equipotential surface. Eventually we reach an equipotential which consists of two closed surfaces touching each other, one (the smaller one) enclosing the gravitating mass but not enclosing the charge, while the other (the larger one) encloses this smaller surface and also encloses the charge. Beyond this, again, we have a series of simple closed surfaces, each of which encloses all the earlier members of the family.³

The electric field is precisely the same as would be obtained, in the ordinary electrostatics, by supposing that the specific inductive capacity and magnetic permeability of the medium vary in a certain way with the distance from the gravitating mass.

Solutions of the fundamental equations have been found which represent more complex fields

³ A figure is given in Mr. Copson's paper, loc. cit.

than those I have described : but they are perhaps not well suited for description in a lecture,⁴ and I will therefore conclude with a remark about energy. In a *statical* gravitational field, electromagnetic energy is a scalar quantity, so we can calculate the 'total electromagnetic energy' contained in a specified region of three-dimensional space by integrating the amounts of energy contained in the sub-regions into which the region may be divided ; and the conservation of electromagnetic energy holds. In *non-statical* gravitational fields these theorems are no longer true, since energy is not then a scalar quantity ; the energy in one region is different in kind from the energy in another region, just as momenta in different directions are different in kind from each other.

⁴ Reference may be made to *Proc. Roy. Soc., A*, 116, 720 ; 1927.

Heirlooms of Industry in the Science Museum.¹

By Col. Sir HENRY G. LYONS, F.R.S.

THE idea of a general museum of science is only seventy-five years old, and was due to the Prince Consort, who, after the Great Exhibition of 1851, urged the formation of an institution which would extend the influence of science and art on productive industry. From this proposal arose the Science and Art Department with, as an essential part of it, the South Kensington Museum, the dual activities of which are now represented by the Science Museum and by the Victoria and Albert Museum respectively.

For a long time previous to this, scientific instruments, pieces of apparatus, mechanical devices, and such like had been preserved in many places, but a museum designed to illustrate the influence of science on technical development did not exist ; even the Museum of the Conservatoire national des Arts et Métiers in Paris, which dates from the end of the eighteenth century, was, and still is, primarily the teaching collection of the Conservatoire. Recently technical museums having similar aims have been established at Munich in 1903, and at Vienna in 1919 ; others illustrating special industries are to be found in many cities.

While no one will dispute the utility of technical museums, it must be admitted that they fall far short of art museums in the attractiveness of the objects which they contain, and this fundamental difference affects every stage of museum arrangement. For the objects in a technical museum to be interesting, something of their history and their purpose, the part which they have played in the age-long development of the branch of industry to which they belong, must be known to the visitor, and to this end carefully edited labels are essential ; important objects may be so displayed that the internal working parts can be seen, and their purpose understood ; coloured diagrams and specially arranged illumination may be employed ; models, etc., may be shown in motion ; others may be so arranged that they can be set in motion by the

visitor ; all this being done with the object of supplying essential information in a form intelligible to the general visitor, with additional technical description for the specialist.

The dominating principle in such a museum must be to illustrate development. Everything, whether it be an industry, or a group of related objects, or a type of tool, is shown so as to emphasise the successive stages of development which have been traversed from early crude forms which sufficed in the days of hand labour through various grades of slow improvement to the rapid advances of modern times so effectively aided by steam and electricity. In some branches of human activity it is instructive to show a few examples from the times of the earliest civilisation, and from the handiwork of primitive races who exist to-day. In this way the story of time measurement, of various hand tools, and of land and water transport for example, can be illustrated far more effectively and attractively than if the exhibits were restricted to those dating from the last few centuries.

To take the case of an industry, aeronautics furnishes a convenient example of rapid development, for air transport has grown from its first experimental stages to an important branch of world communication within the lifetime of many of us. The series exhibited in the Science Museum begins with the first power-driven model aeroplane which John Stringfellow constructed in 1848, and which achieved a free flight of forty yards. Later on experiments in 'gliding flight' were of great importance in providing information on many points in aerodynamics, and Otto Lilienthal was its greatest exponent. One of his gliding machines of 1896 is exhibited. During the next seven years Prof. Samuel P. Langley, of the Smithsonian Institution at Washington, designed and constructed a man-carrying tandem monoplane, of which a model is on exhibition, but it failed to make a successful flight when tried in 1903.

Inspired by the experiments of Lilienthal in

¹ Synopsis of a discourse delivered at the Royal Institution on Friday, April 20.

gliding flight, the brothers Wilbur and Orville Wright, of Dayton, Ohio, carried out a large number of gliding flights during several years after Lilienthal's death, and the success which they achieved encouraged them to construct their first power-driven aeroplane, with which they made their first successful flights on Dec. 17, 1903, the longest being one of fifty-nine seconds, when the distance covered was 852 feet. The aeroplane with which they made their flight is now on exhibition in the Museum, having been lent by Mr. Orville Wright. Another important example is Mr. A. V. Roe's light tractor triplane, which was built and flown by him in 1909, and is remarkable for low power of the engine, a 9 h.p. twin-cylinder J.A.P. engine. Another interesting type is the Antoinette model, of French design, which was flown across the English Channel by H. Latham in July 1909. Mr. S. Cody's machine, which he used in the military manoeuvres of 1912, is also preserved in the Museum as an instructive type of pre-War aeroplane. This series is fittingly concluded by the Vickers-Vimy Rolls-Royce aeroplane on which Sir John Alcock and Sir Arthur Whitten Brown made the first direct trans-Atlantic flight in June 1919. The extraordinarily rapid development of this form of transport is strikingly demonstrated by the fortunate juxtaposition in the gallery of the Museum of the Wright Brothers' aeroplane, which flew 284 yards in 59 seconds in December 1903, and the Vickers-Vimy aeroplane, which covered 1890 miles in 15 hours 57 minutes in June 1919, only 15½ years later.

Road transport also provides a series in which the transition from early types to modern practice is strikingly shown—that of the bicycle. Starting from the hobby-horse of 1818, the first practical form of two-wheeled machine was the early bicycle invented by Kirkpatrick MacMillan, a blacksmith, of Dumfriesshire, in which he anticipated the rear-driving safety bicycle of forty years later. Michaux's bicycle of 1865, one of the so-called 'boneshakers,' the Starley Spiderwheel Bicycle, and Lawson's bicyclette of 1879, bring us to the safety bicycles of to-day.

Just as in an industry, so with each tool or machine, the successive stages by which the early form has advanced through others of increased efficiency, or of greater convenience, bear witness to the inventiveness of successive generations, and, wherever possible, this is illustrated. Miners' lamps are represented by a long series, including every type of importance from Sir Humphry Davy's to the latest pattern of the modern lamp. In the same way a most instructive series of radio-valves, beginning with original valves of Prof. Fleming, and continuing through many modern types, illustrates the rapid advances made in a modern instrument of great economic importance.

In machine tools, the primitive form of lathe, in which the work is rotated by means of the forward and backward movement of a bow held in the right hand, was long in use and still exists in some countries, but it was replaced later by the spring beam, or pole drive, and this type is still

used by the chair-makers of High Wycombe. About 1800, Henry Maudslay combined the slide rest and the use of a lead screw with change wheels for the production of screw threads, and the first workshop tool in which Maudslay embodied his invention is preserved in the Museum. A further advance is shown by Roberts's back-gear slide lathe of 1817, after which examples of the most modern types of workshop lathe complete the story.

The early history of the hammer is illustrated among the hand tools, where there is one of the diorite hammer stones which were used to hammer out the shafts of granite for the obelisks of ancient Egypt; but when greater power was needed mechanical devices were adopted. A lift hammer of 1556 is shown by a model, and lift and tilt hammers were still in use at the beginning of the nineteenth century; two hammers which were erected in Portsmouth Dockyard in 1804 by Simon Goodrich are shown by a model. In 1839, James Nasmyth invented his steam hammer, which is represented by a working model; and other models show the various improvements which were introduced at later dates. The great power presses of to-day are too large and heavy to be shown, but illuminated photographic transparencies are utilised to show the form and character of those used in modern practice.

The early forms of any machine or tool are now of the greatest interest to us as we compare them with later developments, but only in few cases have they been preserved. The first design is modified and improved; its importance is thereby diminished; and it is not until much later that its historical value is realised. By that time it has usually disappeared. Fortunately, a considerable number of such early types have been acquired from time to time for the nation, among which are:

Arkwright's original 'drawing frame' of 1780, in which the drawing of cotton is effected by successive pairs of rollers revolving at increased rates of speed.

Two of James Watt's double acting rotative beam engines of 1788 and 1797, of which the latter is shown in motion. Among locomotives, the original *Puffing Billy* of 1813 and the *Rocket* of 1829 are the most important of four which are shown.

In marine engineering, among many notable landmarks, are the engine of Bell's *Comet*; also the T.S. *Turbinia*, and the turbine engines with which she steamed thirty-five knots at Spithead in 1897.

The collection of ship models contains a number of early and important contemporary models which furnish details of hull construction and of rigging which are not otherwise obtainable; they include a model of Christopher Columbus's ship, the *Santa Maria*, which was presented by the Spanish Government; the *Prince*, which was built at Chatham by W. Pett in 1669; also a contemporary model of a 64-gun man-o'-war of 1805, which has supplied much information for the recent re-rigging of the *Victory* at Portsmouth. Another very instructive model is that of a yacht

of 1660, built in the style of the Dutch vessels of that period.

The wholesale disappearance of the earliest forms of technical instruments, to which reference has already been made, has often deprived us of all but a single specimen of its type. An accurate copy is then the only way of representing it in a collection, and in recent years a number of reproductions of this kind have been acquired by the Museum. They include an astronomical instrument of Egypt (the 'merkhet') which was used for setting out lines, and for determining the time by observing the passage of selected stars over the meridian, and a shadow clock of the same country, both dating from about the eighth or tenth century

B.C.; the 'groma,' as used by the Roman land surveyors, and also one of their 10-foot rods; two telescopes made by Galileo, which are now preserved at Florence; Newton's reflecting telescope, made by himself, and now in the possession of the Royal Society; and a copy of a fourteenth century rain-gauge from Korea.

It only occasionally happens that the life-work of one of the great inventors of the past can be suitably shown in a museum, but in the case of James Watt, the attic workshop in which he worked during the last twenty years of his life has been reproduced, and in it are placed all the machines, tools, and other contents of the original room at Heathfield, near Birmingham.

Obituary.

PROF. OTTO NORDENSKJÖLD.

DR. OTTO NORDENSKJÖLD, professor of geography in the University of Göteborg, died on June 2, at the age of fifty-eight, as the result of a street accident sustained two days before. A nephew of the great Swedish explorer and scholar, Baron A. E. Nordenskiöld, his attention was turned to natural science at an early age, and as a student at the University of Upsala he specialised in geology. He was appointed lecturer on mineralogy at Upsala after taking his degree in 1894.

The spirit of Linnæus broods over his old university, and the young Otto Nordenskiöld felt the old urge which for nearly two hundred years has sent out Swedish naturalists as pioneer-explorers to all parts of the earth. In 1895 he organised his first expedition, when he led a party of Swedish men of science for a summer's work in Tierra del Fuego in order to compare the geological formations, the fauna and flora of that southern archipelago, with those of north-western Europe. The glacial deposits attracted his attention in particular, and after the return of his companions he proceeded to the little-known lake-district of southern Patagonia, where the Cordillera of the Andes is interpenetrated by the fjords of the Pacific and where a narrow zone of sharp transition separates the wooded slopes exposed to the wet west winds from the dry gravel plateaux of the pampas. The region, then unexplored and uninhabited, was of special interest at the time, because of the dispute between Chile and the Argentine Republic as to the delimitation of the boundary set out in the treaty as "the highest summits of the Cordillera forming the watershed," and Nordenskiöld's demonstration that the watershed showed no relation to the Cordillera foreshadowed the compromise which Sir Thomas Holdich's subsequent arbitration commission happily settled. In the summer of 1898, Nordenskiöld conducted a small scientific expedition to the Klondyke region of Canada, then at the height of the gold rush.

On returning from this expedition Nordenskiöld found the interest of European geographers concentrated on Antarctic research, to which his own attention had first been directed at the Sixth

International Geographical Congress in 1895. The *Belgica* expedition had just returned from its experience of the first Antarctic night, the *Southern Cross* expedition under Borchgrevink was wintering for the first time on the Antarctic continent, and preparations for two great national expeditions, working on a common plan in different regions, were going forward rapidly in Great Britain and Germany. Nordenskiöld determined that Sweden should take its part in Antarctic research; he set himself to the tremendous task of raising funds by private and public appeals to the small circle of scientifically minded Swedes. In order to gain personal experience of polar conditions he went to East Greenland as a member of Amdrup's expedition of 1900. He succeeded in fitting out an expedition in time to take part in the simultaneous series of observations. He was fortunate in securing Capt. C. A. Larsen, a Norwegian who had already had experience in the Weddell Sea, to command his ship the *Antarctic*, and in enlisting a very able body of scientific assistants. Early in the Antarctic summer of 1901-2 he reached his base at the farthest accessible point in the Weddell Sea on the east coast of Graham Land, while the *Gauss* under Prof. E. von Drygalski (now the sole survivor of the Antarctic leaders who started their work with the present century) and the *Discovery* under Capt. Scott took up their stations at two far-distant points on the circumference of the continent. A year later the *Scotia* under Dr. W. S. Bruce completed the first of the great combined international efforts to study the physical conditions of Antarctica.

Nordenskiöld alone of the four decided to send his ship back after landing, in the expectation that she should return the following year to take him off. He passed the winter of 1902 at Snow Hill in 64° 27' S., carrying on meteorological and magnetic observations, and on the approach of summer making large geological and zoological collections. He found the conditions adverse to any extended sledge journeys from his base, though he discovered King Oscar Land, and followed its coast to 66° S. On returning he eagerly awaited the return of the ship which never came. A second winter had to be spent in the hut, but the observations were