so more than a thousand years or so; for, cosmically, the variability of a star is a mere transitory state, as it appears certain that irregularities of surface temperature must ultimately right themselves, although it is singular what a number of phenomena seem to tend in the direction of keeping a star that has been unequally heated by partial impact from having its uniform temperature restored. This matter is fully discussed in a paper in preparation on variable stars. Many doubles are coloured. I shall show in the same paper that in all probability the final state of variability in a star is a metallic absorbing atmosphere producing a coloured star; so that coloured doubles are probably the next youngest pair to the variable binaries. But although the variability of a star is a temporary state, their association with each other is not so. After having once absorbed the nebula their orbit is fixed, nothing but another impact can separate them and that is more likely to make a multiple star of them.

The final coalescence of the visible Universe will only weld them into the general mass. It is not wonderful therefore that some 10,000 such pairs exist in the Universe. The fact that there are so few speaks to us in powerful language, telling us that the Universe is not so old as we have pictured it to be—that the first day is scarcely over in proportion to the time before its final coalescence. Without doubt this Universe is quite a new member of the Cosmos, of which it is not improbably as a mere drop in an ocean.

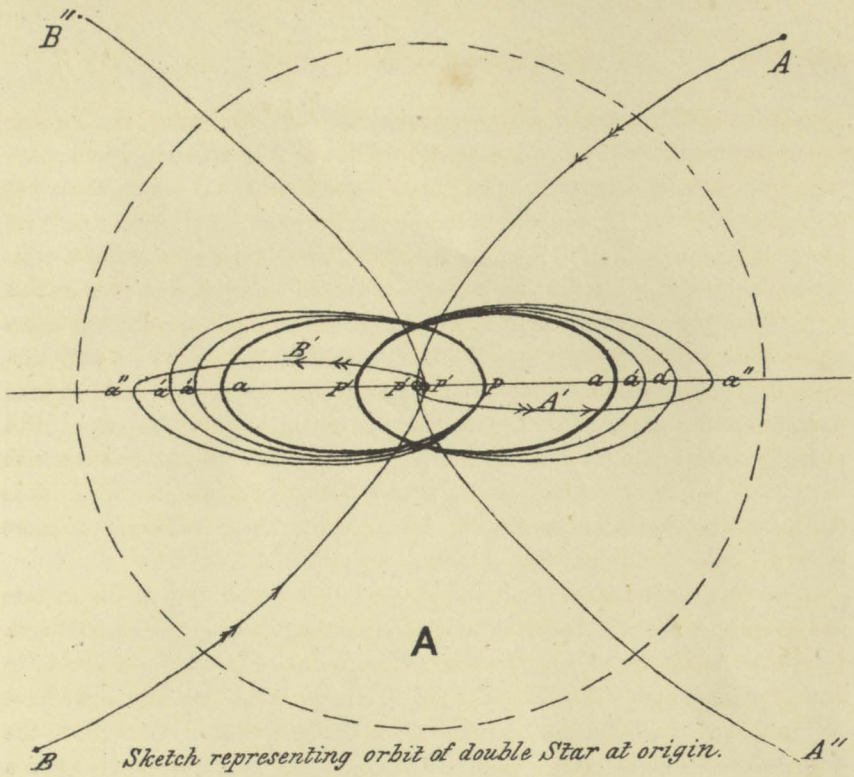
Art. XVI.—*On a simple Method of illustrating the Motions of the Earth.*

By Professor A. W. Bickerton.

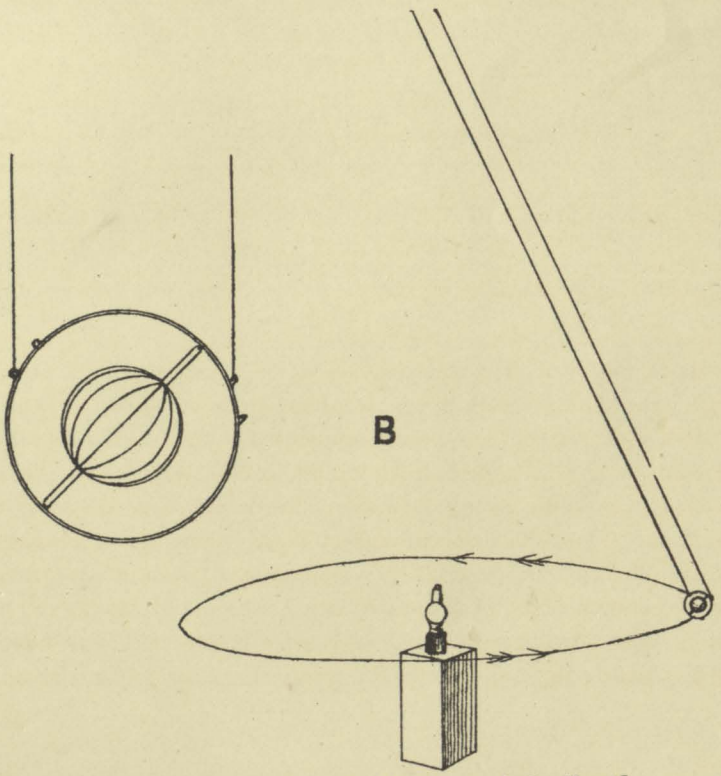
[*Read before the Philosophical Institute of Canterbury, 2nd September*, 1880.]

Plate IIb.

This model is one of the extempore pieces of apparatus that I designed for the purpose of illustrating a course of experimental lectures, which were delivered with the special object of showing that many of the most important of physical phenomena might be illustrated by apparatus at a cost not exceeding a few pounds. The model itself cost less than a shilling, and I made it in about half-an-hour. Since it was made I have found it useful to illustrate so large a number of cosmical phenomena that I thought it of sufficient importance to bring before the Institute. A much larger number of phenomena may be illustrated by its means than by the expensive models usually sold for the purpose. Among these are day and



Sketch representing orbit of double Star at origin.



Model to illustrate the Motions of the Earth.

night, seasons, the solstices, and equinoxes and the precession of equinoxes, eccentricity of orbits, the lines of the globe, etc. It has also the advantage over the ordinary model of possessing nearly all the dynamical peculiarities of the heavenly bodies themselves. It is, as it were, a double pendulum, and so it may easily be made to illustrate the laws of motion, resultant motion, the properties of the pendulum, Foucault's pendulum, and a large number of facts of both the kinetics and kinematics of dynamics. The accompanying diagram (Plate IIB.) represents it on a large scale, and shows it in use. The angle is shown exaggerated.

The model consists of a ball of wood or other material with a thick knitting-needle through it: this represents the earth and its polar axis; the ends of the needle are sprung into two centre punch dents in a light brass ring, the ball thus rotates on the needle as on an axis. This brass ring is hung in a vertical plane in such a manner that the needle makes an angle of 23° to the vertical. There are also other points of suspension for exaggerating the inclination, to render the phenomena more evident. The two cords are attached to the ceiling so as to hang parallel.

On swinging the apparatus as a conical pendulum, the direction of the axis remains all the time parallel to itself. If a lamp be placed in the centre of this cone, and the ball be made to spin, the phenomena of day and night and summer and winter are at once illustrated. The solstices and equinoxes are of course shown with the greatest readiness; the equator, tropics, and polar circle also show themselves, and the peculiarities of polar seasons can, of course, readily be shown. By making the swing of the pendulum an ellipse instead of a circle, and placing the lamp at a focus, the long winter and short summer of great eccentricity are explained. This illustration of the rate of motion during eccentric orbits is, of course, not mathematically accurate. With the apparatus moving in an ellipse it becomes easy to explain the reason why, in the northern hemisphere, the sun is nearer in winter than in summer. By merely spinning the whole model on its two cords, and so twisting them up, the precession of the equinoxes is readily understood.

By these two experiments it is easy to render Croll's theory of glaciation intelligible, by taking a card to represent the moon's orbit to the plane of the ecliptic the causes of the lunar and solar eclipses and their cycles are rendered intelligible. The whole of the motions being due to inertia, and the centrifugal point being the centre of the circle, we have a true central force acting on the body. Thus planetary dynamics is almost exactly represented.

By taking off the ring and hanging two similar balls the exact isocranism of equal length pendulums may be shown, and this may be amplified

by having the oscillations of one small and the other large. By hanging two balls of equal volume and different mass, the oscillations of the lighter will be destroyed much quicker than those of the heavier one; thus illustrating the greater power to do work possessed by the heavy body, as the resistance of the air is the same in both cases.

A large number of experiments of resultant motion may be proved by first showing the isocranism of all lengths of vibrations, and then striking the moving pendulum when at its several points of motion. These form a most instructive series of experiments. The conversion of circular into straight, and straight into circular, elliptical, and diagonal motion, is of course very easily illustrated.

As is well known, the peculiarities of kinetic and potential energy are better shown to a class by a pendulum, than probably by any other method.

ART. XVII.—*Probability of Impact.* By Professor A. W. BICKERTON.

[*Read before the Philosophical Institute of Canterbury, 4th November*, 1880.]

THE remarks made by several members show that the general statement as to the improbability of stellar impact which Proctor made in his lecture, but which was specially directed against Croll's theory of the origin of the sun's heat, are taken also to include tangential impacts. I entirely agree with Proctor in his opinion of Croll's hypothesis, and in 1878 I wrote a letter to "Nature," showing it to be in the highest degree improbable. It requires the stupendously unlikely event that two equal bodies, when at the limits of effective attraction, are directly approaching each other with a velocity of 250 miles a second. Those who have followed the reasoning in connection with "Partial Impact," must see how amazing is the gulf that separates the two suggestions.

Even if such an impact as Croll suggests were probable, such an event would not assist in removing the difficulty of the age of the sun's heat, for in my paper on "The Origin of Nebulæ," I have shown that a nebula must be dissipated into space if it possesses more energy than that possessed by infinitely diffused gaseous matter. Therefore, if at impact the sun received so much heat that it made a nebula hotter than would be the case if it had condensed from diffused gas, then such a nebula would tend to dissipate rather than condense. On the contrary the hypothesis given by Proctor, that the sun is highly condensed in the centre, affords so satisfactory an explanation to me, that when I read the article suggesting this theory I at once accepted it. It is also evident to any one who understands