been perturbed because their mathematical colleagues regard a level surface as necessarily being a plane. Authorities, such as Routh in his "Analytical Statics" (Vol. II, page 23, 2nd Edition), specifically give a definition of the form:

"*Level Surfaces.* The locus of points at which the potential has any one given value is called a level surface. It is also called *an equipotential surface.*

"*At any point of a level surface the resultant acts along the normal to the surface.*"

". . . Level surfaces are therefore also called surfaces of equilibrium."

With reference to the gravitational field of the Earth, distinction must be made between a plane surface, a horizontal plane surface, and a level surface. Over a *sufficiently small area,* a level surface *approximates* to a horizontal plane, because the verticals from all points in it are approximately parallel. Loney, in his "Statics" (1912), page 355, says: "The Equipotential Surfaces are often called level surfaces, or *surfaces de niveau,* from an analogy with the Earth. If we consider gravity constant, the equipotential surface at any *point* of the Earth's surface is a horizontal plane, or rather a portion of a very large sphere concentric with the Earth."

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# MAGNETS AND MAGNETISM.

By Edgar Booth.

Most people think of magnets as toys with which children play for a few hours before discarding them for some other novelty, and magnetism as a subject of mathematical interest to scholars, but of no importance in everyday affairs; but all the electrical energy which is used commercially and in the household depends upon the existence of magnets, and its safe and continuous supply depends upon the proper operation of powerful electromagnets; the design of the elaborate and expensive equipment for the production of electricity necessitates, therefore, a sound knowledge of the subject of magnetism. Until the underlying relationships between magnetism and electricity were first shown by such physicists as Oersted, Ampère and Faraday, electricity was only of scientific interest, and its utilization was not commercially practicable.

Electricity is generated for commercial use by machines called dynamos; essentially, they are instruments in which wires are moved rapidly between the poles of powerful magnets; in the earliest types the magnets were permanent "horseshoe" magnets similar to those sold in toy shops—now very strong electro-magnets are used, the electricity generated being passed through coils wound on, but insulated from, soft iron, so as to produce magnets of much greater strength than would otherwise exist.

Apart from their utilization for the generation of electricity in dynamos, magnets are also used purely on account of the force of attraction exerted between them and pieces of iron: electro-magnets are employed to raise large weights, and sunken ships have been lifted by means of electro-magnets lowered on to their decks. They are also used commercially in separating magnetic from non-magnetic materials. The subject of terrestrial magnetism is of great importance to navigators, and to geophysicists investigating the earth's structure for the purpose of locating "oil domes" or other structures of scientific interest.

Magnets are divided into natural and artificial types—but the same technical discussion applies to both. Naturally existing magnets, in the form of "lodestone", a naturally occurring iron oxide, have been known since early Grecian days, some 500 years B.C. Artificial magnets are first referred to at the beginning of the 11th Century A.D., when Chinese soothsayers are reported as "rubbing a needle with a magnetic stone, so that it may mark the south". Naturally enough, the electro-magnet was not invented until after the electric currents were artificially generated, and after the fact that there was a magnetic field in the circuit of a current was later appreciated; this was not until the 19th Century was well advanced.

Every magnet has *at least* two poles—though, contrary to popular belief, a bar of iron or lump of magnetite may have many North and South poles. These poles are places where the attractive force of the magnet for other pieces of iron material are most pronounced. The simplest magnets have two poles only—one a "North seeking" and the other a "South seeking" pole, called North and South poles for short.

When a closed conducting circuit—such as a loop of wire—is moved in the vicinity of a pole, an electric current will flow in the wire; and when a piece of iron is brought near a pole, there is an attraction between pole and iron. To express this strange condition in the neighbourhood of a magnet pole, we say that there is a "magnetic field" there. All our studies of magnetism, and all our applications of magnetism for economic and commercial purposes, may well be based on the investigation of the nature of "magnetic fields".

It is necessary for us, when discussing the peculiar condition in the vicinity of magnetised matter, to be able to compare the strengths of the "magnetic fields" and to determine the direction of the fields. The direction of the field at any place is the direction in which a freely-suspended bar magnet, or compass needle, would point at that place; so that if we walked round with a little compass needle hanging from a fine thread tied to it at its centre of gravity, so that the needle could take up any position, we would note the direction of the field from place to place. That is one of the important occupations of the Carnegie Institute—in addition to maintaining fixed land stations, they are continually engaged in sailing round in non-magnetic wooden ships, mapping the earth's magnetic field.

The earth has a magnetic field; it is somewhat as though the earth had a short bar magnet buried at its centre pointing out towards spots on the surface termed the North and South magnetic poles, which are about 1,000 miles from the South and North geographic poles.

Navigation by compass depends on a knowledge of the direction of the earth's magnetic field at place to place; a compass does *not* point towards the North and South poles, either geographic or magnetic; it merely points in the direction of the earth's field at the spot where it is placed. For instance, at Sydney it points $9\frac{1}{2}^\circ$ east of true North; at Cape Town it points 25° west of North; if we sailed down the 90° Meridian, from the Bay of Bengal through the Indian Ocean, and south past the West Coast of Australia, the swing of the needle from true North would increase fairly steadily from zero to 50° West—or more, if we cared to penetrate into

Antarctic regions. You can see what a nice curved path we would take if we thought that our needle pointed North—and you can perhaps plot for yourself where we would land. This departure from true North is called the magnetic declination—we say that the declination in Sydney is $9\frac{1}{2}°$ East. Moreover, the declination at any place is continually changing; the North magnetic pole seems to swing in a circle round the North geographic pole, taking about 960 years to do it.

In addition to the more or less regular change in declination as we move from place to place, there are abnormal changes in the earth's field over small areas; these are called "local anomalies". When the local anomalies are big, a knowledge of them is important to navigators, who might otherwise, when sailing on compass, proceed off their course with possibly disastrous results.

Small local anomalies are of importance in mapping out underground rock structure, because they represent effects due to slight differences in the magnetic properties of the local rocks. In such cases the actual strength of the magnetic field is usually compared from point to point over the area to be examined—extremely sensitive magnetic balances, called "magnetic variometers", are employed. Changes in the magnetic field of only one part in fifty thousand are readily measured, so that we can tell when we pass from one concealed rock structure to another, or when a structure approaches the surface or dips from it.

This is not an article on magnetism; it is too general and brief to be of greater service than to indicate to you a few of the very important applications of a section of study which you may have thought not worthy of notice.