Soaring Flight

The San Diego Air and Space Museum has Octave Chanute's copy of Montgomery's original, 131-page, hand-written document, "Soaring Flight", and is available on-line via Flickr: http://www.flickr.com/photos/sdasmarchives/sets/72157632368152612/
Unfortunately, it was scanned at a low resolution (72ppi).

The first page has this notarized inscription:

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This manuscript, of 131 pages, similarly hand written and on similar
paper to this, including two faded photographic prints and occasional
marginal notations penciled by me, was submitted by John J. Montgomery
to me in the year 1895, or shortly before or after.
                                  (signed) O. Chanute
Subscribed and sworn to before me this 12th day of May A.D., 1910.
                                 (signed) A.H.  Hillern[?]
                                 Notary Public
                                 My commission expires June 14, 1911
                                 SEAL
     Witnesses:
     (signed) Victor Lougheed
     (signed A. T. Edmonson
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The last page has a similar, hand-written version of this inscription, at a 45-degree angle over Montgomery's document, making it difficult to decipher the writing underneath.

The copy at the Santa Clara University Archives was typed from the original by Montgomery's wife, Regina Cleary Montgomery, (or a secretary) as she states in her letter of transmission addressed to Rev. Charles J. Walsh, S.J., 25 November 1940. It contains some typographical errors and four missing pages: 2 at the beginning and 2 at the end. It consists of a total of 47 typed pages, including 41 figures and 2 photos.

In this paper Montgomery first presents some "ELEMENTARY MECHANICAL PRINCIPLES", 9 "PROPOSITIONS", a section on "FLUID IMPULSES", 26 "EXPERIMENTS" he performed, and concludes with an "APPLICATION TO AN EXPLANATION OF SOARING FLIGHT". The figures presented here are Montgomery's drawings from Octave Chanute's copy. We have redrawn them using Canvas™ Draw 3.

Soaring Flight

J. J. Montgomery
Mt. St. Josephs College [*crossed out with note "1895"*]
California

Of the various phenomena that have attracted the attention of Scientists during recent years, that of Soaring Flight is pre-eminently the most mysterious and bewildering.

The simplicity of movement, and the apparently indifferent forms in the wings of soaring birds, have done much to hinder the solution of this problem as investigators have been tempted to see this in other causes than the form of surface and its relation to the mobile air.

The wing of a bird resting motionless on a current of air, though the ideal of simplicity, is nevertheless, as worthy the deepest study, as the indifferently shaped piece of load-stone [*sic, lodestone*], which carries in its bosom the wonder and mysteries of electrical science. As the latter performs its operations without visible movement, by mysterious powers, and excites ceaseless investigation; so the former, poised on the air, develops and perpetuates a series of operations according to a code of mechanical laws, whose existence is unsuspected, and whose secret workings, wonderful in the extreme, suggest further inquiry into the relations of forces.

In the hope of explaining these laws, and removing the veil from the mystery, I shall present, in brief form as possible, some of my studies and experiments.

At the outset I shall state, though this phenomenon is based upon the simplest law of fluid action, there are many principles and relations of movement involved, which really constitute a series of laws or branches of this main law.

For the sake of brevity, and to enable the reader to follow the development of the subject, I shall first state the theory, and then a series of propositions or principles, followed by experiments demonstrating them, and finally combine these in the full explanation.

A bird, in soaring, is surrounded by a horizontal cylinder of moving air, having a retrograde rotation, whose axis is perpendicular to the direction of movement. The air, in this revolving cylinder, acts against the front under surface of the wing, in its upward course, and reacts against the rear portion in descending; continual impulses being added to this rotation by reflections of air from the under surface.

The formation of the wing being such, as to conform with these three conditions – motion in a straight line, combined with rotation, developing equal work in equal times – these conditions giving rise to a parabolic movement.

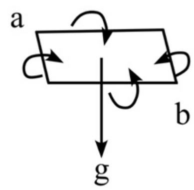


Fig. 1

First consideration.

Let a square plane “ab” descend through the air by the force of gravity. The air will escape around its four edges, from the lower to the upper surface. In drawing it down, gravity develops a certain amount of work, which is proportional to the mass of the plane and the time of operation.

But only a part of this work is found in the moving plane, for this continually imparts the impulses given to it by gravity, to the air meeting it. The quantities of work retained by the plane or transmitted to the air depend upon the relative area and weight of the plane. In the case illustrated, the air escapes equally around the four edges; but suppose the two ends be prolonged indefinitely, or what is equivalent, the plane descend between two parallel surfaces, which cut off the escape at two opposite edges; the air will then be compelled to escape equally around the two remaining edges. In this case the impulses of gravity, indirectly given to the air, will be found in the two currents rushing upward around the two edges.

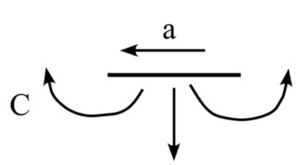


Fig. 2

Second Consideration.

Under these conditions suppose the plane be given a motion in the direction “a” (fig. 2). It will then meet the up rising current “C” and partly cut off its escape, and thus receive an upward impulse which is nothing more nor less than (part of) the energy of gravity so transformed as to operate in an opposite direction. Thus, the impulse of gravity, given at one instant, is turned in its direction, so as to operate during the next instant, against the force that caused it.

This impulse and return stroke may be illustrated as follows (fig. 3).

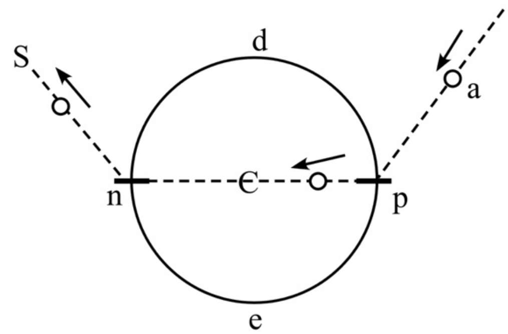


Fig. 3

In the figure (3) “de” is a wheel resting on the axis “c”, having a plane “p”, fastened on its side; “a” is an elastic ball moving as indicated.

When this comes in contact with the plane “p”, its vertical impulse sets the wheel in motion. But suppose its horizontal component brings it to the point “n”, the same instant that “p” reaches there; then the motion which the ball imparted to the wheel, will be returned to it in an opposite direction, and it will follow the path “s”.

Let this simple construction be extended thus.

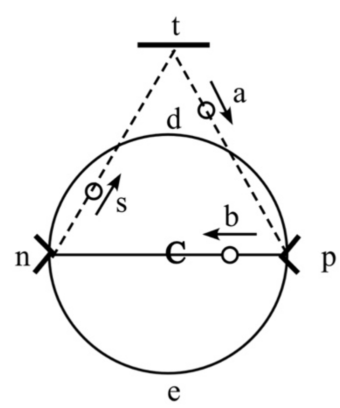


Fig. 4

In fig. (4) “de” is a wheel similar to the last, with planes as shown at “p” and “n”. “t” is a horizontal plane; and “a” an elastic ball, having the indicated motion, which striking the plane “p” will impart rotation to the wheel and be reflected so as to take the direction ”b”. Reaching the point “n” at the same instant as the plane “p”, it receives a reflected impulse “s” which carries it toward the plane “t”, from which it rebounds in the direction “a”, to repeat its series of movements. Under ideal conditions this movement could continue indefinitely; thus imparting equal and opposite impulses to the wheel and the plane “t”.

Having thus stated the elementary mechanical principles involved, I shall present a few propositions, which apply to the movements of fluids between parallel planes. The reason of limiting the study to the movements between planes is apparent from the second consideration, which seems to accord with the conditions found in nature, as manifested in the long, but narrow wings of birds, by which the escape of air is prevented, as far as possible, at the ends, and confined to the front and rear edges.

I use the term “fluid” generally, as I have noticed, there is no essential difference in the nature of the movements of air and water; these being due to the mutual actions and reactions of mobile particles on one another or solids.

Hence I shall confine my descriptions of experiments to those in water, mentioning only such as have particular bearing on the question; and describing them and my apparatus, so that others may test the correctness of my conclusions. Many of the experiments performed with these apparatus, were first performed in large streams and the wind.

The essential difference between the movements of fluids, unrestrained in any direction, or confined between two parallel planes is indicated in the following proposition.

Proposition 1st

An impulse generated in a fluid mass is transmitted as a sphere of motion or energy; hence its intensity at any distance is inversely as the square of the distance; corresponding to the increase of surface of a sphere, proportionally to the squares of the radii. An impulse transmitted in a fluid, between parallel planes, varies in intensity, inversely as the distance; this corresponds to the proposition that an arc varies in length proportionally to its distance from the center.

Prop. 2nd

A body moving through a fluid encounters resistances in a ratio of its velocity – the proportion is generally supposed to be, as the squares to the velocities.

An examination of the rate of resistance from the beginning to the cessation of movement reveals, that the resistances are in the inverse ratios of the times. Accepting the statement as correct, that resistances are proportional to the squares of the velocity; then the resistances, from the beginning to the end of motion, are inversely proportional to the squares of the times. And as it is immaterial whether we consider a body moving through a fluid or a stream acting on a free body immersed in it, this law is equally true. But as the power of a stream to transmit motion to a body is only the resistance existing between the two, it follows, that the power of a stream to impart motion to an immersed body, varies inversely as the squares of the times from the instant of immersion to the time when the two have the same velocity.

Prop. 3

If a body moves with a constant velocity across parallel lines of equal unvarying force, it receives a constant increase of motion or acceleration in the direction of this force. This acceleration will drive it through spaces proportional to the squares of the times. The path thus described by the body, having these two movements, is parabolic, (shown by reference to conic sections).

When a body is projected across a stream, it continually cuts parallel lines of force and should describe a parabolic curve; however, owing to the fluid resistances it loses motion, inversely as the squares of the times of motion. This destruction of its velocity would prevent its traveling in a parabolic path, but for the further fact that the intensity of the parallel lines of force (of the stream) which carry it along, varies in the same proportion. Hence the relations of the controlling forces remain the same as those of a constant velocity and regular increase of motion.

This law applies equally to a single impulse or to a number, following one another in rapid succession, as those of a fluid stream or jet.

However, an important difference in results follows from the application of a force in these two ways.

Prop. 4th

In the first manner of projection, a set of whirls is formed by which the energy of the moving body is absorbed; in the second, the energy is transformed into a counter movement, which in reality, is the rebounding of the jet from the forward resistances. Both the direct and counter movement of this jet come under the previous law, forming opposite branches of parabolic curves, as will appear from the following.

Prop. 5th.

An elastic ball "a" projected horizontally, and being pulled down by gravity, will trace the curve "abc" (fig. 5).

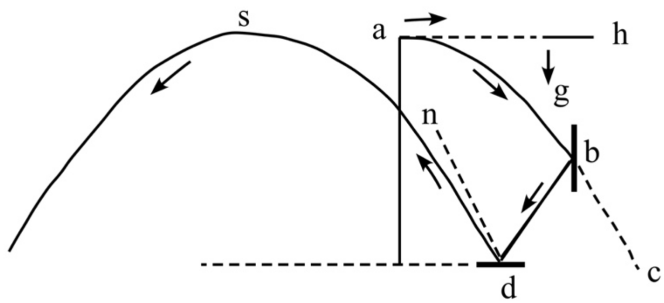


Fig. 5

At "b" it meets a reflecting surface and rebounds in direction "bd". At "d" it meets another plane which, by reflection sends it in the direction "dn"; but being controlled by gravity, it traces the curve "ds", similar to "abc". Reaching the point "s", it again descends, forming a curve the counter part of "abc".

Applying this to the movements of a fluid particle, according to the conditions stated in prop. (3 and 4), we find that a fluid mass projected across a current will form parabolic lines in the first impulse and also in rebounding from the opposing particles. As these movements take place in the stream, the curves which are formed from the direct and reflected impulses will be somewhat as represented in fig. (6).

Fig. 6

Prop. 6

A fluid meeting a solid is reflected essentially in three directions, as will be apparent from the examination of fig. (7).

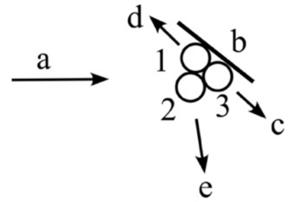


Fig. 7

Let three elastic spheres "1; 2; 3", having the motion "a" impinge against the plane "b"; "1" and "3" will be reflected from the surface according to the established laws; but coming in contact with "2", are reflected from its surface in the directions "c" and "d", while "2" is thrown in the direction "e".

Prop. 7

Any two points taken in the circumference of a rotating circle at any instant, are found to be moving in different directions; conversely, if either of two points, connected by <u>any</u> means which tends to keep them the same distance apart, is forced to move in a different direction to that of the other, they will move in circular paths around a common center, as illustrated in the following case (fig. 8).

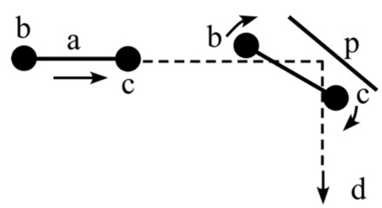


Fig. 8

Let two spheres be attached to a rod "a" having the indicated motion; when "c", which is elastic comes in contact with the plane "p", it will be reflected in direction "d", and reacting on the sphere "b", will change its direction of motion, while it, in turn is deflected from its path "d". And the two thus moving in different directions connected by the rod "a", describes circular paths around a common center.

Prop. 8

Let "abdg" be a column of liquid, resting on the base "ab" (fig. 9). Draw the lines "ce", "ac", and "bc" (ce being perpendicular to "ab" at its center).

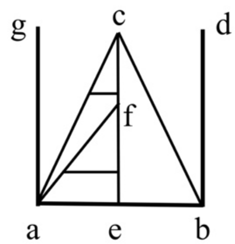


Fig. 9

As the pressure in the column increases with its depth, a perpendicular drawn at any point, from “ce” to “ac” will represent the pressure at that point. The increase of pressure from “c” to “e” represents a constant and regular increase of force.

Let this column be replaced by one of elastic material having motion, which is suddenly arrested by the base “ab”; then the pressure will also be proportional to the depth; for the pressure is expressed in terms of the velocity and mass; but the velocity is the same for every part of the column, hence the pressure at any point “ce” is proportional to the mass pressing against it.

If this column is one of fluid, having indefinite length and breadth, moving between two parallel planes, resting on the opposite edges of the plane “ab”, the same proportion of pressures exists. In this case the line “ce” is an indefinite quantity; however, we may assume any point “f” as the origin of pressures, and calculate the increase of pressure from this point to the base “ab”, just as if no superincumbant pressure existed.

This moving column of fluid represents a constant force having a constant velocity in the direction “fe”. If then, this force commence to develop work at any point, “f”, the work performed between this point and the plane, will be proportional to the time of operation.

And a perpendicular drawn from “fe” to “fa”, at any point, will therefore represent the accumulated work at that point, and which transformed into motion would generate velocities proportional to the time. Therefore, a body moving from “f” to “e” with a constant velocity and urged from the line “fe” by the increasing force, will pass through distances perpendicular to “fe”, proportional to the squares of the times. Representing the times, by distances along the line “fe” (which we shall call y) and the spaces perpendicular to this, through which the body moves, by “x”; at two consecutive seconds we have the spaces and times represented by the equation $x:x' = y^2:y'^2$.

This, as already stated, is the equation of the parabolic curve. Transforming this into the equation $y^2 = 2px$, we may determine the curve, when any values of x and y are given. And if a surface be constructed in accordance with the curve corresponding to any point on the line “ce”, and placed in its appropriate position, the fluid particles urged by the advancing column will move over it exerting their full energy.

But it will be observed that the particles moving toward “a” are pressed upon by those moving towards “b”. If the latter pressure be removed, its reactive influence must be supplied by another force. This may be found by inclining the curve to the advancing column, and decomposing this force into two elements, one parallel with the ordinate (y) and the other (representing the reaction from “b”)) perpendicular to it.

Other considerations will appear in proposition (9).

Prop. 9

In the parabolic curve the following relations appear. If from the focus “c” with a radius, equal to the focal length of the parabola “ea"; we describe a circle we find that a line drawn from the center of the circle to any point on the curve will be cut at the circumference, so that the portion outside the circle equals the perpendicular distance from “ed” to the same point. (This readily appears from inspection of fig. (10) and the construction of the parabolic curve.)

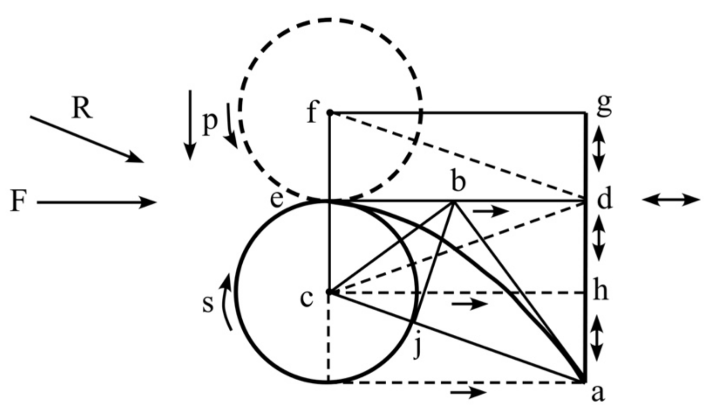


Fig. 10

The line “ed” is tangent to both the circle and the curve at its vertex “e”. The tangent of point “a” bisects this at point “b”.

Suppose while the circle rotates, in the direction of the arrow, a particle escape from it at the point “e”, it will travel along the line “ed”, without restraint, and therefore perform no work. But if it is compelled to move with the rotating circle, it is entirely restrained from giving out any of its energy.

If however it travel along a line equally distant from these two extremes, it will perform its maximum work. From this figure, we find that his line is the curve “ea”.

This development of work presupposes that the particle is urged from the line “ed” and the circumference by equal forces. That such is the case, may appear from the following.

If we refer to the analysis of fluid reactions in figure (14) we find that when an impulse is imparted to a fluid particle, it is opposed by the inertia of those in front of it; and thus are produced pressure and motion perpendicular to the line of impulse, giving rise to two opposite rotations. Referring this to fig. (10), let “F” represent the impulse, and “f” and “c” be the centers of these rotations. Since these rotations are formed and held in position by the external fluid resistances, they exert a constant and equal pressure in all directions. The line “ed” is the direction of the force “F” and is perpendicular to “cf”, the line joining the centers of the two rotations; it then, is the line [of?] mutual reactions from both centers.

Therefore, it may be considered a fixed line upon which either rotation exerts its pressure. Then the following analysis appears.

The force “cd” is composed of “ch” and “hd”; but the point “d” being fixed, produces the reaction “dh”; the force “ca” has the elements “ch” and “ah”. The sum of the reaction “dh” and the direct action “ah” is “ad”. This analysis is general for the pressures on all points along the line “ed”. Then, for all points of the curve below the line “ch” the element “ad” is positive and for those above, it is negative; hence the line “ad” is the algebraic sum of the elements “dh” and “ha”.

Since the forces “cd” and “ca” develop work by pressing on the forward resistances, the point “a” will be found on the line “da”, whose distance from “c” is one-half the sum of the two elements “ch”.

As the point “a” (according to this analysis) is equally distant from the circumference of the circle and the line “ed”, we infer that both exert the same pressure upon it.

The converse of this proposition is true, and we may place a plane “ea” so as to receive the impulses of a current, which in acting upon it, will develop the pressures just discussed, and a tendency to rotation around the focus “c”.

From the figure it appears, when the force “F” produces the two rotations around “c” and “f”, that the element “s” of rotation “c” is kept in balance by the opposing element “p” of rotation “f”. Then if this system is built up by the action of a current on a curved surface “ea”, the deficiency of the element “p” must be supplied by an element of a current having the direction “R”.

As this system is developed by the movement of a current along the line “ed”, equal work is produced along equal portions of this line; for the pressure and velocity of the current are constant. And as the point “b” is in the center of “ed”, equal work is performed on either side of it.

This point then becomes the center of moments, the lines “eb” and “ed”, being the lever arms of a series of perpendicular forces. Then also, the lines “eb” and “ab” may be considered lever arms passing through the same point; but these lines are tangents to the extremities of the curve. Hence the pressures on the portions of the curve subtended by these tangents, are inversely as the lengths of their tangents.

Fluid Impulses.

When a force “f” (fig 11) impulsive or continuous imparts motion to a fluid particle, it meets

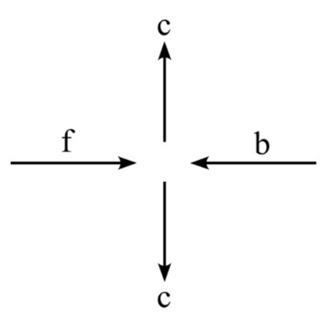


Fig. 11

a resistance “b” due to the inertia of the forward particles.

The pressure of the opposing forces, causes a series of other forces radiating around the point of contact and perpendicular to the line of motion (“f”).

This forms the basis of all fluid action, finding expression in innumerable phenomena, and hence cannot be too thoroughly studied.

Each of the resulting radial forces gives rise to a similar set of movements, and these again to others, till a pressure is produced in the surrounding fluid. This multitude of forces finds a resultant direction of their combined elements, and the fluid particles take up a corresponding movement.

If we examine a section of these forces, the resultants appear as in fig (12). These resultants give rise to two opposite rotations “a” and “b”.

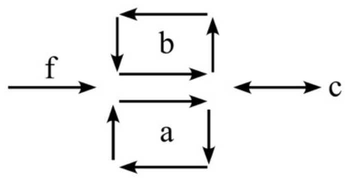


Fig. 12

These rotations if radiating around the lines of impulses, in a fluid mass, give rise to those beautiful rings seen when a quick puff comes from an orifice containing smoke. In its incipient state this phenomenon appears on the under, rounded surface of tobacco smoke, when sinking in quiet air.

In liquid surfaces this law of fluid impulse and reaction produces different phenomena according to the nature and direction of movement. If a pebble be dropped on the surface of water, it will cause concentric rings or waves; whose elements or force, are radiations from the point of contact on the surface of the water.

These different radial elements produce a set of reactions whose analysis is different, according as they are viewed parallel with, or perpendicular to the surface of the water.

When a horizontal impulse is given to the surface of water, by an extended body, a series of concentric semi-curves, of various forms, advances along the surface.

Experiment 1. Apparatus 1.

On a large sheet of glass (leveled), place as much water as it will hold. Then rest the point of a blunt pencil on the glass, and when the surface has become quiet, give the pencil a gentle shove; and a series of concentric semi-circles will advance (best seen by viewing the surface obliquely, looking towards a window). The analysis of the movement parallel with the surface is suggested in fig. (13)

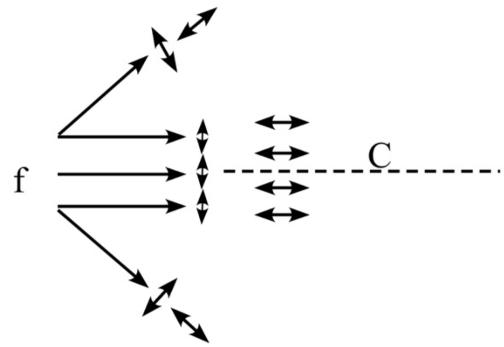


Fig. 13

Here it is apparent there is a difference of pressure in the different directions due to the actions and reactions of the forces, the pressure being greatest on the central line “C”.

These movements on the surface of water result only from impulses: if, however, the force is continued, a set of reverse rotations is formed as seen in exp.(2) fig. (14).

Experiment 2.

Scatter on the surface of the water used in last exp. some fine powder or dust (the water should be free from materials tending to give it a stiff film) and gently blow against it, at a very

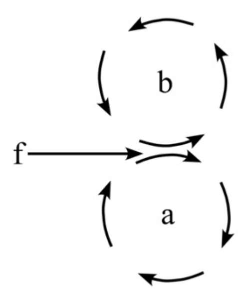


Fig. 14

oblique angle, and rotations “a” and “b” fig. (14) will appear.

Further developments of this law of rotations are seen in the following experiments; the reasons of which are so apparent, that little explanation is required.

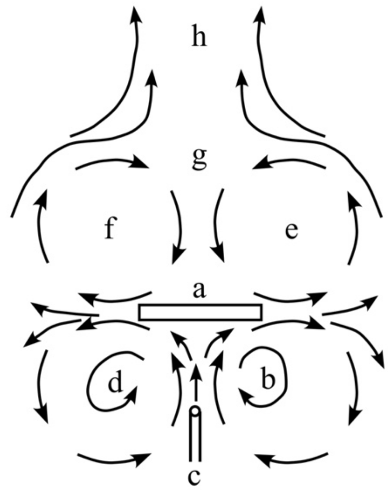


Fig. 15

Experiment 3

Take a piece of glass “a” fig. (15), two or three inches long, and half inch wide, and stand on its side, in the center of this fluid layer. Then blow gently towards it, and against the surface of the water through the tube “c” (this should be connected with the rubber tube and held nearly parallel with the surface of the water). The particles of water being set in motion, strike the center of the plane “a”, causing the various movements indicated. Here we see that each current give rise to two opposite movements, in accordance with the principle shown in fig. (12). The current from “c”, meeting the plane flows in two opposite currents; when reaching the edge of the plane, these are subdivided, part rotating round “d” and “b” and part around “e” and “f”. Two elements of the latter meeting at “g”, are again subdivided, part flowing toward the plane, and part in the direction “h”.

Experiment 4

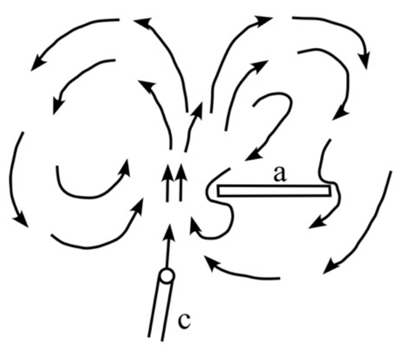


Fig. 16

When the tube is placed two inches in advance of the plane and 3/4 inch beyond its edge so that the current will pass 3/4 inch from the edge the movements take place as shown in fig. (16).

Experiment 5

When the tube is placed parallel with the plane, about one inch away from it, the blast produces the various movements shown in fig. (17).

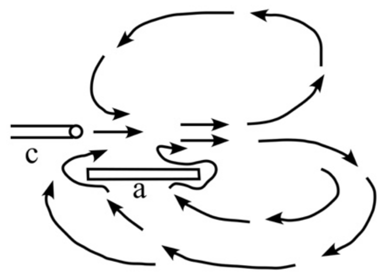


Fig. 17

In passing, I must remark, this experiment suggests the objectionable feature of placing propellers under an aeroplane.

Experiment 6

Place the tube in a similar position relative to a plane twelve inches long, and a further development will appear as shown in fig. (18).

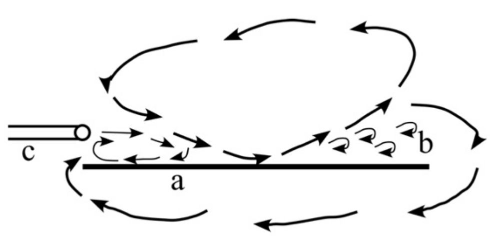


Fig. 18

The particles at "a" have a movement opposite to the direction of the current, and those at "b" revolve while moving with it.

Experiment 7

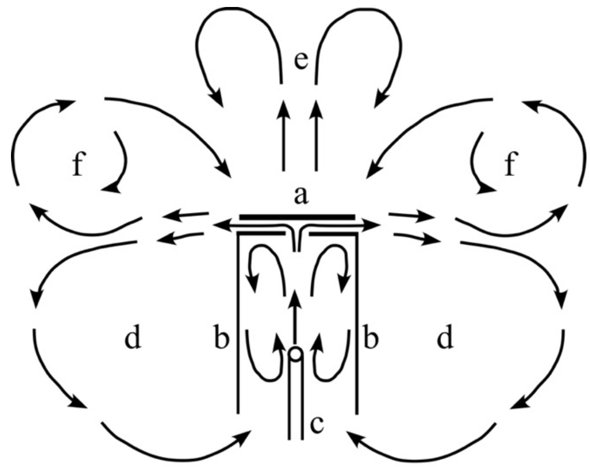


Fig. 19

Place three planes as shown in fig (19); “b” and “b” are small squares. Their small ends are 1/4 inch apart, and 1/4 inch from the center of plane “a”.

A current from the tube “c” will set up a series of movements, whose resultants produce a pressure on the rear of the pane “a”; as shown by a gentle movement from its surface towards “e”; also by the positions of “f” “f” as they appear to be pressed back from the point “e”. This pressure may be also noticed by a movement of the whole surface at the starting and stoppage of the blast.

Experiment 8

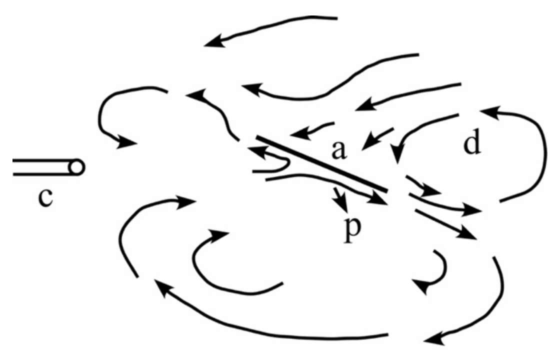


Fig. 20

Place the plane “a” fig. (20) so that the blast will strike it obliquely. The current will be divided. All the upper current “d”, in returning will strike the plane on the upper face. If a little fine meal is thrown near the face of the plane “a”, the particles rebound back and forth, between the plane and an adjacent strata of water, their general tendency of motion being towards “p”. These movements take place in accordance with prop. 6.

In all these various experiments, the nature of fluid currents, produced by a defined force, is manifested. It is also apparent that the current from the tube “c” in all cases produces a pressure on the rear, as well as on the front of the plane.

A further development of these actions and reactions of fluids and solids, in large streams, will be seen in experiments which are best performed and observed in the following apparatus.

APPARATUS 2

A box “ab”, five feet long, two and a half feet wide and six inches deep, illustrated in figures (21) and (22), has a recess extending across its bottom. In this is placed a shaft, reaching its whole length, supporting 6 pairs of fans “f” (the blades are 2-1/2 in. long x 1-3/4 in. wide), placed between partitions of thin material., having appropriate openings at the center and sides, so as to constitute a series of centrifugal pumps. The shaft extends outside through a stuffing box, where it is connected with a water wheel “w” driven by a jet “j”. Four inches above the bottom, there is a false bottom “cd” fastened to the top of the frame containing the centrifugal pumps.

Apparatus 2.

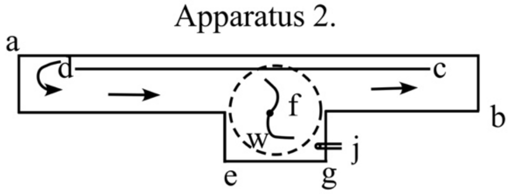
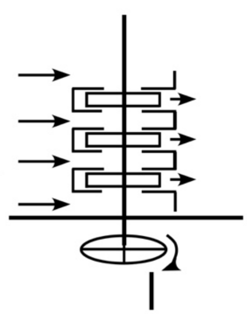


Fig. 21

Section
of the
centrifugal
pumps



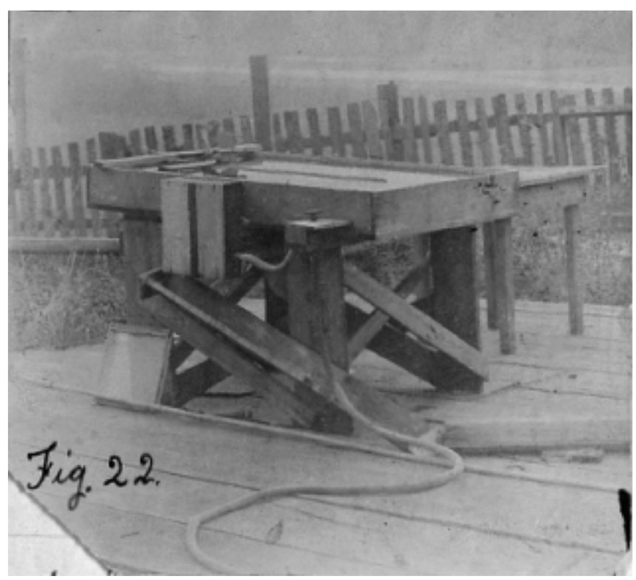


Fig. 22.

This false bottom is formed of thin boards extending to within six inches of the ends, but tightly fitted to the sides, so that no water can pass over it excepting from “c” to “d”. In the center of this parallel with the sides, there is a small thin groove for the purpose of holding thin sharp metallic plates.

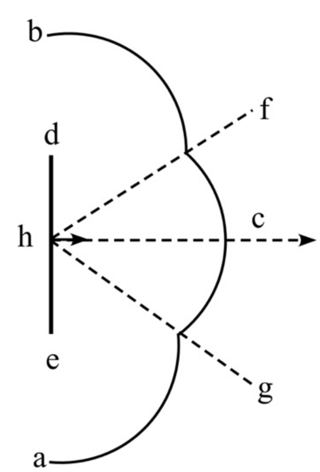
When the vessel is filled with water, and the jet turned on, the rotating fans produce a broad even-flowing stream from “c” to “d”, whose velocity is regulated at will, by a stop cock on the jet pipe. The water over the bottom “cd” is about one inch deep.

This apparatus furnishes the means of many experiments in standing and moving water.

First experiment: to illustrate the movement and nature of an impulse given to a fluid by a plane, is performed thus, in still water.

EXPERIMENT 9

Fig. 23



Take a plane “de” four inches square, and holding it out of the water, give the surface a gentle stroke in the direction of the length of the box; and a wave “abc” as illustrated in Fig. (23) will move over the surface.

The reason of this form will appear from analysis of fig. (13). This form, though prominent at first, gradually changes to an advancing oval wave.

The impulse which appears on the surface as a wave, is revealed in the water by the movement of suspended particles. To observe these movements in the water, throw some wetted bran or saw-dust in it; this will sink and become part of the moving fluid.

EXPERIMENT 10

Start a slow current, and give a stroke (with the small plane) against the stream and the wave impulse will at first move slowly against it and finally remain stationary.

When a steady but limited force is applied to still water, by means of this plane, rotations, similar to those shown in previous experiments, are formed, though varying in many respects, owing to the introduction of new influencing elements.

EXPERIMENT 11

Hold the plane used in exp. (9) in the water, with its lower edge resting on the false bottom “cd”, and move it slowly a few inches, and then stop. Two sets of whirls will pass from its edges, fig. (24), advancing in directions “e” and “f”, separating gradually.

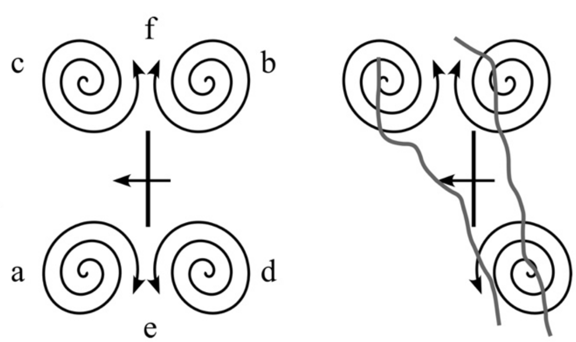
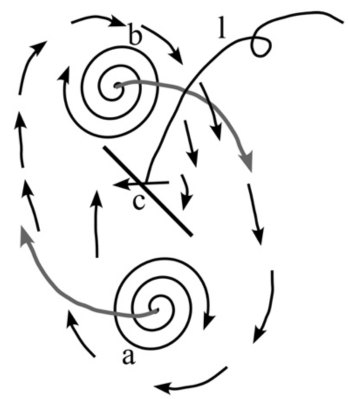


Fig. 24

These movements are produced in accordance with the principles illustrated in exps. (2 and 3), modified however, by a new element of pressure. The plane in passing through the water causes its separation into two currents flowing along its face. These, as in exp. (3) tend to produce similar rotations, but the mass of water beyond the edges drives the impulses to the rear of the plane where they whirl in two circles. When the plane stops, the movements along the face assume their proper rotations and are joined and strengthened by those in the rear; the latter acting somewhat as the currents on the front face in exp. (3).

If the plane is moved obliquely through the water (an angle of 45^o is found best), and then stopped, a similar set of whirls is formed, though that at “c” is very weak (not visible unless the movements are very gentle), and “d” is also decreased some. With a more vigorous movement the whirl at “d” disappears; while those at “a” and “b” are more fully developed; and an incipient movement towards a large rotation, around the two whirls, commences, as indicated by the small arrows in fig. (25).

Fig. 25



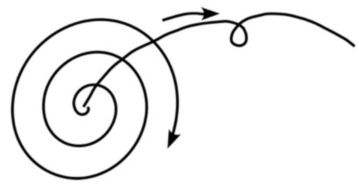
EXPERIMENT 12

Inspection of the figure shows that the whirl “a” presses on the front edge of the plane’s face; while “b” presses upon the rear edge of its back.

EXPERIMENT 13

If at the instant of stoppage, the plane is lifted from the water, the opposing elements of the two rotations coming in contact at the point “c” neutralize one another. This then becomes a center of rotation, and the center of the two whirls move along the line of the large arrows while the center “c” of rotations, moves along loop “l”, and shortly the movements develop into the rotation shown in fig. (26).

Fig. 26



As this plane is moved obliquely to the current, the latter is reflected from the surface according to prop. (6), illustrated in exp. (8) fig. (20), and presents the full development of the principle stated in prop. (7).

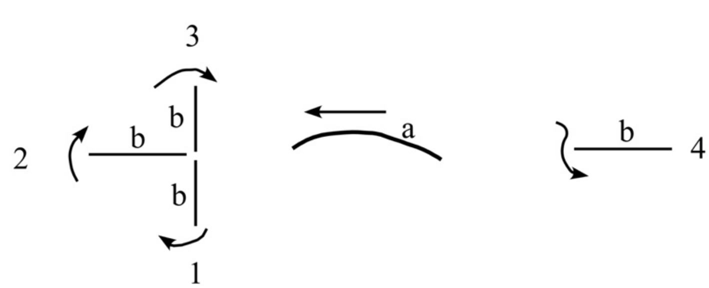
This rotation continues for a considerable time; its velocity decreasing with its increase of area. The resistance to its movement is minimum; as the particles, at its circumference, being mobile, roll around with it upon the adjacent fluid, just as the ball bearings of a journal in its box. And as there is no direct forward resistance, the particles following one another in their orbits, the principles causes of loss in motion are centrifugal force and viscosity.

It will be noticed that, at all times when a flat plane is moved in the water, there are separate rotations, which unite only when the plane is removed, and not even then if adjustments are not correct. This results from the inharmony existing between the fluid movements, and the shape of the plane. If the plane is of such a form as to correspond to the movements, they blend into one complete rotation; as will be shown in the following experiments with the parabolic surface.

EXPERIMENT 14

On the false bottom of app. (2) fasten a plane "b" (6 inches long), in the four positions 1: 2: 3: 4: for four successive experiments. Then take a sheet of metal, 10 inches long bent to the form of a parabolic curve; placing it as shown in fig. (27), give it a regular but limited motion as indicated.

Fig. 27



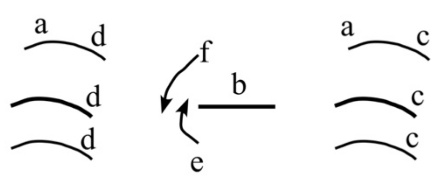
The suspended matter in the water will reveal a movement in the direction of the arrows; thus showing a complete rotation around the plane. When the plane is stopped in these experiments, a small whirl, corresponding to the rotation mentioned in prop. (8) will appear to develop under its front surface and escape around the front edge. This may be seen best by removing the plane "b" and slowly moving the curve "a" about a foot, then stopping.

The ascending and descending movements may be shown in a current thus.

EXPERIMENT 15

Fasten the plane "b" fig. (28), in the groove of the bottom, and place a little sand at its front edge, then start the current. If adjustments are correct, the sand will not be washed around the edge from either side, but if the plane "a" is placed in any position "c" in the rear of "b", the sand is washed in the direction "e", and if it is placed at "d", the sand is washed in the direction "f". These movements demonstrating the rotation of the current.

Fig. 28



EXPERIMENT 16

The complete rotation in the stream may be seen by the following method, based upon the surface reaction of a current.

Whenever a liquid moves in a channel, there is a tendency to a reverse movement at all sides, noticeable on the surface of a very slow current. This surface movement may be used as an indication of tendencies towards any motion; and in the present case is made use of thus.

Place a parabolic plane, properly adjusted (as described in the next exp) and start a very slow stream. On its surface scatter dry bran. The stream will flow on without much apparent deflection, but the surface current will follow any of the fluid impulses (its movements being revealed by the floating bran) and taking up the rotary tendencies of the water, will advance against the stream on the concave side of the plane, and rising in front of it, will move with the stream, then descending behind the plane will turn and <u>advance</u> again. The whole adjacent surface, thus moving around the plane.

These movements are peculiarly interesting and seem to leave no possibility of doubt concerning the existence and direction or rotation around the curved surface.

EXPERIMENT 17

The following experiment shows the workings of this rotation around the curve, thus revealing the admirable operation of many of the laws and principles stated. The curved plane “ae” fig. (29) is placed in the center of app (2), and held in position by resting a rod on its upper edge and the side of the box. A little sand is placed at its front edge “a” and the current started.

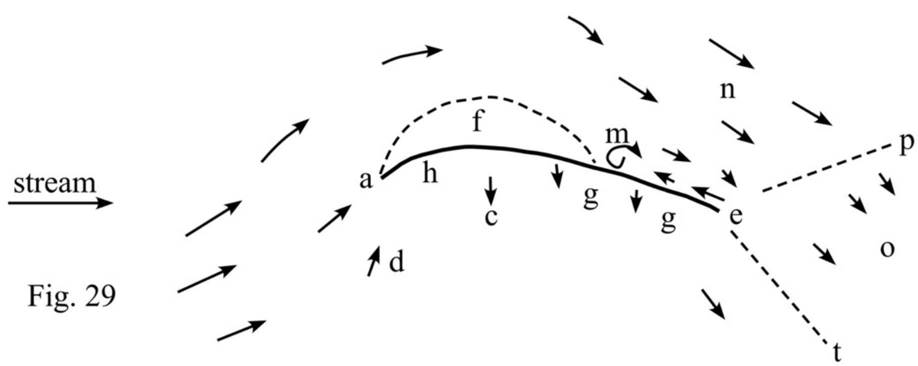


Fig. 29

If the plane is too abrupt to the current, the sand will be washed from the under to the upper surface at “a”; and vice versa if inclined too much. After the plane is properly adjusted, so that the current divides at “a”, fine sand is scattered all around it and some fine corn meal between “e” and “m”.

The directions of the currents at different points are shown by the movements of the sand and meal, and are indicated in the figure by the small arrows.

There is a small whirl at “m”; the sand is rapidly washed away from “f”, but has a tendency to lodge at “h”. It is thrown violently from the surface at “g”, “g”. There is a sweeping whirl around and away from “f” causing a deep depression in the water. The surface from “m” to “e” is in a state of great disturbance, manifested on the surface by conflicting waves, and in the water by violent jerking movements of the sand. This disturbance is due to the meeting of the current swinging around “e” and that of the descending element of rotation. The water at “eg” and “em” is nearly level, that at "eg" being the higher; thus indicating a small upward pressure at this section of the surface. The water in the rear, towards "o" is more or less turbulent, and two lines "et" at [*sic, and*] "ep" are visible (that at "ep" is observed with difficulty). In front of "a", the surface is furrowed with parabolic tracings, whose axes are parallel with the steam.

The water on the under concave surface is quite calm. The level commences to rise at "a", reaches its highest point about 1/3 back from this point and then gradually lowers towards the rear edge "e".

In these experiments, we perceive the blending and united effect of the two rotations exhibited in exp. (12) fig. (25). These rotations are due (as already stated) to the reflection of a fluid from a plane moving obliquely, in accordance with the principles stated in prop. (6) fig. (7); exp. (8) fig. (20). But as the particles reflected from the plane, and moving along its face, fig. (20), are held in connection by the influence of the surrounding fluid, they tend towards a common rotation, according to prop. (7) fig. (8).

This common rotation becomes possible, either when the deflecting plane is removed, as in exp. (13); or when the plane's surface is of such a nature as to force these two rotations together. This is accomplished by a parabolic surface, placed in the proper position; which cutting off the escape of the movement towards the front edge, forces it to blend with that towards the rear.

These two tendencies, being blended, move as a unit of rotation, which reacting on the surface that forms it, produces the pressures discussed in prop. (9) fig. (10).

Having observed the action of a plane, oblique to a current, we shall now examine that of one perpendicular to it.

On referring to propositions (8 and 9), it will be noted, that the form of surface adapted to fluid movements, is determined by the consideration of two distinct phases of the problem.

1st: That of pressures against a plane perpendicular to a stream.

2nd: That of rotations due to fluid reactions.

We have just seen that the latter development is immediately related to the reflection of a stream from an oblique plane.

In the examination of pressures and movements produced in a steam by a plane perpendicular to it, it is first necessary to point out the connection between the different phases just noted.

Referring to prop. (7) fig. (8), it may be observed, that the development of rotation is due to the change in direction of the sphere “c”, and its influence on the sphere “b”, through the rod “a”. The movement of “c” after reflection is resolved into two elements, one against the movement of “b” and the other perpendicular to it.

When an oblique plane reflects a current, the particles in the different portions of the current are brought into the same relations as the two spheres “c” and “b”, producing the rotations already pointed out, particularly in exp. (13) fig. (26).

As this rotation is produced entirely by the change in the movement of one portion of a fluid mass, it is developed in all cases when such a change takes place, whatever may be the cause of the change.

In fig. (23), it is shown, that when a fluid impinges on a plane, in a normal direction, a wave of reaction moves form the surface.

This wave is composed of equal and opposite reactions on either side of the line “hc”, indicated by the resultants, “hf” and “hg”. Each of these tends to form a movement of rotation; but, as their tendencies are mutually opposed, they hold one another in equilibrium on the line “hc”, produced indefinitely.

Should the reactive pressure on either half of the plane “ed” be removed, the rotation due to the remaining half will become manifest.

Since the line of reactions, “hc” is indefinite, the number of possible centers of rotation is also indefinite.

All the elements of pressure on one side of the line “ac” are mutually reactive in all directions, and hence, the extent of the rotation, in any instance, is determined by the location of the point, where the reaction from the opposing side ceases to exist. This statement is in accordance with that made in prop. (8); in which we are at liberty to assume any point along the line of reactions, fig. (9) as the origin of a parabolic curve.

Since the pressure on one side of the line ”hc”, fig. (23), holds the other in equilibrium, either may be replaced by a plane extended along this line.

In which case, either half of the plane “de” may be removed; and then we may make an examination of the pressure and motions by the other half.

The following contrivance furnishes the means for this, and other investigations.

EXPERIMENT 18

Place a plane “b”, fig. (30) (a thin strip sharpened at “S”) about three feet long, in the groove of apparatus (2); and fasten a plane “a” to the device shown, resting on the pivots “p p”, and controlled by the rod “R”, so that it may be lowered at will, on the side of plane “b” as shown in fig. (31).

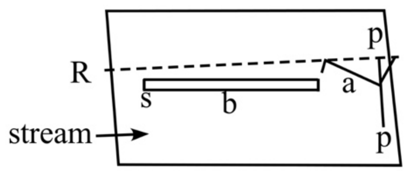


Fig. 30

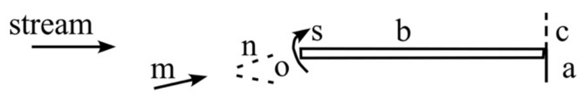


Fig. 31

Sand is scattered before the point “s”; the current is started, and then “a” is lowered. The impulsive shock it gives the current is transmitted as a wave on one side of “b”, taking about four seconds to reach the point “s”. The instant it arrives, there is a rapid washing of sand, indicated by the arrow, which continues as long as “a” remains in position, and about four seconds after it has been raised. The influence of “a” extends several inches in front of “s”, manifested by the moving sand at “m”.

With my crude means of observation I could detect no difference of time in the transmission of the impulse for different sizes of the plane “a” or different velocities of the current; though I believe there should be. The only differences noticeable were the greater extent of the influence before the point “s” and the height of the water level on the two sides of the planes. This difference of level, on the plane “b” was, generally, nearly as great as that between the front and rear surfaces of the plane “a”; indicating the great pressure on one face of “b”.

EXPERIMENT 19

If a small plane “n” (shown in dotted line fig. (31) is placed at the point “s”, a position may be found in which its edge cuts the current and no movement escapes from the under surface to the upper side of “b”. If the plane “n” is about three inches long, and “a” two inches wide, the point of “n” may be removed about an inch from the line of “b”. And although the plane “a” is thus partly shadowed from the current, the pressures are not decreased. The point of the plane “n” may be lowered as its length is increased. However the angle “o” decreases with this increase of length, i.e. the plane “n” approaches parallelism with the stream as its length increases. This variation in the length and inclination of the plane, corresponds to like variations of parabolic planes in streams.

The smallest plane “a” used was 3/4 inch wide, and all the foregoing effects were produced with it.

The height of water is greatest at the intersection of the planes “a” and “b” and decreases very gradually from this point towards the point “s”.

The decrease along the face of “a”, towards the edge, is more abrupt, and forms a curved line.

Several interesting combinations may be made with the plane “b”; e.g. have it separated into sections, or have it continued in the rear of “a” or have it divided in two parts, with the front portion hinged at the point “s”. All these exhibit interesting phenomenon whose descriptions must be omitted here as they would only be superfluous.

EXPERIMENT 20

If the plane “b” is removed, the level on the face of “a” falls and the highest point removes to the center. On placing a similar plane to “a”, along the dotted line “c”, the level on the face rises to the original height and form.

If sand is placed in front of the plane “a” it is thrown from the face in impulsive movements; while on the surface there is a constant darting out, of wavelets. These two sets of movements indicate that the pressure consists of impulses (the impact upon and rebounding of the water from the plane’s face). This conclusion is strengthened by the observations made concerning the rate of transmission of the plane’s effect, both in lowering and raising it.

EXPERIMENT 21

If the plane "a" is lowered in the stream the advancing wave is similar to that shown in fig. (23). As this moves over the surface the particles of sand which roll along with the stream are checked or impeded in their motion, proportionally as they are nearer to the plane; and do not regain their original velocity till after the plane has been raised.

By glancing over the surface of water, towards the plane, at the advancing wave, its height at different points may be noticed and just as one would suppose from the study of fig. (13) is greatest in the center. These waves may best be observed with the plane "a", not less than four inches wide.

EXPERIMENT 22

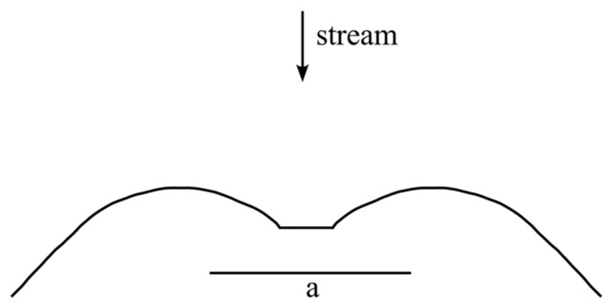


Fig. 32

If the current moves <u>very</u> slowly against the plane, a pair of beautiful, sharply defined parabolic curves, having slow pulsations, appears on the surface of the water, before the plane; these are best seen by the light of a clear sky reflected from the surface. fig. (32) gives an idea of their appearance.

These being delicate, are controlled by small influences, and sometimes can only be seen to advantage by placing the plane about 16 inches from the rear end of the box. The influences, most likely to affect them, are the depth of water and the film on its surface. These curves <u>recede</u> from or <u>rest</u> on the <u>face</u> of the plane according to the <u>velocity</u> of the stream.

EXPERIMENT 23

Similar curves appear on the surface and in the water when the plane is oblique to the stream and may be observed as follows:

The plane “a” fig. (33) is placed obliquely in the stream and fine sand scattered around it. A current moves in the direction “c” which washes the sand away.

The surface of the water before the point is marked by wavelets, indicated by the dotted lines.

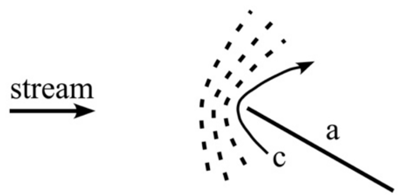
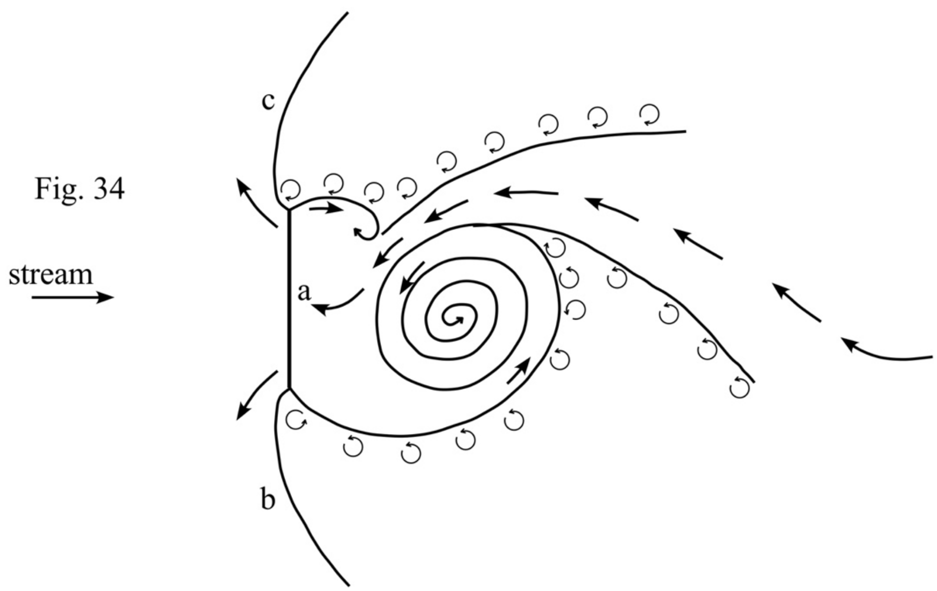


Fig. 33

These and the line of the current “c”, are parabolic curves whose axes are parallel with the stream. The curves in this and the last experiment are due to the movements of the fluid particles, which being reflected from the plane, rush obliquely across the stream, and in accordance with the principles stated in props. (2 and 3) follow parabolic paths.

EXPERIMENT 24

Fig. 34



Within the curves, shown in fig. (32), there are two rotations, presenting many points of interest. These rotations are in the rear of the plane, have opposite movements, emerge from the edges of the plane and each presses upon the edge opposite to its location.

A pressure is thus produced between them, which causes them to waver for a short time, after which they commence to swing from side to side, in isochronous movements, receding from the plane and separating. The times of these movements are proportional to the size of the plane and inversely as the velocity of the current.

The curves “b” and “c”, fig. (34), coming around from the face of the plane, and the moving sand, pulsate in harmony with them. In the rear there is a long line of sand and floating particles, moving towards the plane, waving like a flag as they advance. The fig. (34) gives an idea of the rotations and wave movements.

The little curved arrows represent small whirls that continually dart from the edges; moving with the current. As one spiral develops it recedes, then a new one is formed from the opposite edge. At their point of contact their motions are in the same direction and the old one partly winds into the new one. The waving movement is along the circumferences of the receding spirals.

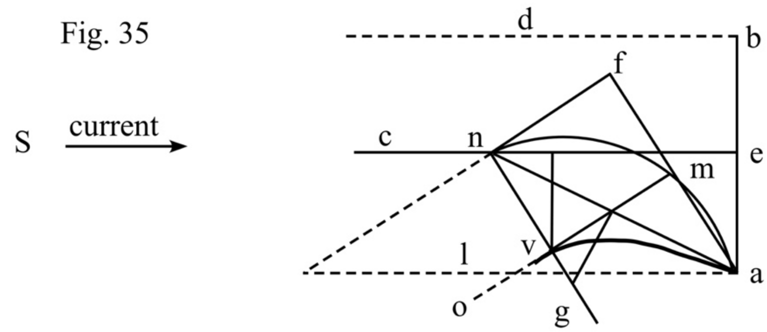
These movements present various appearances in rapid and slow streams. When bran is scattered on the surface of the water before the plane, in a very slow stream, the graceful oscillations are very fine, and their variations are majestic when the plane is large. The phenomenon of the waving current naturally suggests the solution of the waving of flags.

The foregoing discussions and experiments seem to disclose the main principles involved in the beautiful phenomenon of soaring.

Before making a combination of these in a full explanation, it appears advisable to offer a few suggestions concerning the very practical questions as to the proper rate of curvatures and the correct positions of aeroplanes.

These may be determined, most readily, by means of prop. (8) in which the pressure exerted by a current against a plane, is considered as being due to a moving column of fluid, whose length is indefinite and whose base is “ab” fig. (9).

Fig. 35



From the edges of the base, two lines parallel with “ce” form imaginary limits. At all points along the length there is a pressure existing between the central line “ce” and these limits. Therefore, as stated in prop. (8), a parabolic curve of movement may be constructed from any point on the line “ce”, to either edge of the base. But, if a similar curved surface is placed in this position so as to receive the impulses of the moving fluid, and then the pressure on the opposite side of the line removed, it must be inclined to the current so as to receive from it, an element of pressure corresponding to that taken away. Such suggestions, as are necessary on these points will appear in fig. (35).

Let “ab” be the base, “bd” and “al” the limits; “ce” the central line of reactions, and “S” the current, of figure discussed in prop. (8). Incline the base “ab” to any position “af”.

At the point where the limit line “fn” cuts the line of reactions “ce”, erect a perpendicular, cutting the line “mo” at “v”. This point is the center of reactions between the system “vma” and the current “S”.

This point then becomes the vertex of the curve; “vg” is the axis’; “vm” and “ma” the co-ordinates (y and x) of the point “a” in respect to the axis; “an” is the tangent to the point “a”, and “g” the focus, of the required curve.

When the co-ordinates are known the curve may be constructed from its equation ($y^2 = 2\ px$). Or it may be constructed mechanically by reference to the tangent “an”. The relations of angles, formed by inclining the plane “ab”, will also give the point “v”.

EXPERIMENT 25

In testing the correctness of the construction given by this formula, I used thin metal strips about six inches long, bent to curves of different focal lengths, varying from 1/2 to 1/6 of their chord.

When placed in a stream and their point of equilibrium found (by means already described) they occupied different positions according to their curvature. Those of the shortest focal-length were the most abrupt to the current. This being in accordance with exp. (19) and the formula just stated.

These relations of the curves and currents are strictly in accordance with the theories first stated in "consideration second" fig. (2). However, in their practical application, there are elements which produce great modifications both in rate of curvature and inclination.

These will appear in the following experiment.

EXPERIMENT 26

Take two strips of metal, equal in length, bent to the same curvature, but differing in width, so that when placed in the stream, the upper edge of one will be above the surface, and that of the other below it (the second being totally submerged).

Place the first in the stream, and find its position of equilibrium, and mark the points occupied by the front and rear edges. Having removed it place the second in the stream, and adjust it. The positions occupied by the two will be found greatly at variance. The latter being far more abrupt to the current than the former.

The reason of this is. The reactions from the rear of the narrow plane escaping with the current over the side, do not extend their influence towards the front and produce the upward thrust of the current which constitutes the <u>important</u> feature of this phenomenon.

From this experiment it is apparent, that the escape of air around the ends of a bird's wings must be prevented as much as possible. This is accomplished by giving them great length.

It also shows why there is an increase of angle towards the ends (as the escape of air is greatest here).

And in conjunction with the formula and exp. (25) explains, why the curvature decreases towards the ends.

According to these, the front edge is lowered as the curvature decreases.

This property of different curvatures comes into use towards the outer ends, where there must be some compensating element to keep the wing surface from striking the air too abruptly.

Having given the main points derived from a long series of experiments, I shall conclude this branch of the subject with a few suggestions on other means of experimenting.

Most of the phenomena mentioned may be seen in air by a similar apparatus to No. (2), having larger fans and a glass covering to confine the air, as a current over the false bottom. Many others may be seen by placing two large sheets of glass horizontal and parallel, about an inch apart, and projecting between them, a beam of light from a slit. In a darkened room, the particles of floating dust or smoke will reveal the movements of air, which are well shown in the sheet of light. The various phenomena may be shown by projection.

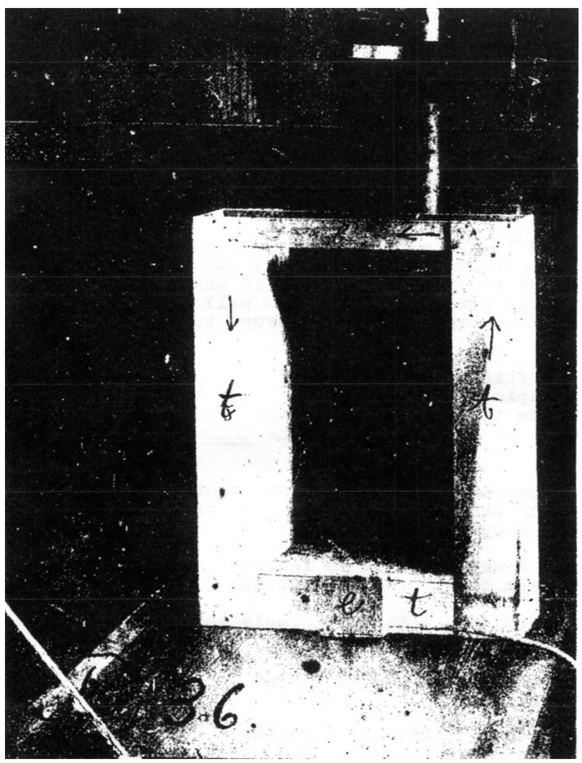


Fig. 36

The simple movements, by placing a sheet of glass on which there is a layer of water covered with dry bran, in a horizontal projection apparatus; and the movements in streams, by similarly placing an apparatus designed on the principles of app (2) illustrated in fig. (36).

This consists of a wide shallow trough “b”, with a glass bottom, open at the ends and connected with the tubes “t t t”, in which there is a small centrifugal pump at “e”. When filled with water and the pump started, a current moves in the direction of the arrows.

Particles of suspended material, and sand will reveal the movements of the currents. The planes used in the experiments, must not be higher than the surface of the water, and a plate of glass should rest on the surface, to prevent distortions of light by the ripples.

When it is desirable to observe the wave formations on the surface, the glass should be omitted.

The movements of the fluid particles may be recorded for examination at leisure, thus. In an apparatus similar to No. (2) though smaller (its proportions should be something as follows: 2 feet long, 1-1/2 feet wide and 2 inches deep) the motions may be traced on glass placed over the stream, or photographed. The layer of water over the false bottom should be only 1/2 inch deep, and the space between it and the bottom of the box, should also be 1/2 inch, so that the water here, might be kept in brisk circulation, and thus prevent the lodgment of suspended particles, used in tracing the movements of the currents. The deflecting metallic planes used, should be short, and wide enough to extend only to the surface of the water. And a sheet of glass, large enough to cover the entire surface, cemented on the sides of a square frame should rest on the upper edge of these experimental planes, and in contact with the water. Some coarse white saw-dust should be put in the water. When adjustments are right, and the stream started, the particles of saw-dust carried by the currents will reveal their movements. If the stream is slow, their movements may be followed and traced on the glass with a pen, using ink in which a small quantity of sugar has been dissolved. When the tracing is complete, a thin sheet of paper placed on it, and rubbed with the side of a pencil or other small cylinder, will take up the ink impression.

The movements may be photographed, by placing a camera above the apparatus, and giving a short time-exposure with a rapid plate. In this case, the particles moving along will leave a tracing. By the lengths of the tracings of different particles, their relative velocities may be compared. In this experiment the false bottom should be black.

APPLICATION TO AN EXPLANATION OF SOARING FLIGHT

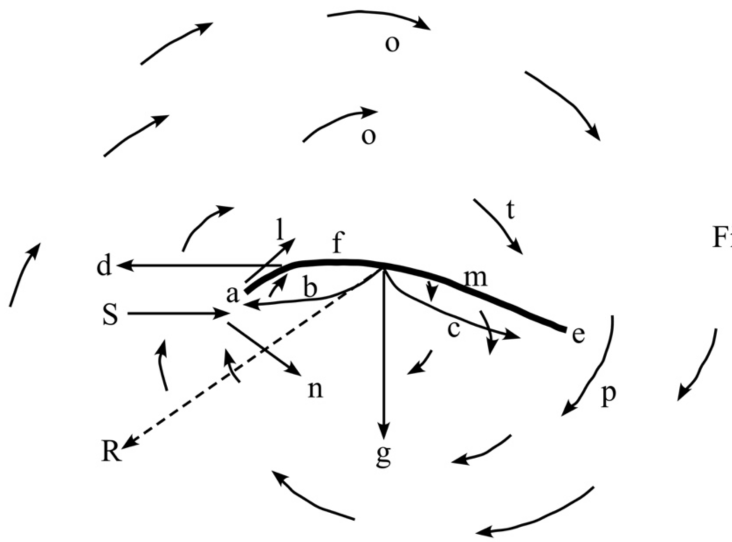


Fig. 37

Application of the various principles of fluid movements, to the explanation of soaring flight.

Let “ae” represent a section of a bird’s wing, and “g” the movement caused by gravity.

As the wing surface encounters the lower air, it produces the currents “b” and “c”. These currents escaping around the edges “a” and “e” move in whirls as shown in fig. 34.

The work performed by gravity, during an instant of time, will be found in the descending bird and the two opposite whirls.

Now suppose the surface be given a motion in the direction “d”, equal to that of “b”; then the air in the line of this movement, meeting the surface with a velocity “S” equal and opposite to “b” will counteract it, and produce a tendency of escape in the directions “l” and “n”. But the pressure in the directions “n” is met and opposed by counter movements from the line of reactions, “g”. The only escape then, is in the line “l”, and the air following the course “S”, takes this direction. The air moving in the direction “b” is thus prevented from escaping beneath the point “a”, and then must move from this point towards the rear edge “e”.

In this development we perceive the division of the air by the action of gravity, and its immediate recombination into one movement (this can only occur if there is actual fall) by the horizontal motion and the curved surface.

The combined current flowing towards the edge “e” escapes in a whirl, to the upper rear surface; but the particles in front of the point “a” moving in the direction “l” produce a rarefaction at “f”, and meeting the resisting air at “o”, are driven powerfully in the direction “t”. Between “e” and “m”, they meet the whirl coming around “e” and force it in the direction “p”.

The air rising at “l” tends to accelerate the motion of the air above the surface and the movement at “p” develops a counter tendency in the air below.

By these processes a retrograde revolution is formed and perpetuated.

If we observe, that the two movements “g” and “d” cause the surface to travel in the oblique direction “R”, the application of the principle stated in prop. (7), and demonstrated in exps. (13, 14, 15, 16, 17) will be apparent.

The forward ascending element, of this retrograde revolution, tends to drive the surface upward; but under the combined action of the surface and the upper air it is driven down, and strikes the lower stratum of air from which it rebounds to repeat its upward thrust.

It might appear that the weight of the surface would force this rotating cylinder down; but it must be remembered, that his rotating mass holds its position, in virtue of the resistances on its opposite sides, and the wing surface is one of the resistances which oppose the upward component of rotation.

[*The following paragraph has Chanute’s marginal note with the word “fallacy” written twice.*]

The loss of motion sustained by the rotating cylinder is compensated by the reflection of new elements of force, from the under surface. In exp. (24), it appears that the work, developed by a fluid striking a surface, escapes in isochronous rotations; but, here, this work is thrown into this one rotation. Thus an impulse of gravity see fig. (2), may perpetuate itself for a time, producing a series of resultants between the wings and the lower air (according to principle shown in fig. (4), whose sum exceeds the element retained by the bird.

A notable feature of this rotation, is, that, while the loss of motion is sustained on the outer surface of the revolving mass, the new impulses that supply its motion, are generated in the center. And the energy thus imparted, slowly escapes to the outside, after having produced repeated impulses on the wings.

[*The following paragraph has Chanute’s marginal note with the word “fallacy” written once.*]

Owing to the structure of the wings and the distribution of pressure on the different parts (see prop. (9) and exp. (17)), the backward pull of gravity is counteracted.

In the act of soaring, a bird may at any time acquire new velocity and energy, by tilting the front edge of its wings, downward. It thereby partly intercepts a forward thrust of the rotating air, and is also pulled forward by a component of gravity. As it increases in speed, the cylinder rotates more rapidly and forces the bird upward where it resumes its former position.

In concluding this explanation it seems proper to make a few remarks regarding the best form of hull, or body; as the successful accomplishment of soaring depends in a measure on reducing the head or hull resistance to a minimum.

For this purpose the body of the bird is given such a shape as to receive a pressure from the rear which partly counteracts that on the front.

A brief consideration of principles and experiments, mentioned, may give such suggestions as are necessary at present.

We have seen, that, when a body moves through a fluid, the pressure is divided; part impedes the movement of the body and part gives the fluid a lateral movement.

In exp. (3) fig. (15) it is shown that his lateral movement produces, by means of reactions, a pressure on the rear of the plane.

Now, it is well known, that the form of surface determines, to an extent, the pressure developed by a fluid striking it, one that is convex, developing less than a concave surface.

Hence, if the front surface of a body is convex and its rear concave, any current striking it on the rear must have a greater proportionate effect than that which strikes it on the front.

Referring to prop. (5), we find that a lateral current in a stream gives rise to a movement which at first is convex and then concave. From this, it appears that a body having such a form would encounter the least resistance; as its form would correspond to the movements of the different lateral currents and present surfaces best suited to receive their pressures.

However, the pressure on the rear would, probably, not be equal to that on the front, on account of losses sustained between the time of impact on the front and reaction on the rear. Yet the deficiency, due to this loss, would be minimized by the operations of the current flowing along the surface as demonstrated in exp. (6) fig. (18); in which it appears, that the current flowing parallel with the surface “a”, first produces a suction and then a pressure. It is probably that owing to these influences, the form as indicated in prop. (5), should be somewhat modified to obtain the best results. However, more definite data on these points may be given after further experiment and investigation.

From this explanation of soaring it seems, that gravity, which is as yet the great obstacle to the accomplishment of flight, may become the ever present and potent agency by which we may be sustained and carried from place to place, without other exertion than that of directing the movements of a soaring apparatus. And aerial locomotion will be accomplished with delightful ease, instead of requiring the almost superhuman effort so universally supposed.

This explanation will be objected to, because it asserts, that, gravity which usually pulls an object down, is made the means of elevating and propelling it through the air. Any such assertion is met by the argument, that this is perpetual motion, or a creation of energy.

I am not prepared to deny that this is perpetual motion; but, I certainly claim the privilege of questioning the conclusion, that perpetual motion is a creation of energy.

This conclusion, though ponderous with the weight of opinion and venerable with age, does not carry an overwhelming argumentative potency; because of the unfortunate fate of many philosophic conclusions, when confronted with facts revealed by investigation and experiment. Scientific history is dotted with instances of the ruthless havoc caused in the most erudite conclusions, by some trivial phenomenon, that refused to be governed by the rules prescribed in books.

Many students of aeronautics, who have availed themselves of opportunities of unlimited observation of soaring flight under all conditions, have repeatedly asserted, that birds may, and do soar in a quiet atmosphere; but their assertions have always been silenced by a gratuitous denial and counter assertion, that this would be a creation of energy.

Let us see whether this assertion is correct.

When a force acts upon a body which is free to move, it may develop a movement with its direction, lateral to it, or against it; the direction of the motion depending upon the nature of the body and external influences.

The last of these movements claims our attention, and the principles involved will be partially developed in the following considerations.

There seem to be two general principles, in virtue of which a body may move against a force that operates upon it.

1st: A repetition of an impulse received from the force.

2nd: A division of the force, whereby a counter tendency is developed, which exceeds the direct pressure.

Suppose a body equal in weight to a cubic foot of air, at 0^o (1.29 oz), be dropped from a height of 27000 feet; it will develop an energy of 2160 foot-pounds, and will occupy about 41 seconds in falling (resistance of air and variation of gravity being neglected).

If this energy be applied as a direct impulse to sustain this weight against gravity, it will support it for about 82 seconds.

But suppose this energy be transformed into heat, which is used in expanding a cubic foot of air contained in an envelope. In absorbing this amount of heat, the air will double its volume, and be capable of supporting a weight equal to its own, viz. 1.29 oz.

If the envelope be impervious to heat, the energy thus imparted to the air will be capable of supporting this weight indefinitely.

In these two cases of applied force, we see the energy developed by gravity performing different quantities of work against it.

The continuance of this work by the heated air, is due to the rebounding of the air particles, whose amplitude of motion being increased by the applied heat produces the buoyancy which sustains the weight. In other words, the work performed by gravity in one period of time is continually repeating itself, so as to produce a constant counter effect.

A similar phenomenon (dependent on an entirely different development) is observed in the working of a gyroscope; in which, a force by its action on the rotating mass, produces a counter tendency. This is best seen in the operation of a reeling top, which under proper conditions rises against gravity, in the process of it gyrations, owing to the effort of gravity, to force it down.

In these two instances, there are several points which might be discussed with some advantage, but may be omitted, as the mere statement of the phenomena serves the purpose of showing that a force in acting on a body may repeat itself so as to produce an equal or greater counter tendency.

[**Vessel Tacking**]

In the following instance a further development will appear, in which a similar effect is produced principally by a divided action of a force.

When a vessel is tacking against a "head wind", she derives her power to move against it, by developing a divided action of the wind, and from a partial repetition of the divided elements.

In the process of tacking, the sails are "close-hauled", and the vessel swung to her course, which is usually five points to the wind. In this position, the wind strikes the sails very obliquely, and its pressure is so divided, that, while one element tends to drive the vessel with the wind, the other gives her a lateral movement. In consequence of the vessel's position and the reaction of the water, she takes an oblique course; and her gain on the wind depends upon the difference between the element of the wind's direct pressure and the opposing element of the vessel's oblique movement.

Though the division of the wind's force is the fundamental cause of the vessel's gain, yet it is not the only one.

Since the wind strikes the sails obliquely, there is formed a set of reactions and changes, according to the laws discussed in the study of fluid movements; and the wind, as it approaches the sails has a slight movement towards the stern. Also, in consequence of the wind pressure normal to the keel, the vessel moves to leeward of her course. In this movement, she strikes the water obliquely, thus giving rise to a set of fluid movements which causes the water ahead to rush from leeward to windward.

As a result of this, there is an extra pressure on the lee-bow which must be counterbalanced by holding the helm to windward.

It thus appears, that the work, of the wind, is repeated to a certain extent. In the first case, giving rise to an increased lateral movement of the vessel; and in the second, developing a movement in the water which diminishes her leeway.

This series of operations, viz., the <u>division</u> and repetition of a force is developed to a greater extent in other phenomena, in which there is a division, recombination and repetition.

The accompanying fig. (A) suggests this development in its simplest form.

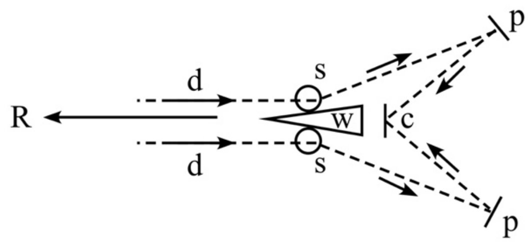


Fig. A

Let two elastic spheres "s" moving in the direction "d", come in contact with the wedge "w". They will impart to it, a slight movement towards "c", and will react on one another, through the wedge, producing movements in the direction "p" "p". On meeting the planes "p" "p" they rebound towards "c", and striking the base of the wedge, drive it in the direction "R", with a force exceeding that imparted to it at the first impact.

In this system, these particular points are to be noted.

1st: A contrivance which brings the elements of the force (the two moving spheres) into such a relation, that they react on one another producing opposite movements.

2nd: An exterior resistance, by which the divided elements are so changed as to tend to a common effort.

And 3rd The form of the contrivance which enables them to impress upon it, their combined energy.

Before applying this development to fluid phenomena, some of the general properties and movements of fluid particles must be noticed.

Since the particles of a fluid are elastic, they rebound from a surface immediately after their impact; and the pressure they exert is due to the momentum of their impact and reflection, and consequently must be expressed by a resultant of these two movements.

In view of these considerations, it is necessary to make distinctions relative to the positions of particles in a stream, and the forms of surfaces they act upon.

The particles, which come in contact with the surface, in rebounding from it, exert a reactive influence on those immediately following. And in proportion as their reflected direction has an element of motion against that of the stream, they produce a retardation, and thereby build up a wedge of pressure, whose base, is the resisting surface, and whose length is indefinite.

These elements of impact, reflection and retardation are pointed out in exps. (20, 21).

In consequence of this wedge of pressure, the advancing stream is gradually turned from its course, and impresses but a small portion of its energy upon the opposing surface.

It then appears from this, that the principal pressure on the surface is derived from the action of the particles proximate to it. Then it is manifest that the form of surface should have great influence on the amount of pressure imparted to it by a stream.

Regarding the forms of surfaces, three general types are to be noted, plane, convex and concave.

The first stands as the medium between the other two.

The particles, striking it in a normal direction, are reflected from it with an equal velocity, and impress upon it a momentum, equal to the sum of their direct action and reaction.

The second form, instead of reflecting the particles back, merely deflects and scatters them; hence receives a less pressure than the first.

While the third form (the concave surface) not only reflects the particles, as a mass against their first direction, but causes a concentration of their movements, which prolongs the duration of their escape and increases its velocity, and thereby it receives a greater momentum from their reaction than that imparted to the plane surface.

This conclusion may be repugnant to some ideas concerning motion and energy; but I trust the following considerations will show it is not against the principles of mechanics.

The increased reaction of the escaping air is due to a continued exchange of momenta between the air particles and the deflecting surface, in accordance with the laws of momentum; expressed in the following statements.

As momentum is expressed in terms of mass and velocity, the momentum of any body may be indefinitely increased by augmenting its velocity.

The opposite momenta, which two elastic bodies impress upon one another are proportional to the intensity of their action and its duration.

Since two bodies in conveying to one another opposite momenta simply exchange their motion, there is not, necessarily, any consumption of energy.

In this exchange of motion, they may act by direct impact or by transmitted impulse.

When they operate by direct contact, they collide and immediately rebound, hence, their action is of very short duration, and the motion exchanged is correspondingly limited.

But when they operate by transmitted impulse, they are capable of acting upon one another indefinitely; and the amount of transferred motion is proportional to the time of action; and this, in turn, is dependent upon the manner and conditions of operation.

Inasmuch as these principles of momentum have special application in the present study, the points relative to the exchange by transmitted impulse are suggested in these illustrations.

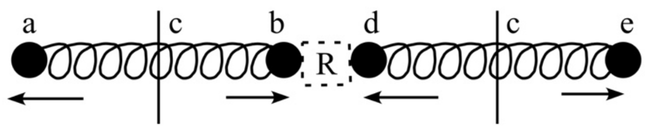


Fig. B

Let “a” “b” and “d” “e” be spheres of equal weights connected by springs.

Each set of spheres and the connecting spring is supposed to be free from exterior influences and perfect in its operations.

Now let each set be given simultaneous vibrations. The spheres “a” and “b” moving apart will stretch the spring, and coming together will compress it; but owing to their equal and opposite movements the center “c” remains at rest. The same may be said of the other system.

As they are supposed to be free from exterior influences and their action perfect, there can be no change in their locations, and no loss in motion of the vibrating parts.

Now, suppose, while the spheres “b” and “d” are moving as indicated, a resistance “R”, placed between them, brings them into such a relation that they react upon one another through it; then they impart opposite momenta; or in other words exchange a portion of their opposing motion.

Because of this change in energy, they do not operate with the intensity necessary to counteract the pull of the spheres on the outer ends of the springs.

And as a result, these continue their outward course, and the centers “c” commence to move.

This movement of translation is due entirely to a simple exchange of equal and opposite momenta.

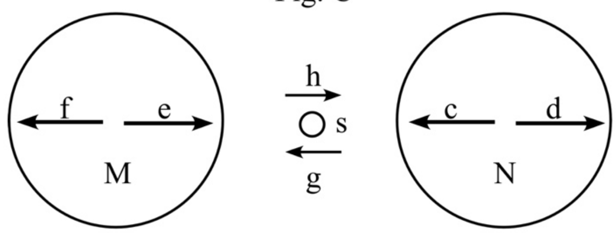
This exchange has necessitated no loss in the internal power of the systems, and while moving, they continue to vibrate as before.

If the resistance “R” continues to exist between them, they may, at each vibration, exchange new impulses of motion, thus increasing their velocity apart as long as the elements engaged in this transmission of energy are efficient.

The principles involved in their efficiency, will become apparent in the discussion of the next illustration.

Let “M” and “N” be two equal bodies of great mass, in a state of rest. Each may be considered as being held in equilibrium by equal and opposite forces, indicated by the large arrows.

Fig. C



Since they are in equilibrium and rest, the algebraic sum of the opposing forces of each sphere and also of those of the entire system is equal to zero.

If these bodies be brought into such relations that the opposing element of force in each, which holds it in equilibrium, may be exchanged from one to the other, then they will move in the direction of the predominant force.

Let “s” be a small elastic sphere, impressed with a single impulse “h”, towards the mass “N”. At the instant of impact it will impress upon the latter the force “h”, which is added to “d”; but owing to the reaction of the opposing force “c”, it immediately rebounds, moving in the direction “g” carrying a portion of the force “c”, which it impresses on the mass “M”, thus increasing the force “f”. Here again it suffers a reaction from the element “e” which drives in [*sic, it*] towards “N”, where it adds a new element to the force “d”, and again receives an impulse of reaction.

This process may proceed indefinitely; the two bodies exchanging their counterbalancing elements; and as the loss of equilibrium increases by the increase of one force and the decrease of the other, they move apart.

The amount of force they are capable of thus exchanging depends on the efficiency of the medium “s”.

There are four elements which determine this, viz. its mass, and velocity; and the distance between the bodies and the motion they assume.

For a given intensity of the operating medium “s”, the quantity of force it exchanges at any instant is proportional to the frequency of its impacts; but this is inversely as the time occupied in passing from one body to the other. Hence the quantity of force exchanged is inversely as the distances between the bodies. It follows from this, that the efficiency decreases as the bodies commence to move apart.

But there is another cause of decrease, due to the increasing velocity of the bodies.

At all times the velocity of impact, is the difference between the velocity of “s” and that of one of the bodies from a fixed point. And as the velocities of impact and reaction are the same, the velocity of “s” <u>towards</u> the fixed point, at the end of the reaction, is, its velocity before impact, minus the velocity of the mass. According to this, the velocity of “s”, gradually decreases as that of the masses increases.

From this element of deterioration, the medium “s” gradually loses its power of conveying force; and there comes a time when it ceases to act, i.e., when its velocity of reaction from one sphere, is not sufficient to cause it to reach the other.

It appears immediately from this, that a given impulsive force, developed between the two bodies “M” and “N”, is more or less efficient, according to its nature. A great amount of force stored in a large mass with slow motion, is necessarily limited in its operation, because the bodies soon assume its velocity, and it can no longer act; but the same force in a smaller body moving with a greater velocity can continue its action for a longer time; thus repeatedly exchanging new impulses of force between the bodies, and accelerating their motion; its duration of action being in same direct ratio of its velocity.

It therefore seems safe to conclude, that the motions of two bodies going in opposite directions, are due rather to an exchange of momenta, than an absorption of energy.

Should this be objected to, then it may be asked, how else can we account for the motions due to attractions and repulsions? These are defined as <u>forces</u> in virtue of which, bodies tend towards or from one another.

If these are properly forces; and if bodies, in obeying the impulses of a force, absorb it; then it follows, that attractions and repulsions must disappear as impelling forces, and be found in the motions of the bodies attracted or repelled.

Under this supposition, we should notice continual diminution of attractions and repulsions in all bodies. Instead of any such change, their powers are constant; and any two bodies, attracting or repelling one another, are found, at all times, moving in opposite directions.

Viewing the questions of motion in this peculiar aspect, it seems more than probable, that the tendencies of bodies to move towards or from one another, are due simply to an exchange of momenta between them, by the reciprocal action of their respective elements through intervening media.

In the illustration offered in fig. (C) the rebounding sphere "s" was supposed to exchange large momenta between the bodies, owing to their large mass and the slow development of motion, which kept them within the limits of its influence for a long time.

A special development of this idea is necessary for the present study.

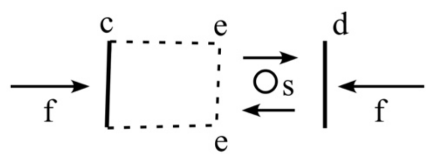


Fig. D

Let "c" and "d" be two bodies urged in the directions of "f" "f", by a limited force; and "s" an elastic sphere rebounding between them, and exchanging just enough of the counter forces "f" "f" to keep them at a fixed distance apart.

Now suppose that an obstruction "e" "e", be placed against the surface "c" so that the surface "e" "e" bisects the distance from "c" to "d". Then the sphere "s", having only half the distance to travel, between the reflecting surfaces, will double its impacts, thereby doubling the pressure between the bodies "c" and "d". As these are held in position by a limited force. they must, under the increased pressure move apart, till the forces are again equalized. If after this readjustment, another obstruction similar to "e" "e", limit the movements of the sphere "s", the movement of separation will be repeated.

In these illustrations of motion arising from the continued impact of an elastic body, the all important element is, the continued relations, of the bodies (exchanging their momenta) which allow the rebounding medium to repeat its impulses.

In applying these laws to the operations of a fluid coming in contact with a concave surface, this development appears.

When the particles impinge on the surface they are reflected towards a common point, and tend to form a *vena contracta* [the point in a fluid stream where the diameter of the stream is the least] in their escape.

In this effort to escape in a limited space, the particles in advance are urged forward by those in the rear. In turn they react on the latter, driving them towards the surface, which receives additional impulses of impact and reaction.

As all the reflected particles endeavor to pass out through this limited space, these actions and reactions continue, for a time, between the escaping particles and the surface.

And the mass of fluid, which strikes it at any instant, tends to form itself into a jet, whose velocity increases as the duration of its escape, and whose reaction impresses the reflecting surface with a proportionate momentum.

The fluid movements I have here indicated may be observed as follows. In the stream produced by app. (2), place a sheet of metal bent to a semi-circle, and drop some fine meal before it – the concave side facing the stream.

The particles will rush towards the center, and either pass rapidly out against the stream or rebound against the surface. Sometimes a single particle will continue indefinitely, to rebound between the out-going water and the surface; thus clearly indicating the operations of the imprisoned particles in developing opposite momenta.

Other phases of the continued reaction of escaping fluid particles appear in the following illustration.

Suppose two plane surfaces, a foot square be erected a foot apart, on a table. Now, suppose another plane, a foot square, be placed between them at their upper edges, and let fall. In descending, it will press upon the air driving it out at the two open sides. The air dividing at the center of the surface, will flow equally in either direction, exerting a reaction against the descending plane.

Now suppose another plane be so placed as to cut off the escape at one of the sides, and the third plane again raised and let fall. In this case the opening for the escape is only half that of the first instance, and if the plane descend at the same rate, the air must escape with twice the velocity and its reaction will be doubled; or, if the plane descend under the same pressure, the reaction of the escaping air will double its duration.

In this illustration, it appears that a given mass of air, moving with a given velocity, against a body, is capable of producing different quantities of work, according as it is allowed to escape as a divided or a united current.

Incidentally, it is to be observed, that his illustration intimates an increase of average pressure per unit of surface, with an increase of area; and also an increase in the rate of resistance, with an increase of velocity.

The first of these appears from this consideration.

When the air is free to escape towards either edge, it divides at the center of the plane; and the particles at this point are impeded in their escape only by those between the edge and the center. But, when the escape at one edge is cut off, those furthest from the side of escape are pressed back by the whole mass along the surface of the plane; their reactive pressure from this cause is greater in the latter instance.

Now, suppose instead of this combination, there be another consisting of a plane two feet long which descends between parallel planes of the same length; then, the reaction last stated will exist on each half and the total pressure on the double surface, with free escape at both edges is greater than that on two planes of one half the size under similar circumstances. Demonstrations of this conclusion are given in exps. (19, 20).

The increase of the rate of pressure with increase of velocity appears from the following.

The illustrations, just given, show that the reaction of the escaping particles is inversely as the limit of the escape.

On referring to exp. (22) fig. (32), we find that the water escaping from the face of the plane, moves in curves whose distance from the plane varies (in some ratio) inversely as the velocity of the current; this indicating that the increased pressure due to the impact of the fluid particles decreases the limit of the escape.

Under the supposition that the limit of the escape is decreased with an increase of velocity, it follows, that the reaction of the escaping particles is increased correspondingly.

Then, as the pressure on the surface is due to the impact and reaction of the fluid particles, it must be expressed in terms of the velocity of impact and the velocity of the escape. The latter should be expressed in terms of the velocity of impact ± some variation dependent upon this.

The principles, pointed out in the foregoing discussions, find special application in some phenomena of fluid action which at first sight seem contrary to mechanics.

The development of that pertaining to the division, recombination and repetition of a force, suggested in fig. (A), may be observed in the little disk instrument, devised (I believe) by Professor Willis.

When the jet of air strikes the outer disk, it is divided, and the particles reacting on one another are mutually driven in radial lines from the center. And in accordance with the laws of aspiration, produce a rarefaction, in consequence, of which the disks are forced together. Comparing these operations with the illustration given in fig. (A) it appears that the outer disk, at the point of impact, brings the air particles with such a relation that they drive one another asunder. And hence it receives but a portion of the pressure of the impact. But it receives less from the escaping particles, which moving radially, encounter only a small resistance, and consequently exert little reactive pressure. As the particles rush along between the disks, their diverging movements are blended into a united force, lateral to their movements, and opposite to that of the impact.

In this development of a counter force, we observe the influence of the exterior elements the extended surfaces of the disks and the atmospheric pressure.

The principle of force, demonstrated by this simple apparatus, is carried a step further in the phenomenon of soaring; in which there is a compound division of force, a reunion and a repetition of impulses.

When gravity draws the bird down, its energy is divided. Part is found in the descending bird, and part in the air set in motion by the pressure of the wings.

Now the question is; can the element of gravity force found in the moving air produce such resultants, as will overbalance the element, found in the descending bird?

In the tacking of a ship, we saw that one of the elements derived from dividing the force of the wind, is capable of developing a resultant which <u>exceeds</u> the <u>opposing</u> pressure of other element. As a consequence, the vessel advances <u>against</u> the <u>force</u> that gives it <u>power</u>.

If this principle applies in one case, it may in another; though the nature of the operating force be different.

As the movement of a ship in tacking against a wind, depends upon the division of the wind's force, and the subsequent development of one of the elements; so, the descent or ascent of a bird, depends upon the division of the force of gravity and the relatively advantageous application of the force absorbed by the disturbed air. The efficiency of this force depends upon the volume of air set in motion, its velocity, the manner and continuance of its application.

As a bird sinks through the air the fluid particles, beneath it, are divided, and flow principally around the edges of its wings.

As the air has free escape in the two opposite directions, its reaction is weak; hence the work of gravity, transmitted to the air, is expressed in terms of a large mass with a slow motion.

According to the illustration of fluid reactions (last given) if this divided current be blended into one movement, it may operate for a longer time with the same intensity.

This prolonged operation is secured by the formation of a united rotation.

From the various experiments and studies on soaring already mentioned, it appears, that thus divided, current, formed by the sinking of the bird, is blended into a retrograde rotation, by the movement through the air and the form of the wings.

This rotating mass, then, contains the energy of gravity, imparted to the air, in its effort to force the bird down.

Since the ascending portion of this rotation is continually acting against the wings of the bird, and is, in turn, driven against the lower air, from which it again rebounds, the energy of gravity imparted to the air, continues for a time to repeat itself.

The movement of rotation makes it possible for the elements of impact and escape to continue their operations without confusion and mutual destruction; as the impact rises with the ascending element of rotation, and the escape moves with the descending.

Owing to the universal adaptability of the air to the most complex movements, the three processes of the development of energy in two opposing currents, their reunion into one movement of rotation, and the repetition of their rebounding impulses between the wings and the lower air, are continually and simultaneously carried on.

It will appear from these considerations that the energy imparted by gravity, to the air surrounding the bird is not directly the power by which it is elevated. But this energy is confined in the rotating mass of air, whose elements rebounding between the wings, and the lower air, impart opposite momenta, to them, according to the principle illustrated in fig. (C) and (D). And the bird rises or descends according as the upward momentum thus imparted to it, is greater or less than the downward impulses of gravity, which it retains.

This movement depends upon the mass of rebounding air, its velocity and the frequency of its impacts.

In a general way, it may be stated that the area of surface determines the mass, and the rapidity of horizontal motion, and the weight conjointly, establish the velocity of its movement, and the frequency of its impacts.

To conclude -- it appears that the soaring as herein explained, is not a creation, but a transformation of energy in accordance with mechanical laws which have not been fully developed.

These laws, though constantly operating in familiar phenomena, have remained hidden, because the mechanical principles of these have not been fully analyzed.

Probably the first positive indication of these laws, was given by the little disk instrument.

The operation of this is so extraordinary that one is, at first, inclined to doubt the testimony of his senses. And when fully convinced of its certainty, he asks himself, for the first time, have we mastered the elements of mechanics?

Whatever may be the explanation of its *modus operandi*, the one great principle it establishes, is, <u>that a force in operating upon a body may produce a counter tendency greater than its direct effect.</u>

The universality of this principle is made manifest by several phenomena, particularly the movements of variously formed bodies against an impinging stream or jet, mentioned occasionally in the published experiments of the students of fluid-dynamics.

The conclusions prompted by these extraordinary manifestations certainly run counter to some suggested by the first studies of mechanics.

And as the laws, upon which these are based, are as yet undeveloped, none dare predict the limit of their application.

Then it seems hardly due to discretion to maintain, that the peculiar manifestations of force, found in these limited instances, cannot exist in others more extended in their application and utility. Neither does it appear consonant with the lessons taught by experience to assert, that these infant eccentricities of force, [*end of Regina Cleary's typed copy*] are incapable of other results than the amusement of the curious; for all that is great in the discoveries of science, was first observed in trivial phenomena.

[*The following page, number 130, was taped in three places, which has turned nearly opaque over the years, rendering some words unreadable.*]

When Galvani's frog started convulsive quivers at the electric thrill, who would have thought that this was the feeble [unreadable] [unreadable] to man of that mighty [unreadable] which would one day transform the world and minister to his every want; carrying his thoughts with inconceivable rapidity around the Earth, making his voice heard in its remote parts, bearing his burdens in tireless effort, and changing the dismal shadow of night, into the scintillating splendors of a Fairy-Land!

These few but suggestive phenomena of fluid manifestations seem no less worthy of a still grander transformation.

[*The last page, number 131, was written over at a 45-degree angle with the notarized inscription, rendering some words unreadable.*]

Already they reveal themselves in flight, for whose attainment, man has yearned so incessantly for years whilst vainly he has endeavored to pierce its veil of mystery by his scrutinizing gaze and which after years of unordered[?] contemplation crys [*sic, cries?*] out more light; yet more light.

As the eagle glides along in graceful majesty through improbable space, borne aloft by a power almost preternatural he seems to betoken possibilities in the future never dreamed of in our philosophy.

And can we say this power not perpetual?

Then[?], who honors but the Chimera of[?] the past, banished from the schools, and exiled in every land, may yet rise as masters of the world?