accord with an earlier determination of W. Herschel's (10h. 16m. 7s.), but involves a serious correction of the value 10h. 29m. 17s. given in most of the text-books. The error probably came from a servile copying of a slip of the pen made by some book-compiler, fifty years ago or more, in accidentally writing Herschel's value of the rotation of the inner ring, instead of that of the planet.

Much time has been spent in observations of the rings, and Trouvelot has reported a number of remarkable phenomena, most of which, however, he alone has seen as yet. The most recent micrometric measures have failed to confirm Struve's suspicion that the rings are contracting on the planet. Extensive series of observations have been made upon the satellites by H. Struve, Meyer, and others in Europe, and by Hall in this country. Hall's observations are especially valuable, and the series is now so nearly completed that we may soon hope to have most accurate tables. In the case of Hyperion, there is found a singular instance of a *retrograde* motion of the line of apsides of the orbit, produced by the action of an *outside* body, the effect being due to the near commensurability of the periods of Hyperion and Titan. This most peculiar and paradoxical disturbance first showed itself as an observed fact in Hall's observations; and, soon after, Newcomb gave the mathematical explanation and development. He finds the mass of Titan to be about 1/12,500 that of Saturn. It may be noted, too, that Hall's observations of the motions of Mimas and Enceladus indicate for the rings a mass less than 1/10 that deduced by Bessel: instead of being 1/100 as large as the planet, they cannot be more than 1/1000, and are probably less than 1/10,000.

The satellites of Uranus have also been assiduously observed at Washington, so that at present the Uranian system is probably as accurately determined as the Jovian, perhaps more so. The form of the planet has been shown to be decidedly elliptical (about 1/14) by observations of Schiaparelli and at Princeton; and the same observers have detected faint belts upon the disk, which have also been seen at Nice, and by the Henrys in Paris. Many of the observations appear to indicate a very paradoxical fact—that the belts, and consequently the planet's equator, are inclined to the orbits of the satellites at a considerable angle. The mathematical investigations of Tisserand appear to demonstrate that, in the case of a planet perceptibly flattened at the poles, satellites near enough to be free from much solar disturbance must revolve nearly in the plane of the equator; while those more remote, and disturbed more by the sun than by the protuberant equator of the planet, must revolve nearly in the plane of the planet's orbit. Thus the two satellites of Mars, the four satellites of Jupiter, and the seven inner satellites of Saturn, all move nearly in the equatorial plane, while our moon and Japetus move in ecliptical orbits. It is very difficult to believe that the satellites of Uranus, which are certainly not ecliptical and are very near the planet, do not move equatorially. And yet it is unquestionable that most of the observations with sufficiently powerful telescopes (my own among them) do seem to indicate pretty decidedly that the planet's equator is inclined as much as 15° or 20° to the orbit plane of the satellites.

As to Neptune, there is nothing new. One or two old observations of the planet have turned up in the revision of old star catalogues, and Hall, of Washington, has made a careful and accurate determination of the orbit of its one satellite, and of the planet's mass; while Maxwell Hall, of Jamaica, has deduced a very doubtful value of the planet's rotation from certain photometric observations of its brightness.

There has been some hope that a planet beyond Neptune might be found. Guided by certain slight indications of systematic disturbances in the motion of Neptune, Todd made an extended search for it in 1877-78, using the Washington telescope, and hoping to detect it by its disk, but without results. If such a planet exists, it is likely to appear as a star between the 11th and 13th magnitude, and may be picked up any time by the asteroid-hunters. But its slow motion, and the fact that our present charts give but few stars below the $11\frac{1}{2}$ magnitude, will render the recognition difficult.

The indications I have spoken of, and certain others first noted in 1880 by Prof. G. Forbes, and depending upon the behaviour of certain periodic comets, furnish pretty strong reasons for believing in its existence, though as yet they fall far short of making it certain.

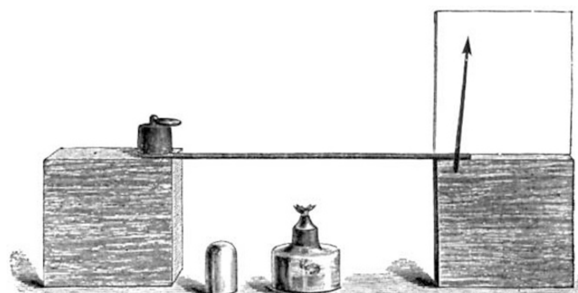
(*To be continued.*)

A LECTURE EXPERIMENT ON THE EXPANSION OF SOLIDS BY HEAT

I VENTURE to call attention to a simple and effective way of demonstrating the linear expansion of solids when heated, first suggested, I believe, by M. Kapoustine (*Journal de Physique*, December 1883, p. 576). It answers at least as well as the system of levers known as "Ferguson's pyrometer," which is usually employed for the purpose, while the cost of the apparatus is almost nothing, and any one can make it in ten minutes.

The principle is, to magnify the slight extension of a bar by causing the end of it to roll upon a needle, and thus turn the latter round and move a pointer attached to it through a sensible arc.

The figure given below will show the nature of the apparatus.



A small flat rod of the material to be examined, such as brass, iron, or glass, about 30 cm. long, 1 cm. broad, and 2 or 3 mm. thick, is laid upon two wooden blocks, placed about 25 cm. apart. A weight is put upon one end of the rod to keep it from moving; under the other end, at right angles to the length of the rod, is laid a fine sewing-needle, to the eye-end of which a light pointer of straw, about 16 or 20 cm. long, is attached by sealing-wax. Behind the pointer (which is painted black) a screen of white cardboard is fixed on the wooden block by drawing-pins.

When the rod is heated by a lamp-flame, the free end of it, as it expands, moves forward upon the needle and rolls it round, its movement being shown by the motion of the pointer. Even the slight expansion of a slip of glass is thus easily rendered evident to a class.

I have constructed for my own use a double apparatus on the same principle, in which the surfaces between which the needle rolls are of brass, ground true and flat. Two bars of different materials lie side by side, each having its own bit of needle and aluminium pointer, ranging over the same scale. They are heated equally by a broad flame (spirits of wine in a wide trough) and the difference of expansibility as well as the fact of expansion by heat is thus shown.

It is advisable to counterpoise the pointer by putting a shot or two into the lower end of the straw which projects below the needle, and cementing them in by sealing-wax. Also, before the experiment is shown to an audience, it is well to make sure that the needle rolls fairly and freely between the bar and the block. Such precautions, however, are not in the slightest degree necessary for school-work; for there is always one thing which gives the typical boy greater pleasure than to see an experiment succeed, and that is—to see it fail.

Eton College H. G. MADAN

COMPARATIVE STUDIES UPON THE GLACIATION OF NORTH AMERICA, GREAT BRITAIN, AND IRELAND[1]

OBSERVATIONS extending over several years upon glacial phenomena on both sides of the Atlantic had convinced the author of the essential identity of these phenomena; and the object of this paper was to show that the glacial deposits of Great Britain and Ireland, like those of America, may be interpreted most satisfactorily by considering them with reference to a series of great *terminal moraines*, which both define confluent

[1] Abstract of a Paper read at the Birmingham meeting of the British Association, September 1886, by Prof. H. Carvill Lewis, M.A., F.G.S.