

GLEANNINGS

IN

SCIENCE.

JANUARY TO DECEMBER,

1831.

VOL. III.

The Gleaners spread around, and here and there,
SPIKE AFTER SPIKE, their scanty harvest pick.

THOMSON.

In the knowledge of bodies we must be content to *glean* what we can from particular experiments; since we cannot, from a discovery of their real essences, grasp at a time whole sheaves, and in bundles comprehend the nature and properties of whole species together.

LOCKE.

CALCUTTA :

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1831.

III.—*An Essay on the Game of Billiards.*

The following essay on the popular game of billiards, taken from a printed work, scarce in India, will, we doubt not, be acceptable to many of our subscribers, who may be pleased to see the theory of the game, and may find amusement in tracing their own play to first principles. Notwithstanding its quaint style, it appears to be worthy of the attentive reader's study. It will be found to treat pretty largely on a supposed new method of play, which it thus appears is not so new, for our book was published at Bath 25 years ago. A work like ours must study variety, but even were it otherwise, the present essay would demand admission, as a branch of practical science, not the less entitled to the term "utility," because its more immediate object is recreation only.

Introduction.

It is not supposed, that a perusal of the following pages can be of any use to a good player; for, to play well, practice is indispensibly requisite; and experience, the most infallible test of theoretical opinions, serves to point out the means; therefore, the information necessary to that purpose is already acquired, from documents that blend the greatest simplicity with the strongest proofs. Neither is it expected, that a novice in the game will derive much advantage from it; as that course of instruction, which affords the most entertainment, having always a predilection in its favour, is generally preferred. Yet, whether at the instance of some friends, or prompted by a desire to find out intermediate affinities between causes and effects, now viewed in proximity; so that, by shortening the stages, and promoting the intercourse, the "Inquisitive Traveller" may be better accommodated on the road to Science; or whatever else may have urged an examination of the present subject; if a few hours thus employed, should elicit a further investigation of NATURE'S LAWS, by which her works may be subdivided more minutely, or shown collectively with better success, this attempt cannot be charged as altogether useless.

THE THEORY OF THE GAME OF BILLIARDS.

The motion of a ball struck¹ by a CUE², depends not only on the direction in which it is impelled, but, very considerably, on the manner of striking it; and it is resolvable into two or more divisions; which, together with their efficient causes, are now separately brought into view, and should be carried in the mind, as respectively distinguished, that their effects in composition may afterwards be rendered the more explicit.

¹ The word *strike* and its inflections, whenever they occur, refer immediately to the CUE; but *hit* and its inflections, to a ball, cushion, &c.

² This is the proper instrument to play with; the other (not worth naming) is no better than a trifling contemptible toy.

Viz. The first is *simply forward*: it is produced by the *CUE* only, and analogous to the motion of the body of a wheel carriage, which preserves a relative position of its parts with the plane whereon it moves; and may be called the *PROGRESSIVE*.

The second is *forward and rotary*: it arises from attrition, by the action of the ball, while in progression, against the surface of the table: hence a rotation is produced, analogous to the wheels, which change the relative position of their parts, by turning at the same time round their axis—this will be named the *ATTRITIVE*³.

These two motions constitute what may be termed the plain game of Billiards, and are always coincident upon the same line; but there are others also, which (if introduced) affect them with various influence, in different directions, modifications and degrees; and these likewise, with their origin and characters, it is now endeavoured to discriminate and explain, on physical principles, without the intervention of *CHANCE*—the common enemy of bad players—who are ever intruding this unbegotten phantom, between *NATURE* and her operations, to fill up imaginary voids, with metaphysical agency; hoping thus to find, by the subversion of her order, some palliation for want of judgment, or deficiency of execution in themselves.

But let it not be inferred, that it is here intended to expunge the word from the player's vocabulary—far from it—no more is endeavoured, than to have it confined within due and reasonable bounds: where it is made to signify only an *effect*, contrary to expectation, or beyond design, it is without objection; for there it occupies its proper place: but when it is used as a cause, originating with itself, an independent and unaccountable *principle*, the phrase then becomes absurd. Yet in this sense it is often used; and, though intemperate or bad players (as before observed) are most sedulous advocates in favour of its existence, and clamorous supporters of its authority, from a worthless *client* out of place and notice, it (courtier-like) becomes, in power, an ungrateful reprobate; for they all charge it with injustice or ill-natured partiality, insist it rarely does them a friendly office, and declare aloud that most of its acts are hostile.

Chance and Luck are terms nearly synonymous, at least in common use, yet, strictly considered, Chance seems to be, in the technicals of logic, the *Genus*, and Luck the *Species*; for though the latter frequently has an adjective to qualify its meaning, as good, or bad, &c. it is often also without one, and then always taken in a good sense. But the quality of Chance, is unintelligible in this last predicament, and must, therefore, indispensably have an epithet to specify it, which being sometimes formed from an inflection of the very word with which it is compared, *viz.* "lucky chance," the distinction at once becomes manifest, and further proof needless.

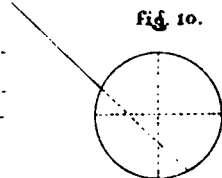
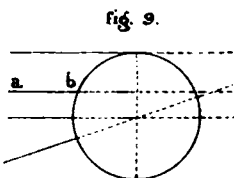
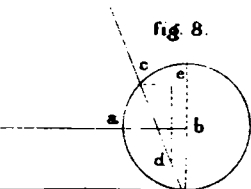
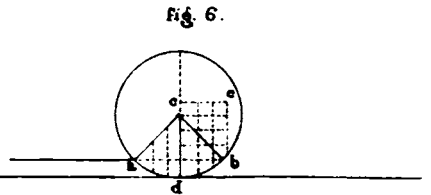
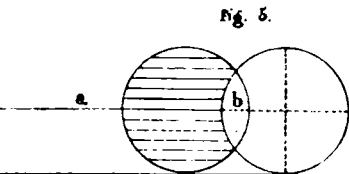
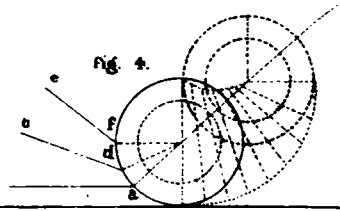
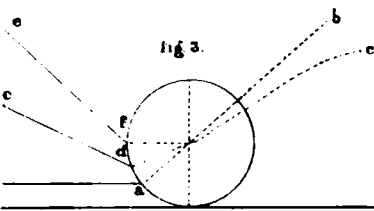
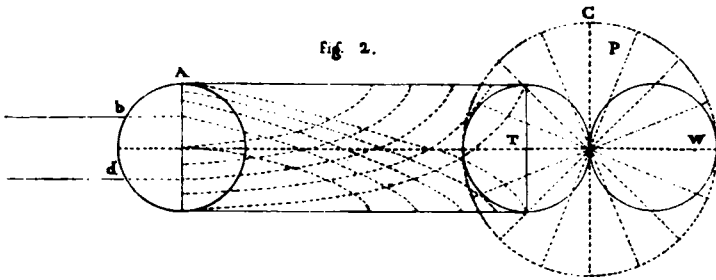
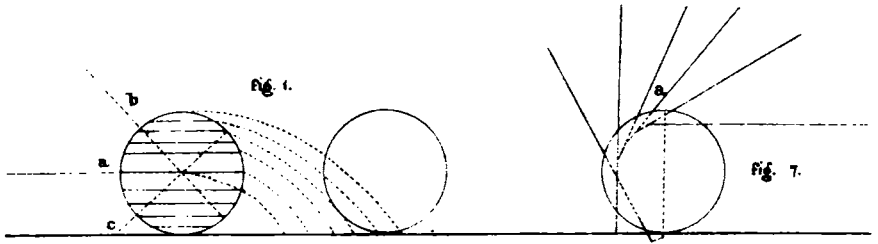
It may not be amiss to take notice also, of a consequence from using those terms, either as affections only, appertaining to the persons of particular players, or as characters of beings that have a separate and independent existence; but which, considered abstractedly, would be perhaps denied. This will appear in such trite remarks (which also exemplify their comparative meaning) as "he has so much *LUCK*, (*i. e.* good *LUCK*) and I have so little, that there is not a fair *CHANCE*, (*i. e.* simple accident) in playing with him." If *LUCK* then exists, it must be in

³ This word (not sanctioned by the dictionaries) the author ventures to form from *attrition*, and assimilate in termination to *PROGRESSIVE*, as likely to convey his meaning better than any single one of established use, whilst it precludes the necessity of a *periphrasis*, which frequently repeated would be intolerable.

substance, or in *spirit*; but it cannot belong to the first class, otherwise it would, at one time or other, be evident to some of the senses; and if it belongs to the second, what can possibly be the object of its mission, attendance, or presence, unless to influence the actions of mankind: yet, if this be admitted, which cannot be denied, without destroying the only evidence offered to support its existence, it is inconsistent with free agency, and this is the doctrine of necessity; the merits whereof, however, being foreign from the subject of this essay, it is not intended to discuss, having made the deduction only to prevent a negligent incongruity of diction with sentiment, as it is much suspected those words are often employed, without any precise or definite ideas annexed to them. If, on the other hand, they be supposed only affections or qualities of individuals; the two opinions, when examined, will be found, like neighbouring streams, converging towards the same pool, either to unite upon the way, or having finished their courses separately, to become stagnant in the same place^a.

To return from this digression: the *progressive* motion takes place, when the middle points, at both ends of the cue, and the centre of the ball makes part of a right line at the time of impulsion; and if this position be also parallel^b with the table, as *a* (see *fig.* 1.) it will be smoothest, lightest, and least impeded. For should the cue be pointed downwards, as *b*, the motion of the ball must be partly destroyed by reaction from the table; and, if pointed upwards, as *c*, or any where else, the power of gravity would be more directly in opposition to it, and, contracted at the same time within narrower limits, as *d*, *e*, still further in effect augmented. But, when pointed horizontally, that power acts against the ball at right angles only, and being extended, by a stroke of no more than equal violence, between limits that embrace a greater latitude, as *d*, *f*; it is weakened by diffusion, and, if the *impetus* be considerable, will be almost lost in the minuteness of division; till by continued operation, together with the resistance arising from the roughness of the cloth, and opposition from the air, the volocity of the ball becomes so much diminished, that, though at first it scarcely touches the surface, it afterwards (more emphatically) rubs, and at length constrained to roll, (as the only means of discharging the progressive force which remains,) it thus advances to the place of rest.

[To be continued.]



GAME OF BILLIARDS.

IV.—*An Essay on the Game of Billiards.*

[Continued from p. 81.]

But a *third* motion, and a *fourth* in direct opposition to it, which, between them, take in all the radii of a circle, having the middle¹ of the ball played at for its centre, must be taken notice of a little more at large.

They arise from striking the ball in such a manner, that it will follow, or return from the other, directly or obliquely on either side, as circumstances or fancy may require. One of these effects or secondary powers, is called *WALKING*; it is produced by striking the ball *A*,² any where (as at *b*, see Fig. 2.) in the semicircle, passing through its middle, intercepted between the part it rests on, and that diametrically opposite, but in a direction above its centre; by which means, after hitting the ball *p*, it radiates from the point of contact, in the most remote division of a circle, as *C*³—denoted by *W*, and when in action, is frequently taken for the *second* motion already mentioned, into which it at length declines. The other is called *TWISTING*; it is produced by striking the ball as at *d*, in the same semicircle, but in a direction below its centre, which makes it radiate after contact, in the opposite division—denoted by *T*, and completes the circle; where,

¹ The middle of the ball is here, and will be hereafter used in contradistinction to the centre—which will be used strictly; and it is intended to denote that part of the surface, with respect to the ball played at, which is in a right line between the centres of both; but as to the ball played with, that part of the surface, which is struck to give it the progressive motion most completely, as has been already shewn.

² The capital *A* denotes the *active*, or hitting ball; and *P* the *passive*, throughout this inquiry.

³ This circle is to be supposed horizontal; but its rays are not strictly rectilinear, as the figure represents. They will be shewn hereafter more correctly upon a larger scale, when treated of more particularly.

being excited, rather by a reverse in the mode of application, than a change in the nature of the principle, it rules with equal influence.

The second position of the cue here represented, is chosen only to exhibit the Theory more clearly, by making the contrast with its former place more perfect ; for it is obvious, the middle at the but-end cannot, by reason of the cue's thickness there, be so much depressed ; neither, perhaps, is it always eligible, as far as it can be done ; because, if the violence be considerable, the ball will bounce from it, in a line passing through its centre from the point of impulsions, (see a, b , Fig. 3.) and turn in the air, (see Fig. 4.) with too small a share of the *progressive* to carry it effectually to its object ; whereas, by elevating the but-end, and at the same time applying the point somewhat higher towards the middle, as c, d , in those figures, that line will approach nearer to a coincidence with the *progressive* ; and the ball be less apt to rise ; while, if the direction be equally distant from the centre, the twisting power can suffer no diminution.

Hence a ball is often struck thus, and considerably higher, as e, f , with good effect, providing the ball played at be remote ; and the degree of violence, as well as the mode of applying it, should be in proportion to the distance between the balls, so as to have as little of the *progressive*, and as much of the twisting motion as possible, at the time of contact, their action being in opposite directions. Because, if the balls be far asunder, and the impulse small, the twist will be quickly overcome by the roughness of the cloth, and sink into the *attractive* ; but, if it be great, the twist will be so likewise, and the ball fly over the same space with less interruption from that impediment, as a former observation shews, and consequently less consumption of the twist imparted. If, on the other hand, the balls be not far asunder, and the impulse great, the ball impelled will at first be apt to rise (as above explained) ; and to hit the other before it falls into level motion ; or, should that not be the result, the twist will be counteracted, by the quantity of *progressive* force remaining after contact, with which the ball had been overcharged ; and proportionably destroyed.

These effects also are rotary ; but (abstractedly considered) the centre of motion is not confined to the external parts of the ball, as they severally fall in succession upon the table, like the *attractive* ; for the ball, according to the nature, manner, and force of the stroke, is often driven with a tendency to move round points beyond its surface, and its course may be assimilated to (see Fig. 2.) that which takes place, before the *progressive* be sufficiently subdued, to coalesce, and form the *attractive* ; or, the compass may be so reduced, as to have its centre within the ball's surface, (see Fig. 4.) and produce locomotion, by means of repulsive agency against the cloth, without much attrition or any *progressive* aid.

This last effect, a twisting stroke may exhibit very clearly ; for a low application of the point will detach the ball from the table, without imparting almost any *progressive* motion ; but a temporary separation from the table, with so small a share of the *progressive*, can scarcely (if possible) be produced by a walking stroke ; neither can it take place until after reflection, nor even then be seen distinctly.

Yet striking the ball merely as heretofore directed, in order to make it twist, with the point of the cue unprepared or smooth, serves to little purpose ; for its absolute tendency afterwards must be upwards, in the line a, b , from which rectilinear courses however, being continually acted upon by the power of gravity, it will be diverted ; and describe a parabola, as a, c , according to the law of projectiles.

But, should the point be rough, a temporary hold is taken of the ball, and both, like indented machinery, are for an instant locked together in the inequali-

ties of their surfaces^a; while the centre of the ball not being in the line of direction, the equilibrium of its parts is destroyed by the stroke, in a ratio expressed by the radius of a concentric circle, in the last Fig. to which it is a tangent; and the ball, obedient to its *vis inertiae*, undergoing less change by avoiding than submitting to the violence that would necessarily ensue in a contention between the *impetus* on one side, and its own weight and resistance from the air, on the other; turns backward round its centre, presenting the parts immediately behind, in quick succession to the cue's surface. For all round bodies can with less force be turned about their centre, than driven in the progressive only; because, in the first case, there is no resistance from the air, except what arises from attrition in its rotation—the ball still occupying the same place; and the opposition from the *vis inertiae* also, is very much diminished; but locomotion being an inseparable character of the second, the impediments are more considerable.

This will appear in a stronger light, by extending the analysis a little further. Thus (see the line *a, b*, and its parallels, Fig. 5.) that part of the ball at *a*, which receives the impression, cannot move in the progressive only, otherwise than by forcing all the rest of which the body consists, to pass in conjunction with it, as it moves to *b*, through equal spaces, in equal times; whereas, by turning round its centre it describes in the periphery of the ball, an arc of equal extent, (see *a, b*, Fig. 6.) while every part within the circle, or without its plane, whether the motion be concentric or parallel, is carried with an inferior degree of velocity, in proportion to its distance from the axis on which it turns; and may be expressed by the sector, or mixed triangle *a, b, c*, constructed by lines radiating from the centre of the ball, to the extremities of the arc it describes; each division of the intercepted portion, representing, in arithmetical progression, a constituent particle. It also appears, by drawing the line of bisection *c, d*, and inverting the position of one half, viz. *a, d, c*, into *c, e, b*, a quadrilateral figure *c, e, b, d*, is formed, the breadth of which, *d, b*, being equal to half *e, b*, is a mean proportional to the sum of its motion; but the *vis inertiae* excited, is as its motion, therefore the resistance is but half also. Thus, by obeying the impelling power, in moving through a space corresponding with the force impressed, and at the same time avoiding the difficulties opposed, by withdrawing from them; a conflict between Nature and Art is most effectually prevented, while rotary motion seems to be employed as the means.

Or, should a ball be struck above the middle, in a direction below the point resting on the table, as is represented (Fig. 7.) a similar effect may be produced. Here the progressive motion is impeded; and a line drawn between both parts of contact, a lever of the 2d kind, in the order of mechanics, viz. the point touching the table, the fulcrum, that portion of the ball perpendicularly beyond it, the weight to be overcome, and at the part struck, the power, which, being in direct proportion with the distance between the line of direction and the fulcrum, consequently (if similarly applied) increases, as it is advanced towards that point of the semicircle to which it is perpendicular, as *a*; where, after traversing an arc of ninety degrees, it loses its name—in other respects being still the same; and as it passes beyond this boundary, (supposing the stroke made from the opposite side,) acquires that of walking. But, when a ball is struck in this manner to make it twist, as it cannot obey the impulse directly, it is apt to elude the effect by reflection from the table; and besides the inconvenience from attitude, the portion of the cue before the sight, is not only frequently very small, but to the view,

^a It is best formed for this purpose, by sloping it, and usually prepared by *chalk*, as a substance that does least injury to the cloth.

still further diminished by its elevation; so that the aim must be in the same measure uncertain; neither can the cue be applied in this inclined and limited direction, without much danger of tearing the cloth: for which reasons, this stroke is seldom more than an expedient, when the use of the cue is confined by the ball being close or near to the cushion, and the effect cannot be produced otherwise; or, (if in a more open situation,) to avoid making a foul^s one, when the interval between both balls is small; for the horizontal distance, over which the point of the cue moves after contact, decreases, as it deviates from the horizontal line; that is (see Fig. 8.) if the line of impulse *a, b*, should be placed as *c, d*, it will reach horizontally only to *e, e*, a distance considerably less. This motion, with its causes, may be clearly exhibited in degrees of slow operation, by turning the ball upon the table, with a dry finger, or any other soft and rough substance; but as, in playing the game, it is never designed to take place, till it hits another ball, the direction given should partake of that necessary for the progressive also, and be a composition of both, as the case may require. Here also, it is obvious the point must be chalked, and that the corresponding parts come into succession as before. It may be added, when rotary motion excited by the cue, and the part of the ball struck, are upon the same side of a perpendicular line passing through the centre of the ball, it is called twisting: and when on opposite sides, it is denominated walking.

In a view of this last power, or effect of power, which is the reverse of the former, and with which it has been in some measure contrasted; in order to be more explicit, it will be necessary to revert to the part the ball rests on, from which the consideration of the twisting power began. In the first arc of ninety degrees, that is, from thence to the middle of the semicircle beforementioned, the cue must be held with the but-end lower than the point (see Fig. 9.), so as to impel the ball in a direction above its centre, which is in this case necessary to make the ball walk; and being thus scarcely applicable to a very small portion of this arch, in the ordinary way of holding it, the power here may be considered as almost useless: but, in the upper arc of the semicircle, though the back-hand be somewhat raised above that position, this impulse may be given easily, and with increasing effect, so far as about the middle of it; and might till the cue became a tangent to the ball's surface, (the power being as the distance between the line of direction and the centre of the ball,) would not the deflection of the arc be thus almost identified with the line of impulse, and make it impossible to prevent the point from slipping; or though it should not slip, the small part exposed to the invading force, being instantly detached by turning under the stroke, while the main body lies intrenched below, and participates equally of the impression made; the walk imparted, as well as the progressive motion, (without which the other is of little use,) must be very trifling. It is better, therefore, to strike the ball in some intermediate part of the arc, where the point will not be so apt to slip, or the force so quickly evaded, and a sufficient of the progressive may be received. The same observation may be made in playing for a twist, where the weight of the ball assists the chalk, and is the only difference.

This effect likewise branches into a division, collateral with that of twisting; and may be produced by striking the ball also above the middle, but in a direction beyond the part whereon it rests, though below its centre. (see Fig. 10.) Here, too, the progressive motion is impeded by the table; neither can the ball obey the impulse directly, otherwise than by passing through its surface, and it is

^s This will be fully explained hereafter, with some comments—too much at length for a note.

on the same account likely to be reflected by their mutual elasticity, hopping or ricocheting frequently, as it advances ; so that the walk thus produced cannot be very great, though often supposed otherwise, when the ball after hitting another, moves with a celerity not much retarded. This, however, should be ascribed to a different cause, and is the consequence of their centres not being opposed in an horizontal line, at the time of contact ; but let it be remarked, the centre of gravity lying above the line of direction, if the point of the cue be rough, and the ball, therefore, cannot disengage itself, at the instant of reflection from the table, the result must be the contrary. The same expedient by which a foul stroke may be prevented in playing for a twist, will serve here likewise.

It may also, from appearance, be supposed, that the walking is greater than the twisting power, because the ball has more motion after hitting ; but this is a mistake, and takes place from confounding it with those of attrition and progression, which concur in carrying the ball forward ; whereas, the other power moves in opposition to them, and unassisted by any co-operating aid, till, combined with the re-action of the ball played at, those allied forces are overcome, and it returns with the difference. Besides, to give effect to either, in every degree ; since the cue, as has been shown, should be cut, prepared, and relatively applied, precisely in the same manner, over surfaces equal and similar, and sometimes the same ; turning the point respectively, because the objects are different, with every thing else in common between them, it may be concluded, that (abstracted from these intervening powers) both are equal.

A lateral twist or rotation also, may be given, by striking the ball sideways⁶, with the point of the cue chalked as before : and though the effect be not easily discerned, in progression, it is very sensible in the angle formed on reflection from the cushion, the check it receives from thence, changing the centre of this twist or rotation, to the point of contact ; for, suppose the ball divided into an indefinite number of horizontal planes, and three of those, represented by three concentric circles (see Fig. 11.) on one of which the curved arrow is intended to exhibit this lateral rotation, given to it by the cue, *a, b*, in a direction at right angles with the cushion, *c, d* ; and supposing this effect equally distributed through all its parts, in proportion to their distance from the centre respectively, as has been before explained ; then, while the chord *e, f*, describes the arc *e, g*, the diameter at *A*, is advancing to *t*, and will arrive afterwards at *A*, through which point, or with a deviation from it, according to circumstances, the ball will be reflected. The two inferior planes are precisely (as it may be seen) in the same predicament, and so is every other one whereof the ball is composed.

⁶ A ball played in this manner often serves to a good purpose, when the cannon ball is within the balk, and neither far from the string-line, nor near to a side-cushion, after both white balls have been pocketed, or off the table ; for, by playing back against the end-cushion opposite, in the usual way, the danger of going out of the balk, from the application of too much force, prevents the use of a sufficient degree, to send the ball so high, on its return from the balk-end, as the player might like. But, if he should strike the ball thus, against that part of the side cushion, just beyond the string-line, it will return within it, and occupy a place high enough, to command a good losing hazard in one of the corner pockets ; and in some situations with the adversary's ball in the balk, a cannon may be expected with confidence, if the player be accustomed to the stroke. The farther from the cushion played against, the ball is laid on the string-line, the better ; for the interior angle will be greater, and the stroke therefore more efficient, or less of it necessary to accomplish the same design.—(See additional note in Appendix.)

IX.—*An Essay on the Game of Billiards.*

[Continued from p. 119.]

Here, perhaps, it may not be improper to introduce some remarks on the merits of an opinion, that "The angles of accidence and reflection are equal;" since it is advanced universally by the first authorities, and applied particularly by some, to the present subject, with a latitude of expression, not qualified by any exception, as might be expected when reduced to practice, if any were supposed to be; and none having been made, the fairest inference follows—an opinion that none existed. Yet (with due deference), the most simple act, by which information can be had in this case, is also the most convincing proof, that the doctrine is not only erroneous, but, that its universality is more frequently destroyed than one instance shown in playing the game, where it is not fallacious. For, let a ball be struck or driven indifferently with any thing against the cushion, at an angle less than a right one; and the lines of accidence and reflection marked: then reverse the stroke, by making the line of reflection that of accidence, and the ball will not be reflected in the other, but, in a line making the remote angle with the cushion considerably less, if not prevented by a twist. This diminution evidently takes place from the rotary motions in aid of the progressive, and if their influence be not denied, surely either such concomitants of the progressive, as are almost physically inseparable from it, should be mentioned abstractedly; or, admitted as giving no interruption to the universality of the doctrine, by being involved. But, to bear up the position in some measure, it may be said, Billiards (as a particular game), should be excepted; and that the doctrine will hold most completely in any other view. Is it then supported by the game of Tennis, when every Tennis-player knows how much the angle of reflection depends upon the manner of striking the ball with the racket? If Tennis will be called a particular game also, it may be asked, what game is not particular; and how many instances it will require, to unbinge the reception this doctrine has met with? Let the position be carried still farther, to any projectile, from a cannon ball, to a common bullet; if it obtains there, for what purpose are guns rifled, but, in order, by a twirling motion in a plane at right angles with the progressive, to diffuse the rotary tendency equally around, and thus correct the aberration of the ball, in its flight to the object aimed at: or if rotary motion be admitted, it is presumed similar causes will be allowed to have similar effects here also: for it is of no consequence, whether they proceed from a cue, racket, or gun-powder; the surface of a billiard-table, the floor of a tennis-court, or the barrel of a gun. Moreover, if the digression would not be thought too great, by infringing the department of metaphysics, the view might be extended from palpable, heavy substances, to air and sound; and applied there with no better success: for, how can the particles whereof they are formed, after impinging upon a surface, be supposed to float, and roll along it, if the angles of reflection, be equal to those of accidence? or, how can a whispering gallery be accounted for on a principle which precludes the possibility of conglomeration?

But the hallowed ground, upon which (it is conceived) this doctrine, when applied to light and colours, chiefly rests; although it should be approached with still more circumspection; it is hoped, will not be thought profaned, by flickerings of dark and tremulous conjecture. The co-existence, length of duration, and

consimilarity before and after reflection, with which they are endued, and the precision their various rays display, together with the facility of making and multiplying experiments, seem to have recommended these subjects for examination, as paramount to all others in the field of nature, and fittest for the purpose of having the merits of the present question ascertained. But it appears, as if the issue, which (fostered by the greatness of a name), is now so much revered, and rules with universal sway, had its birth in a confidence—perhaps too firm, (though resulting from careful and persevering investigation thus directed,) and was thence transferred, rather by analogy than otherwise, to matters not supposed as favorably submissive to experiment: yet if the instances already brought forward, wherein it has been endeavoured to show this principle cannot hold, deserve any notice; may not the same kind of argument be used to render the position at least suspected; and negative universality made the inference from many particulars, with as much propriety, as positive from only one; and still more so, should the validity of this particular instance be at all disturbed, by hypotheses not at war with reason, or established principles?

It will be admitted, that with regard to light, no variation between the angle of incidence and reflection has been observed to take place either through the intervention of many mirrors, or any distance the eye can comprehend, after repeated trials: but it does not follow, that what has not appeared to our limited faculties can have no existence: and, if we consider the wonderful minuteness of its particles, compared with the smallest division of matter which can be distinctly presented to our senses; as also, that no two points within the same horizon are sufficiently distant to give the least idea of its progressive velocity, why may it not be projected from the luminous body with rotary motion likewise, and its momentum¹ have a similar effect upon the angle of reflection, for aught we can perceive to the contrary? But waving this, which seems to lie beyond the reach of intuition, and though some bodies at least must be allowed to have rotation antecedent to reflection, no small degree of it is acquired after, from the very act of striking against the reflecting surface; because the point of aggression being always necessarily between it and the direction of the accidental line, whatever be the form or nature of the projectile, a tendency to turn in proportion to the interval must be the consequence. How then even light, which is now the subject principally before us, can claim exemption from this law without destroying its materiality, is the difficulty submitted to be removed before received opinion should pass as proof of sterling rate, or currency be offered for its assay.

But to return. Players in their noviciate, not knowing how much the angle of reflection depends upon the manner of striking the ball; when it differs sensibly from that of incidence, are constantly finding fault with the cushion; though the charge is often more properly attributable to their own awkwardness, by not holding the cue in a line with the centre of the ball. This is a very common

¹ It has been found that the force with which bodies move, is, as their quantities of matter multiplied by their velocities; and Astronomers have proved from the eclipses of Jupiter's satellites, that light moves two millions of times faster than a cannon ball at the moment of discharge, when the least grain of sand would be intolerable to the most stubborn part of the human frame. Since then its particles, with all this velocity, make no painful impression on so delicate an organ as the eye, we are left rational means to be assured of their extreme minuteness.

failing, which a looker-on, aptly placed at a distance before the players, may clearly perceive; and if not corrected early, grows into a confirmed habit; yet its ill effects being confined to the active ball, and not materially taking place till after reflection, are therefore not preclusive even of eminence, in other executive departments of the game. All of this description (which is by far the more numerous), should invariably play back with the but-end of the cue, lateral accuracy being the less necessary on account of its breadth, as the middle of the ball must be struck by some part of it; and sudden opposition, which always promotes a tendency to twist, may be prevented by trailing. But the few, to whom a strict and timely attention has given established claim in the other class, should as uniformly play back with the point; because that power, which acts against the progressive motion, as has been already shown, and consequently makes a greater impetus necessary to drive the ball the same distance, may be prevented by a walking stroke also: and still more particularly where much force is required; for, not only the cushion may be struck with more exactness in the part designed, the eye being less detached from its object; but, the bodily frame is less shaken, and the nerves thrown into less disorder; on which account, for a little fanciful or doubtful advantage to be gained by a few strokes, it does not seem advisable (where coolness and composure are so essentially necessary), lightly to use means that may disturb and unfit themselves for the rest of their play.

Here it may be noted likewise, the point of the cue should be always a little round; not only because it better serves the purpose of twisting, or walking; but, the middle of the ball is more truly struck, by being thus formed: for, suppose (see Fig. 12) *a*, *b*, to represent one position of the cue, where the middle is exactly opposed to it, as in the progressive; in that case, it is immaterial whether the point be round or flat; but suppose the position changed in the act of striking, to *c*, *d*; then, it appears, if the point be flat, the ball will be driven towards *e*; but if it should be round, it will be struck in an intermediate part with less aberration from that intended, and its motion be towards *f*: yet, as it is also more apt to slip from the ball, extremes should be avoided, making it at least sufficiently round, that all its parts may describe similar arches, when turned upon the bridge as a centre.

Also, a short bridge, if it admits of striking the ball with sufficient force, is preferable to a long one; this may be seen (in Fig. 13) where *b*, *c*, represent part of a cue, centrally in the line of direction, and *d*, the bridge; there the hand which forms it, is supported by the table, and steadiness only is required: but the chief difficulty rests upon the back-hand, which is without support, and at the same time, to give the impetus in the line of direction. Suppose then, in striking the ball *a*, a variation from the original position (which very few players, if any, can altogether avoid); and the cue to occupy the place of the dotted lines; it is obvious, the edge of the point would strike the ball in the middle: but if at twice the distance from the bridge, it is equally plain, the cue, without altering the angle, would vary twice as much; that is, the whole breadth of the point, and miss the ball almost entirely.

(To be continued.)

VI.—*An Essay on the Game of Billiards.*

[Continued from p. 181.]

Hitherto, a consideration of the game has been nearly confined to the ball played with, as it regards the different ways of striking it : To examine, and account for the effects of both, after hitting, will be the object of the next endeavour.

Suppose a ball perfectly elastic¹, as A (see fig. 14) and to hit another at rest, of equal weight and size, as P, with their centres exactly in the line of direction ; the hitting or active ball will give up to it the whole of its own motion, and stop

¹ Elasticity is that power which many bodies have towards a recovery of their original form, and would be called perfect, if equal to the force that changed it. What immediately follows is as much a test, as a consequence of this perfection, but no body has yet been known to possess that property so amply.

quiescent at *b*, the point of contact : but, should it hit obliquely (see fig. 15) the passive ball *P*, at whatever distance, will be driven in a right line drawn through its centre from the point of contact, and with a velocity inversely as its deviation from the line of direction, compounded with the loss of motion in *A*, the active ball, which is carried off by the difference, making an angle with the line of accident always greater than a right one, and inversely commensurate with the portions opposed.

It is obvious this angle of reflection cannot be so small as a right one ; for since, in the former case, where the balls are centrally and completely in opposition, the active one is not driven back beyond the point of contact ; therefore (a fortiori) it cannot take place where the opposition is less ; and the angle must increase according to that diminution. Besides, otherwise the balls must have an elastic force more than equal to the aggressive ; whereas, on the contrary, reflection simply², (that is) without these rotary motions which influence it conformably with their characters, as already described, has ever proved it to be inferior. The walking power operates over this angle with a tendency to enlarge it ; and, although it may be increased at the same time with the progressive ; not only, its increments of motion are always proportionably small, but the quantity performed in any definite distance, regularly less, as the other becomes augmented : so that increasing the violence counteracts the means of enlarging it.

The twisting power influences this angle to an opposite purpose : but, as it may be increased by violence, in a definite distance, without adding to the progressive also, the active ball may be drawn back upon the line of accident or towards it, and the angle accordingly in a great measure reduced. This power is most efficient when the balls are not further asunder than a free use of the cue make necessary, because, in that case, having less attrition to contend with, it will therefore be less diminished, and consequently return with a greater quantity. Moreover, the angle resulting from such a situation appears to be smaller than if the balls were more removed, though no twisting should have taken place ; because the active ball struck at different distances upon the same right line, between the centres of both, will be most reflected from it, when the interval is shortest ; though the passive ball be hit in the same part precisely. But this conclusion (admitting the statement) is drawn erroneously ; for the line of accident from which the angle should be measured, also changes with the distance. This may be seen in fig. 16, by putting *A, A*, to represent the active ball, and *P*, the passive, at different distances upon the same line *b, c* ; and the dotted lines *d, d, e, e*, those of accident and reflection respectively ; and though the portions opposed, viz. *f, f*, increase with the interval as the figure shews ; the reflection from the original line *b, c*, will not be equivalent to the angle which attends a diminution of the distance.

Hence it is obvious, that giving back the active ball in the line between both produced, when not within reach of the cue's point (which is sometimes done in careless play), alters the angular relation with a cushion or pocket ; and, to leave the position with respect to both unchanged, it should be put back so, that the centre may occupy some place in the parallel *g, h*, as *i*.

But the active ball can never make so great an angle as a right one with the motion of the passive ball, except by means of twisting ; yet, were it not for

² This may be shown by suspending two equal balls from the same or adjacent points, and letting one fall against the other : the angle thus formed between the lines of accident and reflection will always be obtuse, and consequently a proof of this inferiority.

rotary motion, and their imperfectly elastic nature which will not retribute in adequate proportion as the quantity of aggressive force increases, it would be always of this magnitude: But, although to this extent they cannot separate, these circumstances (granting a choice of situation) render them efficient of any angle less, till they coincide: or to be more explicit; one ball, as A (see Fig. 17) being driven from the point *b*, in a tangent to another as P, the angle which both thus make after hitting, is the nearest to a right one, and greatest that can be made; but, if driven from the several positions *c, d, e, f, g, h, i, k*, notwithstanding the opposition, and of consequence the reflection also, be increased with each advance, the vertical angle will be in the same order progressively diminished, till at *k*, whence they hit centrally, it vanishes altogether, the active ball following in a line coincident or corresponding with that wherein the passive ball moves.

This may be further illustrated by supposing A and P, divided into eight or any other number of parts, and only the two divisions immediately adjoining to be excited when the active ball A is driven from the point *b*, whence the opposition must be least; consequently the quantity of direct force turned towards reflection, will be affected by no more of that deficiency from elastic perfection, than resides^d in those parts which receive the impression; and a situation necessary to increase that opposition, will also add to the quantity of that latent principle which proves a drawback on the reflecting line; for, by altering it from *b* to *c*, &c. to *k*, though the absolute reflective power be enhanced at each promotion, the opposition becoming more direct; the concussion which the balls undergo, penetrating at the same time further from the point of contact, will rouse into action this attenuating quality of matter which lies dormant in the portions behind; and thereby deteriorate reflection, without a suitable or any alteration in the direction of the passive ball—the other constituent line of the angle in the proposition. It must therefore be diminished in the like ratio.

An effort, or tendency towards lateral rotation, arises from this indirect opposition also; and may sometimes be perceived; but that it always exists, will appear, by supposing *c, d*, (fig. 15) equal portions cut off from the balls on opposite sides, changing their centres to the line of direction, *e, f*, as in fig. 14; then likewise, the portion on one side being opposed by an equal portion on the other, and no predominating influence to turn the scale, the balls may be said to be in equilibrio. It is plain therefore, that, not only a difference in direction must take place, by restoring these crescents, which alter the centre of gravity, and destroy this equilibrium; but also, that the crescent of the active ball, being unopposed, is warped from its rectilineal course, by the violence its complement receives in reaction from the passive ball, and carried by its momentum, horizontally and slowly round, having that part of its surface, which came in contact with the other, as a centre or focus point of its motion. A similar effect is produced in the passive ball, but its crescent having no momentum at the time of contact, it is of much less consideration.

Lateral rotation acting, as it seems, obliquely against progressive motion, may be conceived as somewhat analogous to the power of gravity, making the ball, in subservience to the law of projectiles, describe a parabola, whose principal vertex

^d Giving to a negative quality a positive place, may be a cruet for a critic, but the author's chief aim is to be explicit, and if that abuse administers to this purpose, he will readily admit his acumen; with the same view only, he has sometimes ventured to express his meaning figuratively, Theory having a little claim to this indulgence, beyond the bounds of Practice.

(if thus generated, and the ball walk after hitting) is commonly at or near to the crescent point *e*, though subject to be further removed by the stroke, and the power greatest in its nascent state; whence it declines uniformly, and deviating from the line of direction according to the superiority or inferiority of the impelling and repelling powers respectively, the ball proceeds, gradually unbending its way, as *g*, *h*, &c.: but, if the ball moves under an influence of the twisting power, sufficient to overcome this forward and rotary effort of the crescent, its agency will succeed, and hanging on (as it might be) or attracting the line of reflection, change the former termination of the parabola into its origin; and also make the ball describe that curve backwards, increasing or decreasing as similar circumstances may prescribe^d.

Some may suppose, as these crescents are the immediate causes of lateral rotation, that the quantity should be as their magnitudes; but let it be observed, it has the progressive to contend with, and that the same means, viz. obliquity of opposition, by serving the purposes of both, renders the effect nugatory; or from the eccentricity of its curve, undistinguishable from a right line.

The parabolic curve is fully evident to a common observer; but the horizontal or lateral rotation, whence it partly takes its rise, is not very perceptible; because it requires much more quickness of sight to catch the parts of a surface as they come and go, if the body be uniform, and the colour or whiteness the same. The curious, however, by a close attention to the red ball, (should the colouring not be equal,) may frequently perceive it, and the experimentalist may render it still more visible by using contrasted colours for that purpose; but even the most determined sceptic may be convinced (if a digression will be allowed from elastic to non-elastic substances, without changing the principle) by suspending two non-elastic balls, for instance, of clay, or wax, from nearly the same point; so that by drawing one backward to a convenient distance, the other may be hit obliquely, and afterwards adhere to it: the horizontal or lateral rotation in this case, can no longer be a matter of doubt, nor does it appear how the effect can be attributed to any other cause than that already stated.

It has been just shewn, that a ball impelled by a twisting stroke, obliquely against another, will after hitting, describe a parabola backwards; but, if that stroke be combined with the means necessary for horizontal rotation, it will discover a tendency to that figure unassisted by any opposition, and move curvilinearly the breadth of an inch or two, within the distance of a few feet, by which the direct interposition of another ball may be entirely eluded; for this purpose, the ball should be struck upon the side, and high up also, with the but-end of the cue raised, after the manner *e*, *f*, (in fig. 3); and thus, it will be made to circulate (as it proceeds) in a plane cutting the horizon at an angle of about forty-five degrees, producing the above effect.

(To be continued.)

IX.—*An Essay on the Game of Billiards.*

[Continued from p. 369.]

When the passive ball lies directly between the active ball and a pocket, the winning hazard is most easy, and according to the deviation from that position, it, in like proportion, becomes difficult; for the part to be hit cannot be chosen so accurately, nor seen so distinctly in this, as the former case; and the same angular variation from the proper line of direction, will err further upon the passive ball's surface, than when the hitting point is less distant, and the declination consequently not so great—(see fig. 18.) But, in the above situation, the losing hazard is most difficult, for the walking motion (which is necessary to execute it) should be strictly vertical; and, since angular relation with a pocket varies as the distance, the hitting spot depending upon that interval, cannot therefore be absolutely defined; however the manner of hitting, most favorable for that purpose, perhaps may; which seems to be, when they are half opposed to each other at the time of aggression: for thus the resistance will neither be great enough to make the active ball apt to twist, nor direct enough to give much efficiency over the angle to a walk, (the simple motions being less fallacious) while the hitting spot, not being far from the middle of the ball, the declination cannot be very considerable: at the same time it is evident, if the hazard made from that measure of opposition, with moderate force, be allowed the most convenient or eligible, the angle which the situation of the passive ball should make, is (a posteriori) relatively ascertained.

A ball is more reflected from another at a distance, by a strong stroke, than a weak one; because, neither the progressive motion, nor the twist which in some measure at first accompanies it, from the necessary elevation of the butt-end (when the ball is struck with force, and no higher than the middle) is so completely overcome, before it hits the other ball.

For the same reason, a ball struck with violence, if the direction be inclined to the cushion, will be reflected more towards the player, making the interior angle less, than if played easily; as also because, the form of the impression, made against the cushion, is rather the arch of an ellipsis than a circle, till the part first hit recovers its place; but, in the mean time the ball is advanced, and the further part of the cushion (see fig. 19) embracing it exactly, will reflect it more abruptly, elasticity not returning the other with quickness enough to prevent it¹.

¹ In playing *bricole* when necessary to hit the cushion very obliquely, the inexperienced player seldom does it soon enough to answer his purpose; for, the more distant the point of contact (i. e. the fulcrum) from the line of direction, and the less the progressive violence, the more operative in lateral exertion is the power, which in some measure thus deceives him.

A ball, somewhat obliquely hitting another, close or near to the cushion, after being repelled to some small distance by the kiss, frequently returns to the cushion, or runs into an adjacent pocket. This (at first view) may seem extraordinary; but, it is to be noticed, that, without increasing the progressive velocity of the ball, a force may be superadded, which will carry it farther; and, that the progressive velocity which remains after hitting, may be completely destroyed, without necessarily annihilating the rotary motion also. For (see fig. 20) suppose A and P, vertical sections of two balls centrally opposed in the line of motion, and placed laterally to view: though the progressive of A, may be stopped by the kiss from P, yet, the walking rotary momentum, derived from its weight with the impulse given by the cue b, and denoted by the curved line c, is not consequently stopped also: but making the point of contact the centre of motion, raises the ball with a conatus, from d toward e^a, and moreover, should those sections not be in the same plane, will co-operate with the horizontal or lateral rotation produced by this obliquity, as has been already explained, and both be expressed by the curve, it afterwards describes (see figs. 21, 22, 23.)

Hence, a ball hitting another near to the cushion, and not far from a pocket, is more frequently holed^b in this manner, than is generally imagined; because, the hitting, and kissing, are too simultaneous to be well distinguished by the noise: but it may be remarked, the active ball is often holed thus, (a walking stroke being always most apt for the purpose) which would be thought impracticable, where a kiss could not take place^c. Hence also, the active ball is more apt to bounce, than the other; and, if the view would not be thought too minute, it might be said, that the passive ball being quiescent, and dwelling with its weight upon the cloth, sinks lower than the ball in motion, which rises therefore immediately after contact; but, the other not till after reflection from the table also, by which its force is much weakened.

When one ball hits another close to the cushion, in an acute angle with it, the tendency upwards from its rotary motion is much enhanced by not hitting both exactly together; for, then the ball, meeting, as it advances, with a kiss below

^a Hence the reason, why a ball played with much force against a cushion, is more apt to bounce up after a walking than a twisting stroke.

^b The word held, when applied to the ball in this sense, is not English; holed being the inflection of hole, but held that of hold: neither is the word immisable, which is sometimes used (by those who should know better) to signify not to be missed; but with this view the fabrication can have no excuse—both are instances of a very confined education.

^c A similar effect may (notwithstanding) be produced without the intervention of a kiss, when the passive ball lie not far from the cushion, yet so far as to admit being hit with a considerable degree of opposition, and on its return not meet the other, provided the walking stroke be made with a violence somewhat extraordinary, and according to the distance: for, the rotary momentum thus received, which it partly retains after the progressive motion be destroyed by the passive ball and cushion afterwards, brings it again forward (as has been already shown) in the generation of this curious result.

The opposition (as above) should be considerable, that the active ball may only lose as much as possible of the progressive, and not have it also turned against the object intended, by assailing the fixed, and more repulsive power of the cushion: and the distance from the cushion should not be great, that the walking power may neither be too much wasted, nor fallen into a smoothness of motion, after the hitting it receives from the passive ball, as is explained in the next paragraph.

its centre, or touching the cushion above its most prominent part, rises, and is carried by the progressive over the table.

Should the active ball by any means hop on the passive, somewhere about half way in or near the arch between its middle and summit, with only a small degree of progressive force, it will be driven backwards : for as in this case, it urges the other to pass through the table, its forward motion is impeded, not only by the resistance and re-action of the passive ball ; but by similar properties in the table also, and must be returned from their ascendancy, and according to that direction wherein they are assailed.

The active ball after hitting the passive has (*cæteris paribus*) the same degree of latitudinal range with it : but, if the interval between them be small, and the active ball invested with those subsidiary powers, from which the other is debarred, it may have more than twice as much, and traverse a circle entirely, (as shewn at the beginning of this essay, see fig. 2 :) whereas, the passive ball is subject to a government, the limits whereof cannot by any means or situation be extended to half the compass, and its influence diminishing in direct proportion with the interval, the space accordingly will become contracted as they are approximated, till distance vanishes, and it be reduced to a single line. Or (by conversion) supposing them thus in contact : as the hitting point cannot be altered by any manner of striking the active ball, neither can the direction of the passive be capable of latitudinal variation ; and, in proportion as they are removed, the arch intercepted between the tangents *b*, *c*, and *d*, *e*, (see fig. 18.) formed on opposite sides by the motion of the active ball, will increase ; but on account of their divergency after intersection, as at *f*, or any where else, as at *g*, cannot (however great the distance) be equal to a semicircle. Hence a losing hazard occurs much oftener than a winning one, and dexterity the effect of practice, gives it with most players the preference. Yet they cannot well be compared ; at least, their comparative facility should not be decided by the distance from the pocket only, but also by the arch, on the surface of the passive ball intercepted between the middle, and the part which it is necessary to hit for the respective purposes. However a person executes that best, which he is most accustomed to play for, and fancy the offspring from success, assists execution. Players therefore equally good may have different design.

A cannon, or losing hazard, is made with less certainty, if the first ball be within the distance of an inch or two from the second, and the third one or *p. c.* somewhat remote, than when extended to that of so many feet ; because the manner of striking the ball must be more precise, to avoid complication from the various motions which are in the beginning more particularly apt to occupy it, as before explained.

A cannon is more easily made than a hazard, if the distance be the same ; because, should the first ball after hitting the second, move within three diameters of the third, it must be made ; but no table has the opening of its pockets so wide.

If the progressive motion of a ball be slow before it hits a cushion, it is often observed to be somewhat accelerated after ; the increase arises from a coincidence of motions by reflection, which had been at variance in progression.

In the winning and losing game, a winning hazard made of the adversary's ball is generally of less value than a losing one, as the fewer balls left upon the table, the less obviously must be the remaining chance ; on which account, good players will frequently give it up in favour of a worse hazard, and relin-

quish a cannon beside, for as much attention should be paid to the consequences^d, as to the immediate object of the stroke.

Players of the old school (as they call themselves) bigotted to former habits, have but little relish for this game: they think it so much under the dominion of chance, that experience, judgment, and execution, have not their meet rewards; and that Tyros carry off a larger share than their merits give just claim to: but they do not place the game in its proper light; for, though it be allowed absolutely a game of more chance than the winning only, and of much more than the white game, still that conclusion may be disputed; for, suppose in this the chance be as two to twelve, which is the sum total of the game, while in the other it be as six to twenty-four: though it may be said, there is three times the chance, that is six to two; their respective proportions are only one-fourth and one-sixth; but, if the winning and losing game were extended to thirty-six, (which perhaps would take up no more time in playing than the white game,) they might then be viewed correlatively also, and chance being overpowered by numbers, would lose that extraordinary influence which now forms the objection: however, for obvious reasons, an alteration to this effect, at public tables, is not likely to take place.

Besides the white and cannon games here mentioned, there are others; and upon the same principle of variety (which is merely numerical) there may be many more; but additional balls, without diversifying the manner or effect, by increasing still further the predominancy of chance, abridge the exercise of those faculties which chiefly render a game entertaining, and enhance this objection unprofitably. To enumerate the several games at Billiards, with their rules and laws, &c. not being within the scope of this essay, they are only transiently alluded to.

A cue should be chosen with a degree of stiffness, or otherwise, according to the force which the player is capable of using; for if it be too weak, it will be overcome by too small a measure of resistance; and its reaction, upon which the ball's velocity depends^e, must be feeble in the like proportion; and, if it be too stiff, the power cannot make it bend effectually, to excite a sufficient quantity of elastic force; but it is best adapted, when moderate power produces the greatest comparative violence; for violence of aggression does not altogether depend upon the degree of power, but also upon the closeness of the bounds wherein it is exerted: this will be more manifest, by supposing the impelling power to consist of ten parts in arithmetical progression, as 1, 2, 3, &c. beginning with unity; and, the elastic force capable of being excited, divided into the like number^f; the violence of effect upon the ball, will be directly as the power, but inversely

^d This is the reason why good players make more voluntary misses than bad ones, and few perhaps give so many as they ought, the game being often won in one hand from the advantage gained by ill-timed frugality.

On the same account, if a player think he can make an hazard, as well as a cannon, or even more, by one stroke; it is frequently better to take them separately, not only because he will then be more certain of marking, by contracting his views, but also enabled to provide for those which follow, with more exactness and advantage in the end.

^e This will be evident if by reversing the cue, and using the butt-end as the point, the effects of both be compared: for the power, manner, and weight being the same, the difference can be ascribed to nothing else.

^f The power, when excited to the utmost, can scarcely be comprised within the limits of ten inches, but the elastic force resulting from only the difference in the length of the cue, before and after it has been constrained by the stroke, can scarcely exceed one-fortieth part of that distance.

as the distance in which it is made to act, that is greatest when the stroke is shortest, because, the ball having less time to make its escape, the resistance arising from inertness, and other impediments to motion, which bend the cue, is increased by suddenness of opposition; but, if the stroke be extended, or lengthened by continuation to a greater distance, as when playing for a walk, though the quantity of power employed remain the same, by the time the fifth or sixth degree arrives, the resistance will be subdued, and the elastic force beginning to expand itself, the ball will either be driven too fast for the successive numbers to overtake it; or should it not be detached, the opposition being so small, they will discharge themselves to little purpose, merely pushing it forward, while the elastic force, instead of being augmented, relaxes, and the cue immediately recovers its form.

It will be endeavoured to render visible how the measure of aggression, which evidently depends upon the power, is increased by contracting the distance wherein that power is exerted. Suppose, therefore, *b*, (see fig. 25,) the point of a cue drawn back to *c*, with any degree of quickness, and immediately returned for the purpose of striking the ball *A*. If its motion (assuming the power of the hand for that of gravity) be admitted as uniformly accelerated, in the order of 1, 3, 5, 7, 9, 11, &c. like that of bodies falling from a state of rest; an Isosceles in analysis, as *d, b, e*, taking the first division of the area as comprising a given degree of celerity, or primitive quantity of power, represents the same ratio of arithmetical increase during its emotion: and under the above law of acceleration, by supposing the cue further removed to *f*, (that is twice the distance,) with *bd* produced to *g b e* to *h*, and then joining *g h*, the relative spaces, degrees of celerity, and quantities of power, may, by transposition be obtained at each consecutive interval, and the last will express the aggregate on its return to the ball. Or two triangles, constructed equal and similar to the given one, and placed as in the figure, will exhibit the progression more concisely, with an initial of the like proportion, as 1, 3, taking the first triangle for unity. But if twice the quantity of power be excited within the same distance, the increments of acceleration will be doubled also, and (pressed between parallels at similar intervals) driven into lateral expansion, and require twice the space to range in, as may be seen in fig. 26. Again, suppose the cue drawn back to *c*, as before (see fig. 27), and then, for an instant stopped (as is the practice with some players), the momentum will by this intermission, be destroyed, the advantage acquired from it lost, and the force must originate there *de novo*, by which the aggressive effect (as the spaces indicate) will be no more than half, though the active power be unimpaired. Hence it appears, why bodily or muscular strength, without the art or knack of compressing its powers by a sudden jerk or the like, is so often unavailing.

A cue should always have a little preponderance forward from the part where it is usually held, and in this the weight should chiefly be; for if behind it, the same weight will alter the preponderance to the other end, or if before, it will press too much upon the bridge, to move with sufficient lightness; and reducing the weight to correspond with the distance, is cutting off a principal source whence the momentum and elastic force take rise.

Before the butt-end of a cue be used, it is often material to know the transverse section there; for, if at the time of striking the ball, it makes with the table the interior^a angle less than a right one, the point of aggression will be under the middle; if greater, over; but if neither, the middle will be struck exactly, and the consequences resulting—twisting, walking, and the progressive respectively, as

^a (That is) the angle opening towards the player.

before explained : the elevation of the hand should therefore accord with the design.

The habit of applying the hand or finger to the top of a cue during play, is a bad one ; for the moisture exuding through the pores, being somewhat oleaginous, makes it slippery ; yet a smooth-pointed cue, though of less compass than a rough one, is often more certain in effect, if by striking the ball centrally it does not slip upon the surface.

The rule, which requires the marker to hold the cannon ball in his hand, till another which occupies its place be removed, is slovenly, ill chosen, and should be altered : to give it a corresponding situation at the other end, or (should that also happen to be engaged,) to place it in the middle between the two side pockets, would be a much better one.

A stone foundation upon a ground floor is the best for a billiard table, because it cannot lose its level, or be affected by walking or stamping around it : whereas, if it be placed upon a joisted floor, supported only at the ends, it often requires adjusting, and the balls are more likely to be influenced by any violence that takes place on the boards with which it is connected.

Whether the general tendency of such causes be to retard motion, or accelerate it, is perhaps scarcely to be ascertained by any practical observation : but as in particular cases the effect (however small) may sometimes be material, it falls within the tenor of this treatise to seek the issue theoretically.

In favour of retardation it may be said, because the motion communicated proceeds from a pressure of one kind or other directly upon the floor, the agitation excited is necessarily perpendicular ; and the surface of the table which lies parallel to it, will vibrate in like manner, till the action of their elastic force subsides : consequently, this tendency of up and down motion imparted to the ball, must be a corresponding incurvation of the right lines in which it was moving, and therefore a contraction of the distance ; but (it may be objected) this incurvation being the effect of attraction, operating uniformly without increase, or variation of direction, over the ball as it moves, cannot therefore be the means of contracting the distance, by any extraordinary influence : on the contrary, should this power, which is the principal impediment to its motion, be opposed directly by any force or cause (as in the present instance) it must for the time be equivalently diminished : and, unless the ball be entirely detached from the table, (by which the motive power will be consumed in simple revolution (that is) without advancing it) a single elevation, which does not deprive it of the advantage arising from attrition, will add energy to the momentum, and the result be acceleration—besides, if any power acting in a line perpendicular to the centre of a ball at rest, produces no horizontal motion^o, and that some effect of that nature must take place afterwards,

^o This is in the presumption that the centre of the ball, and that of gravity, are the same : otherwise, if the ball be raised above the table, by any violence from beneath, it will incline to turn from the perpendicular, towards that direction wherein the centre of gravity (which takes the shortest way downwards) happens to lie.

When a ball is said to rest upon the edge of a pocket, and afterwards without any apparent cause falls into it, the present law at billiards declares the effect as a kind of chance-medley ; and since it would be hard the adversary should suffer, through the impertinent interference of such an agent, visible or invisible, the sentence dismisses the claim as of no account. This chance, be it besides what it may, is certainly a very wonderful and convenient menstrum, for it dissolves difficulties by wholesale ; and were it only as comprehensible as it is efficacious, or the narrowness of human understanding somewhat enlarged, perhaps its reputation might make its way beyond

when changed from that state; since the ball is advancing, while the impression from the table is successively communicated through its parts, its centre must be supposed to have passed beyond the perpendicular line, before it be totally disengaged from the action of the surface whereon it rolls, rather than to have occupied any retrograde position. From this view follows the same conclusion as before, and both seem to shew a preponderance in favour of acceleration.

A stroke is said to be foul, when the cue is not parted from the ball played with, before both balls touch¹⁰. If the ball played at be hit in the middle, or near to it, the foul stroke is more obvious; because the striking ball cannot be supposed otherwise to follow it with much motion: but, if only a small portion of it is opposed; because the striking ball is therefore less retarded, its motion afterwards is generally attributed to that circumstance only; and the stroke called fair, though it be often really foul. For, suppose two balls A and P, (see fig. 24,) one inch asunder, if the cue moves in the direction *b, c*, farther than from *d* to *e*, after striking A, before it be detached; it constitutes a foul stroke: but in the direction *f, g*, it may be advanced as far as from A to *i*, before the balls touch; still it is much suspected, that the motion of the cue, is frequently not confined even within these limits: for in the latter case, or where the ball is struck as *k, l*, so that it may hit less obliquely, making *m, n*, the interval before contact; there is so little caution used, that the cue is often driven twice the distance.

Yet, sometimes it is difficult to decide, and the best judge, the most unqualified, by being the player; for, if foul, he will have felt an opposition to his cue, greater than he has been accustomed to meet with from a single ball: but as no one's opinion is asked where he is interested, the best criterion by which a judgment can be formed, on the nature of ultimate effects, when the intermediate elude the senses, appears to be obtained by adverting to causes more remote; and therefore the distance between the balls, the fulness or obliquity, and the force of the stroke, with the manner in which it is made, whether short or otherwise, added to the experience of the person in a similar situation, to whom the question is referred, are, if not the only documents the case admits, the surest guides to direct his answer.

the confines of a billiard-table; but, until those who have discovered this impenetrable secret grow a little more communicative—'tis probable, those who have not yet been so unfortunate, will be stubborn enough to attempt the solution through the medium of common sense: accordingly, presuming a ball, once stopped, can never of itself begin to move again, they may ascribe the hazard to the effect of the stroke, saying the ball stopped to appearance only, but was really at that time in motion nowever slow, either by gradually pressing upon the pile of the cloth, where it loses of its thickness as it turns round the edge; or, suppose the centre of gravity not in the centre of the ball and the equilibrium just beginning to be destroyed, &c. It seems as if this law (like others of a higher nature dignified for their uncertainty) was made for the sake of disputation only, and in harmony with its principle, as it begins in error, it often ends in discord.

¹⁰ But, as frequently there are no means of ascertaining this, which is allowed to be the proper criterion of that character, if a foul stroke were made to turn upon the distance between the balls, before the stroke takes place, for instance, an inch or half an inch, it would prevent many disputes, and be the same to both parties.

Perhaps it would be still better, to do away a foul stroke of this kind altogether except when the balls touch; for, supposing a near situation be generally advantageous to the striker—which is very much doubted, both players have an equal chance to profit by it. The other kind of foul stroke is, when the cue touches the ball a second time in the same act of impulsion.

Thus, all the motions which can be given to a Billiard ball, and the different ways of producing them, have been set forth, simply, as well as in composition; with every other circumstance that occurred, as connected with the game, or distantly relating to it; and however extraordinary some effects may at first appear, they will be found on examination to be the genuine result of principles long known, and well established on the basis of unerring laws¹¹.

There are few games (if any) where the united efforts of judgment and execution are so indispensably occupied in such a diversity of situations, as that of Billiards; no wonder, therefore, it be a fund of so much entertainment: neither perhaps any, which affords at all times more temperate, and salutary exercise, or diffuses it so equally, with less danger of excess. Surely then, while health claims concern, the game before us is entitled to some regard; and these two characters, which comprise so much of the *utile dulci*, should be sufficient not only to preserve it in estimation, and to those unengaged in avocations of greater moment, to make it a favorite, and give it a prior place to other games not possessed of those advantages.

Perhaps at the same time, no game admits of more deception; for, execution being the chief department, and success depending upon the concurring excellence of so many agents directly under influence from the nerves, it is often extremely uncertain, whether an effect proceeds from previous intention, or unavoidable control; here opens a large field for feints also, whereby determined purposes may be made to pass for accidents, and the highest degree of executive excellence, for the lowest of inferiority; but here indifferent players (excepting those whose perspicacity sees design in every casualty) though generally most suspicious, are much more apt to be deceived.

Games of judgment and execution are the proper sources of amusement for man, as they may be creditable to his talents or ingenuity; but those merely of chance, never can: where all pretensions to superiority are relinquished, his exalted nature becomes inactive, or nugatory, and the most insignificant animal of the creation, may have an equal claim with its votaries, to the favours of that capricious deity who presides.

The eye being the organ first employed in this fascinating game, as a communicating medium for the judgment to act upon, it should at least be free from imperfection; and the objects conveyed to the mind clearly and unconfused, that the judgment may give its orders with precision. But, though the sight must not be defective, extraordinary acuteness is by no means necessary to play well, neither does a superior degree of excellence, turn upon this hinge.

The visual rays darting in right lines alike to all, if the eye presents them distinctly, that the perception may be transmitted to the sensorium in a proper dress, it does its duty, can do no more, and should not be made further accountable. To place it in a station where its powers may be used to the best advantage, by choosing proper bearings, is a different affair, and belongs to the mental faculty: when this also is done, and the eye enabled by practice to recover

¹¹ To enter into the practice more particularly by adducing cases, would lead to a detail irksome to the last degree, and unavailing in the end: besides, a knowledge of the minutiae in this department, like all other arts, must ever be very defective while instruction depends merely upon precept. The practice already shown is chiefly elementary, and although otherwise somewhat copious also, still it is only verbal. To complete the player, the greatest difficulty yet remains to be surmounted—to turn it into use by making that practice actual—“*hic labor hoc opus est.*”

that point with facility and exactness, as far as circumstances will permit, the judgment likewise should be free from blame. But to arrive at eminence in the game, so much depends upon execution, for the final issue; and more particularly on the address of the back-hand, (as before noticed,) to which is committed so large a share, that it is the grand desideratum of the whole, and the judgment feeble and of little value without it: besides, the doors of judgment are always open to receive, and its dispensations not confined to any period of life; but the executive manner is of more limited access; and if not acquired early, while the muscles and sinews are yet tender, flexible, and may be formed to the game, it is hopeless, with any assiduity, to court it afterwards, when the stubbornness of age renders them callous to impressions they have not been accustomed to, and the affections of younger days fixed, and unalterable by any practice, however persevering.

The rays of light may shoot with nature's charms, and bear her blossoms without toil or care, through the lapse of many years; the seeds of judgment, though not sown till late in life, by cultivation substituted for loss of time, may quicken, and the crop grow to maturity with less of nature's aid; but the scions of art, if not grafted upon youthful stocks, and cherished with attention beside, vegetate slow and sickly; for, notwithstanding they may germinate, and even push forth some branches, they are of that cramped and stunted growth, which cannot flourish; and though appearances may flatter with the promise of some fruit also, the idea of its ever coming to perfection will most assuredly be indulged in vain.

PHILOBILL.

APPENDIX.

After the Note in p. 119, read—In like manner a balk may be frequently made, by a player dexterous in the use of it, when it is not otherwise to be attempted from the danger of kissing, and the ill consequences attending it, viz. if the cannon ball be only a small distance from the side cushion, and a little beyond the string-line, with the active ball somewhat further on; so that the striker may be apprehensive of the cannon-ball meeting on return with his own.

Note to the second paragraph of p. 181.—It is advisable to have always the same part of the cue uppermost, for the accomplishment of similar designs; as, the more precisely it be held, the less apt the player is to be deceived by any want of uniformity about the point, or in the length of it; and although otherwise, or at any time, no more than the edge, and a little within it, would require chalking, (for those parts nearer to the middle can never touch the ball,) a much less portion will obviously be sufficient by following this advice—if the cue be not perfectly straight, it should be held (when striking the ball) in such a manner, as to have the bent either up or down, that its elastic force may not be exerted laterally.

But, notwithstanding the above form be thought most convenient for general use; if a player wish to have much within his power, and understand how to manage it, the point should be a little sloping and somewhat rounded at the sides only, having the most backward part sloped still more, to about the eighth of an inch from the edge; for with such a point, a ball may be made to twist or walk to an extraordinary degree (without relinquishing any efficiency over those between), by holding it up or down, according to the occasion. But as first-rate players pertinaciously adhere to that knowledge which combined with execution has already ranked them so high, they form their judgment in the aggregate, and vain of the superiority they have acquired, yield with reluctance, from accustomed habits, to any novel means that may be recommended, appreciating them as the wild suggestions of a speculating unpractised theorist.

