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 my theory of "selective escape," that to be denser in the centre than at the outside is an absolutely necessary condition of any body largely gaseous, and consisting of a mixture of molecules of varying weight.

I shall now attempt to show that although the kind of impact Croll suggests may well be considered improbable, yet the grazing impacts discussed in my papers are not only not improbable, but that evidence actually demonstrates their occurrence. But it must not be supposed that my theory suggests that even partial impacts between bodies of true stellar mass of our own Universe are frequent events. The present evidence appears to show that, out of the tens of thousands of millions of stars that stud our galaxy, only one or two graze each other sufficiently to produce a temporary star in a hundred years.

Proctor has, in my opinion, incontestably shown that the stars cluster much more thickly in the Milky Way than in the other parts of the heavens. Although these stars are mere points to us, yet we must not forget they are suns; and it is almost certain that hundreds among them have disks many thousand times larger than our earth.

These stars are all moving almost indiscriminately, with perhaps an average velocity of twenty miles a second; yet the space separating them is so large, compared with their dimensions, that in a finite portion of time it is improbable that any two approach each other in a straight line and come into direct impact, for if two stars are not approaching each other directly gravitation can never make them do so. It is quite otherwise with a graze; it is probable that gravitation increases a hundredfold the probability of partial impact among bodies of very great mass compared with the chance there would be from direct motion alone.

Supposing the average velocity of stars to be twenty miles a second, and a body with such independent energy to approach Sirius and graze its surface,—the energy developed by its attraction will be many thousand times its indedendent energy, unless the density of Sirius is incomparably less than that of our sun; and if this were the case its volume would be so great that the chance of impact would be much increased.

This furnishes a striking illustration of how enormously the deflection due to gravitation will increase the probability of a grazing impact between large cosmical bodies. It must be remembered that the probability of impact is not simply proportional to the deflection but is directly as its square.

It is impossible by the most careful watching to avoid collisions between vessels on mid-ocean, but how much would the probability be increased if all the ships that travel the Atlantic were steered by blind men, and if each attracted another approaching near with such force that their own independent motion was nothing to that developed by the pull!

Moreover, just as where the ships are most thickly spread we should find most wreckage, so in the thickly strewn galaxy we find nearly all the phenomena which tangential collision may be shown to be capable of producing.

But even without the influence of gravitation, the indiscriminate motion, the vast size, and countless number of the stars, must result in occasional collisions. Let us examine the case of the molecules of a gas as an analogy.

The velocity of a gaseous molecule at ordinary temperature is nothing to the stellar velocity, and the space occupied by the molecules in a good vacuum is many million times less than the volume of the molecules, yet spectrum analysis shows that such molecules are in incessant impact, and there is practically no gravitation. The explosion of a large vessel of oxygen and hydrogen appears instantaneous, yet each molecule of hydrogen and each of oxygen must find the other in their excursions during the duration of the explosion. Newcombe compares the motion of the stars with the dance of the molecules, and surely if the impacts are so inconceivable in number in the one case, they may sometimes happen in the other. As though to make the analogy stronger, the case of chemical mutual exchange may be considered a kind of molecular partial impact.

To repeat an argument I have used before, cosmical impact is actually in constant occurrence. Every meteorite that strikes the earth is an instance of it, and what occurs on a small scale must surely be expected on a larger, but is of course of rarer occurrence. But supposing our present knowledge, instead of rendering it highly probable (as it is thus seen that it does) that partial impact occurs, made it instead appear improbable, then the vast number of celestial phenomena which receive a perfectly scientific explanation by partial impact—and are so utterly inexplicable on any other theory that positively no explanation exists—furnish such remarkable evidence of these impacts that their apparent improbability would have to be set down to our imperfect knowledge rather than to any improbability in fact.

Thus it is apparent that though Croll's idea of a direct impact may be highly improbable, and if it occurred could not possibly explain his difficulty, yet tangential collision—whose phenomena have been described under the title of "partial impact"—is both in itself probable, and is known to be constantly occurring on the small scale. Therefore, when this consideration is combined with the amazing mass of evidence the phenomena of the heavens offer, the probability of such impact is erected into a position as near certainty as it is probable that human knowledge can attain. But if Proctor means that all impacts are improbable, he does not seem to me to be logically consistent, for his idea of the Universe is that it is eternal, while the life of a sun is, to him, distinctly finite. The number of the finite in infinity is infinity, therefore what a vast cemetery of dead suns our Universe must be if there is no resurrection.

If the chances are as small as supposed—that a million million bright suns are rushing about and pulling each other, and never clash—surely among the inconceivable multitude of the extinct suns that an eternity must thus have sown broadcast, beaconless, and blindly wandering, the chances are not hopelessly small that their ceaseless attractions and never-ending journeys may sometimes make them clash together, and thus receive the Promethean spark that would cause their inert mass to become once more suns instinct with life and beauty.

Without "partial impact" every attempt to conceive of an eternal Cosmos appears to lose itself in vague cloudy words, while the conception that flows from this idea is as clear and sharp as a rock at noonday.

Although it may be a splendid poetic achievement to talk of a Cosmos of which dead suns are to form the constituent atoms, it is quite another thing to conceive of one. Surely if the present order can be intelligibly and scientifically shown to be a possible phase of an eternal rhythm, as it certainly can be, whatever such a cosmic philosophy may lack in poetic fancy is compensated by intellectual satisfaction.