, the gradients in the direction Ox, Oy respectively. Also the direction of this maximum gradient is given by μ, the angle which it makes with Ox.

The magnitude R is equal to the difference between the reciprocals of the principal radii of curvature of the level surface at O, and is always positive. Thus, if ρ_1 is the least radius of curvature at O, and ρ_2 the greatest,

$$R = \frac{1}{\rho_1} - \frac{1}{\rho_2},$$

while λ is the angle which the plane of greatest radius of curvature, or least curvature, makes with the plane Oxz.

The work of survey consists in finding these values S, R, λ, μ at as many stations as possible, correcting them for normal gravity effects and known irregularities, and plotting the final values, representing the maximum gradient S by an arrow drawn through the station in the direction μ, and proportional in length to the magnitude of S, and indicating R by another arrow in the direction λ. The positions, directions, and lengths of these arrows are then compared with the corresponding arrows given by certain simple mass distributions of which the effects can be calculated, and the probable distribution corresponding to the observed results is deduced.

To illustrate the gravitational effect of a subterranean mass and the variation of the magnitudes measured by the balance from point to point on the earth's surface above such a deposit, we may consider the simple case represented in Fig. 3. Here a horizontal layer of matter, having a density greater by unity than its surroundings, is bounded on the top and bottom by horizontal surfaces at depths 200 and 300 metres below the earth's surface. The layer extends to infinity in the north, east, and west directions, but terminates at the south end in a vertical plane through the east-west line. Let O be a point on the earth's surface on the line where this vertical boundary meets the latter, $x'Ox$ the meridian through O, and Oz the downwards vertical meeting the faces of the deposit in A and B. Consider the force of gravity due to the deposit alone—which is thus to be regarded as having a density unity—at any point X on $x'Ox$. The force at X will be wholly in the plane xOz, and the corresponding potential surface through X will be a cylinder having its axis perpendicular to this plane. In these circumstances the magnitudes U_{11}, U_{12}, etc., specifying

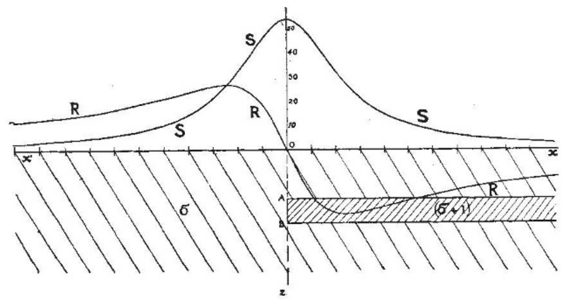

FIG. 3.—Results for a simple case.

the disturbing field due to the deposit, can easily be calculated. Moreover we have

$$U_{12} = U_{22} = U_{23} = O,$$

and therefore

$$\lambda = \mu = O \text{ or } \pi,$$
$$R = U_{11},$$
$$S = U_{13}.$$

In Fig. 3 the values of U_{11} are plotted as ordinates corresponding to the abscissæ OX in the curve RRR, and the values of U_{13} in the curve SSS. It will be noticed that the point O, vertically above the edge of the deposit, is strongly marked in each curve by a maximum on one and a zero value on the other. The maximum value of S has a magnitude 53×10^{-9} C.G.S. units, and the maximum of R is 26×10^{-9} units. Since values of R and S as low as 1×10^{-9} unit affect the balance, it is apparent that the instrument would readily show the effects due to such a subterranean deposit, and indicate its extremity.

Science and Industry in Sweden.

THE exhibition recently opened at Gothenburg to celebrate the tercentenary of the founding of that city by Gustavus Adolphus, with its display of Swedish manufactures, is an eloquent reminder of the part taken by Sweden in the development of certain industries and also of the debt of the world to Swedish men of science. Though she cannot lay claim to mathematicians of the rank of Leibnitz, Newton, or Euler, or to astronomers equal to Galileo or Herschel, in chemistry and mineralogy Sweden has often led the way, and few countries can boast of names more widely known than those of Bergmann, Scheele, Gadolin, Berzelius, Nilson, Cleve, and Arrhenius.

The rise of science in Sweden is generally traced to Linnæus, but it really had its foundation in the middle of the seventeenth century. Like all the western nations Sweden felt the influence of the discoveries of Copernicus, Kepler, and Galileo, and one of the objects the young and eccentric Queen Christina had in view when she invited Descartes to her capital, was to place him at the head of the academy she proposed to establish. The plans of Christina, however, came to nothing, for Descartes died in 1650 and four years later she herself abdicated.

Sweden has a comparatively large territory but a very limited population. Until recent times there were but two seats of learning, Uppsala and Lund. Both are still small cities, the former having about 20,000 inhabitants, the latter some 4000 less. Uppsala is about 40 miles north of Stockholm, while Lund is not far from Malmö in the extreme south. Lund University was founded in 1666, Uppsala in 1476. It was in Uppsala that Swedish science had its birth, and there it has found its principal home. Johann Gestrin and Magnus Celsius (1621–1679) were among the mathematicians of Uppsala during the seventeenth century, the former being the author of a commentary on Euclid and works on astronomy and mechanics. The grandson of the latter, Magnus Celsius, was Anders Celsius (1701–1744) who accompanied Clairaut and Maupertuis on their degree-measuring expedition to Lapland. To him we are indebted for the Centigrade thermometer. For some years he was professor of astronomy at Uppsala.

The great Swedenborg (1688–1772), the learned Klingenstierna (1698–1785), Martin Stroemer (1707–1770), Peter Elvius (1710–1749), and Peter Wargentin (1717–1783) were all either students or professors at Uppsala, as was Melanderhjelm (1726–1810), whom Brougham met when he attended a meeting of the Royal Academy of Sciences at Stockholm in 1799. Klingenstierna was the discoverer of the fact that refraction of light could be produced without colour; Stroemer made the first Swedish translation of Euclid, while Wargentin devoted much of his life to a study of Jupiter's satellites and was associated with Lacaille in his work on the parallax of the moon. He was also the first director of the observatory at Stockholm founded in 1759 largely through the instrumentality of the capable and public-spirited administrator, Claude Grill (1704–1767).

Of all the men of science connected with Uppsala the place of honour must be given to Linnæus, whose tomb is in the Cathedral there. Whether we think of him as a boy watching the bees and flowers in his father's beautiful garden at Rashult, as the budding botanist at the school at Wexio, or as the struggling student first at Lund and then at Uppsala, or again as the intrepid explorer in the wilds of Lapland, we are impressed with his untiring energy and his singleness of purpose. Born in 1707, at the age of twenty-three Linnæus became an assistant professor at Uppsala, but the years 1735 to 1738 he spent in travel. In Holland he became the friend of Boerhaave and worked in the garden of the wealthy Cliffort, near Haarlem. He also visited England, France, and Germany, and it was during this time he brought out the first edition of his "Systema Natura." Returning to Sweden he was made the president of the newly founded Academy of Sciences at Stockholm, and in 1741 became professor of anatomy at Uppsala, where he died on January 10, 1778. With his never-ceasing industry he combined a passionate love of order, and it has been said that thus "he was able to serve his own generation with great effect, to methodise the labour of naturalists, to devise useful expedients for lightening their toil, and to apply scientific knowledge to the practical purposes of life."

Contemporary with Linnæus, but occupied with a different branch of science, was Johann Wallerius (1709–1785), the writer of many scientific books and for a long time professor of chemistry, metallurgy, and pharmacy. It was to his chair that Bergmann succeeded in 1767. A native of West Gothland, where he was born in 1735, Bergmann as a student came under the influence of Linnæus and passed nearly the whole of his life at Uppsala. He was one of the earliest chemists to deal with chemical problems in a strictly scientific manner, and he was the pioneer of systematic chemical analysis. Holding his chair until his death in 1784, he counted among his pupils Johann Gahn (1745–1818), who added manganese to the list of elements and instructed Berzelius in the use of the blowpipe, and Johann Gadolin (1760–1852). Gadolin became a professor at the university of Abo, then belonging to Sweden, and to him Finland was indebted for the introduction of a knowledge of the discoveries of Lavoisier and the other French chemists. The town and university of Abo were destroyed by fire in 1827, but when visited by Bishop Heber, the writer of the hymn "From Greenland's icy mountains," in 1805, he described it as "a place possessing an archbishop, fifteen professors, three hundred students, a ruined castle, a whitewashed cathedral, and certainly the most northerly university in Europe."

Gadolin had been a candidate for the chair left vacant by the death of Bergmann, but this was given to Afzelius (1755–1837). Bergmann's greatest contemporary was undoubtedly Scheele. Seven years younger than Bergmann, Scheele began life as an apprentice in Gothenburg. From Gothenburg he removed to Malmö, then to Stockholm and to Uppsala, and finally settled at Koping where he purchased a business. It was here he made his great discovery of oxygen. Endowed with a genius for resolving the most obscure chemical reactions, Scheele stands almost unrivalled for the number and value of his discoveries. He died two years after Bergmann, and his statue now adorns the Swedish capital.

Though, with the death of Bergmann and of Scheele, the progress of chemical discovery slackened somewhat, the greatest of Swedish chemists had yet to appear. Berzelius, who stands beside Linnæus in the roll of Swedish science, was born in 1779, a year after Davy. In 1798—the year Davy went as assistant to Beddoes at Clifton—Berzelius became an assistant to the medical superintendent at Medvi. While Davy was establishing his reputation at the Royal Institution, Berzelius as a professor of medicine was gaining the admiration of Stockholm, and on Davy's death in 1829 he was recognised as the leading chemist in the world. Sir William Ramsay once remarked that he believed that since the time of Boyle none had done more for the advancement of chemistry than had Berzelius. His kitchen laboratory at Stockholm was as famous as that of Lord Kelvin in the cellar beneath the old College of Glasgow. Dulong, Mitscherlich, Gmelin, Gustav and Heinrich Rose were all taught there by the great master, and Wöhler has fortunately left a description of it. "The laboratory," he said, "consisted of two ordinary rooms furnished in the simplest possible manner; there were no furnaces or draught places, neither gas nor water supply. In one of these rooms were two common deal tables; at one of these Berzelius worked, the other was intended for me. On the walls were a few cupboards for reagents; in the middle was a mercury trough, while the glass blower's lamp stood on the hearth. In addition was a sink, where the despotic Anna, the cook, had daily to clean the apparatus." When in 1833 Berzelius married, the King of Sweden wrote of him, "Sweden and the whole world were debtors to the man whose entire life had been devoted to pursuits as useful to all as they were glorious to his native country."

Berzelius died in 1848, and the torch of chemistry has been handed on by worthy successors such as Lars Fredrik Nilson (1840–1899) and Per Theodor Cleve (1840–1905), while to-day science in Sweden has no more illustrious name than that of Svante Arrhenius, the originator of the theory of electrolytic dissociation and the director of the Nobel Institute of Physics, who began his career in the old university where Bergmann had taught.

While chemistry in particular has flourished in Sweden, other sciences have by no means been neglected. In all that appertains to the sea and fisheries, to agriculture and forestry, and to exploration, much valuable work has been done. One of the meetings to be held at Gothenburg this summer is the Congress of Scandinavian Naturalists. In astronomy, in physics, and in geology, Sweden has also played her part. Uppsala has possessed an observatory since about 1730, and during the nineteenth century this was directed by Gustav Svanberg (1801–1882), Herman Schultz (1823–1890), known for his micrometrical measurements of nebulæ, and by Nils Christophr Duner (1839–1914), who devoted himself to a study of stellar spectra and in 1892 received the Rumford Medal of the Royal Society. Another well-known astronomer was Hugo Gylden (1841–1896), for more than twenty years head of the Stockholm observatory, where Backlund was his pupil. Anders Jonas Ångström (1814–1874) began his career in the Swedish observatories, but his great work on the solar spectrum was done while he held the chair of physics at Uppsala to which he was appointed after the death of Adolph Svanberg (1806–1857). Ångström's successors, Tobias Thalen (1827–1905) and Knut Johan Ångström (1857–1910), were also distinguished workers in spectroscopy, while it was said that Thalen's magnetometer was in use in every iron mine of importance in Sweden.

Geological studies in Sweden may be said to have been begun with the writings of Urban Hiarne (1641–1724), physician to the king, who in 1694 published his views on the history of the earth. Some of the earliest geological maps of Sweden were prepared by Gustav Hermelin (1744–1820) a student of Uppsala and an officer in the Swedish mining service. Geological surveys of Norway and Sweden were inaugurated in 1858. Among the directors have been Otto Torell (1828–1900) and Alfred Törnebohm (1838–1911). In a country possessing rich mineral deposits, the work of these geologists has been of the greatest value.

Apart from agriculture, which still employs about half the population of 6,000,000, the main industries of Sweden depend on the iron mines, the magnificent forests, and the ample water power. The manufacture of wood pulp and the timber trade have grown enormously. At one time Sweden was the principal iron-producing country in the world. Though to-day her position in this respect is much more modest, the quality of her iron is still unrivalled. The steam engine was introduced into Sweden by the Swedish man of letters, Abraham Edelcrantz (1754–1821), while the first marine engine was made by Samuel Owen, whose bust has been placed in the Gothenburg Exhibition together with a model of the engine he built. In the field of shipbuilding Sweden has done much pioneering work, and at one time no writings on naval architecture were more highly esteemed in England than those of Chapman (1721–1808), who was a native of Gothenburg. The famous engineer and naval architect, John Ericsson, was a Swede, and began work on the Göta Canal, which had been first surveyed by Swedenborg, but was built to the plans of the British engineer Telford. Ericsson was in England from 1826 to 1839; he then emigrated to the United States and it was there that he produced the *Monitor* which during the civil war saved the North. After his death in 1889, Ericsson's body was sent to Sweden in an American warship, and it now lies at Filipstad in the beautiful Wermland district.

Many Swedish civil and mechanical engineers have gained a world wide-reputation. Nordenfelt, who died in 1920, was one of the pioneers of the submarine, Goransson, who died in 1900, assisted in perfecting Bessemer's great invention, while Fredrik Kjellin (1872–1910) was a pioneer of the electric steel industry. Of the three brothers Nobel, it was Alfred Bernhard Nobel (1833–1896) who first produced dynamite and afterwards left more than a million sterling to found the Nobel prizes. The list could be lengthened considerably, but few names have stood higher than that of Gustav de Laval (1845–1913), whose cream separators are to be found in use all over the world; he is also widely known as the inventor of the de Laval steam turbine, the first patent for which was taken out in 1884, the same year that the Parsons turbine was patented. De Laval, it may be added, was a student and graduate of Uppsala University, and was thus one of the makers of modern Sweden who laid the foundation of their knowledge in the ancient university where Swedish science had its birth.

Current Topics and Events.

AN important paper by Prof. Georges Dreyer, of Oxford, in the last number of the *British Journal of Experimental Pathology* has been the subject of widespread comment, as, apparently, it is likely to inaugurate a new era in the specific treatment of infective disease, and particularly of tuberculosis. It is a matter of common knowledge that the "tuberculins" hitherto employed have not been completely successful against the highly resistant bacillus of tuberculosis. Dreyer's main thesis—and it is supported by a mass of accurate experimental evidence—is that the relative failure of certain vaccine preparations is due to the presence in some bacteria of various lipoidal substances which, covering or incorporated with the protoplasm of the microbe, offer a considerable protection to the latter, so that it is able to escape the destructive bactericidal and other antibodies which are evoked by the host in response to the infection. By a process consisting essentially of the extraction of the lipoids, the "defatted" bacteria have been found not only to preserve their antigenic properties, but also the latter are actually enhanced when compared side by side with antigens which still preserve their