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SOME ASPECTS OF PHYSICS IN WAR AND PEACE[1]

PART I. SOME APPLICATIONS OF PHYSICS TO WAR PROBLEMS

A YEAR ago in Baltimore we met with peace in prospect. The armistice had been signed. But like a strong runner who had just gotten under way we found it difficult to stop. We continued many of the programs of war. Many of us were still in uniform. Our thoughts were still largely concerned with those problems upon which we had been engaged. But now most of us are back to our normal pursuits, eager as we had been during the war to contribute our energies to securing the welfare of the nation. The tumult and the shouting dies, the captains and the kings depart, still stands the ancient and abiding sacrifice, the labor of unselfish service which we regard as the natural birthright of scientific men.

We are still too near the war to get a clear perspective of the extent to which the various agencies contributed to its successful prosecution. But we can examine it in part and later the results of our examination can be gathered together. It had been my intention to pass in review the many ways in which physics had been applied to the problems of war, but these had been so numerous and so extensive that my time would be given to a mere enumeration of the activities. For the war was one of many elements and many dimensions. Leaving aside the human and, I may add, the inhuman elements, and considering those confined to space, we had warfare in the air, on the surface of the earth, under the earth, on and under the sea. Applications of science were everywhere. Many of the applications of physics have been presented else-

[1] Address of the vice-president and chairman of Section B—Physics—American Association for the Advancement of Science, St. Louis, December, 1919.

where and at length. You have been told the story of aviation, of the physical laboratory on wing; the story of wireless between stations on the surface of the earth, under water and high in the air; the story of signaling through the darkness of night or the brightness of day; the story of sound-ranging, of spotting enemy guns and the explosions of our own projectiles seeking out those guns and of the re-directing of our guns until those of the enemy had been destroyed; the story of submarine detection and of the extremely valuable applications which the study of that problem brought to us—the ability literally to sound the ocean—the ability to guide a ship through fog or past shoals. These and other stories you know. Indeed, many of you contributed to their unfolding. It is my desire here to present briefly some developments in a branch concerning which little has been written, viz., warfare with guns, projectiles, bombs. Later I want to turn from the contemplation of problems of war to view our subject in its relation to peace.

The English playwright, John Drinkwater, represents Abraham Lincoln as saying "the appeal to force is the misdeed of an imperfect world." Unfortunately the world is still imperfect. In the horrible business of killing people in war, guns of all sizes and kinds are the effective weapons. Have you reflected on the enormous extent to which artillery was used in the Great War? According to Sir Charles Parsons, on the British Front alone, in one day, nearly one million rounds of nearly 20,000 tons of projectiles were fired. Extend this along both sides of the Eastern and Western fronts and you may gain some idea of the daily amount of metal fired by guns.

The actual American contribution of artillery to the war was very small but at the time of the Armistice we were making progress. In America we often measure things by money. The total amount of money authorized for artillery, including motor equipment, was $3,188,000,000, and for machine guns was $1,102,600,000. Judged by the money expended for them, guns are of importance. It is essential that we get as effective guns as possible and that we know how to use them. Aircraft, and anti-aircraft warfare, barrage firing, long range guns—all of these call for a very complete and accurate knowledge concerning the motion of a projectile and the energy required to carry it to a certain place and to cause it there to explode at a chosen time. Exterior and interior ballistics are thus matters of great importance.

For two hundred years or more the subject of exterior ballistics has been regarded as belonging to pure mathematics. But into this realm physicists at times intruded. To Newton we ascribe the law that the resistance which a body experiences in passing through the air varies as the square of the velocity. But that great scientist made it clear that that might not be the only law. Euler, one hundred and fifty years ago, proved various mathematical results. Assuming the air resistance to vary as the square of the velocity and that the density of the air did not change with altitude, he showed that the coordinates x, y, and the time can be computed by quadratures. His method of taking the angle of slope of the trajectory as the independent variable has been followed by most of his successors in ballistics.

Even in Euler's method the variation of the density of the air with altitude can be allowed for by using small arcs and by changing the constant of proportionality in the law of air resistance to accord with the new density. His method can in general be followed where the law of air resistance is that given by Mayevski, viz.,

$$R = \frac{A_n V^n}{C}$$

where

$n = 2$	for V between	0 and	790 f.s.
$= 3$		790	970
$= 5$		970	1,230
$= 3$		1,230	1,370
$= 2$		1,370	1,800
$= 1.7$		1,800	2,600
$= 1.55$		2,600	3,600

Siacci, with his elusive pseudo-velocity, has been the chief contributor along this line. His method as elaborated by Ingalls and Hamilton has been the standard in American works on ballistics.

In Mayevski's law as given in American texts

$$R = \frac{A_n V^n}{C},$$

C is called the ballistic coefficient. Being the reciprocal of a resistance it represents the penetrating power or ability of a projectile to continue in motion. It is assumed to be constant for any definite projectile. But it was found that when the angle of elevation was changed, or even the muzzle velocity, in general C had to be changed to allow for the new range. Attempts have repeatedly been made to find a functional relation between C and these variables. At certain proving grounds in the United States a relation was supposed to have been established but we find that the law adopted does not agree with data which we have secured from Aberdeen. It follows that, though the mathematical computations have been carried through with great rigor and accuracy, actual firings for various elevations have to be made in order, from the ranges observed, to compute the ballistic coefficient for those elevations. In other words, the ballistic coefficient always contains in it a factor which represents the amount by which the theoretical range has to be multiplied in order to obtain the actual range. If range and time be the only quantities required these can be found by actual firings and almost any approximate law of air resistance will satisfy. But it costs money to range-fire guns. For example, this cost for a 12-inch gun is of the order of $12,000 and for a 14-inch naval gun $20,000. These amounts are apt to be exceeded.

It would be a very great saving in time and money if the range and trajectory of a projectile could be determined with a known powder charge without range firing. This can only be done when the complete law of air resistance is known. The modern problems connected with antiaircraft warfare and with accurate barrage firing absolutely require such a law.

Notwithstanding the fact that the law of air resistance for modern projectiles is unknown and that the ballistic coefficient merely represents an approximate relation between the theoretical and actual ranges, great confidence has been placed in so-called experimental determinations of this quantity. For example, in the official manual for the U. S. Rifle the value of the ballistic coefficient of the ordinary service rifle bullet (.30-inch caliber) is given as 0.3894075 "as determined experimentally at the Frankford Arsenal." The experimental skill which can determine to an accuracy indicated by seven places of decimals a quantity as highly capricious as the so-called ballistic coefficient, is of rather questionable value.

Going back to the law of air resistance, it is evident that Mayevski's law is not satisfactory either to mathematicians or to physicists. There are abrupt changes when the index n is changed. The mathematician can not differentiate at these corners, the physicist can not see the necessity for their existence. The law as laid down by the Gavre Commission which is ordinarily written in the form $R = cv^2B(v)$, where $B(v)$ is a function of v, is satisfactory in that it has no discontinuities. But though it is satisfactory in this respect it may still be incomplete.

The Gavre law or any other smooth law lends itself to numerical integration by the method of Gauss, who developed it one hundred years ago. He used this method in the problem of special perturbations in celestial mechanics. It has since been presented in some text-books in theoretical astronomy. An early application to physics curiously enough was made by an astronomer, John Couch Adams, in the integration of an equation occurring in the theory of capillarity. But though Adams was thoroughly acquainted with this method he apparently did not feel that it was as satisfactory for computing a trajectory as that of Euler. For in an article on "Certain Approximate Solutions for Calculating the Trajectory of a Shot" (Collected Works), he refers the motion to the angle that the tangent to the trajectory makes with

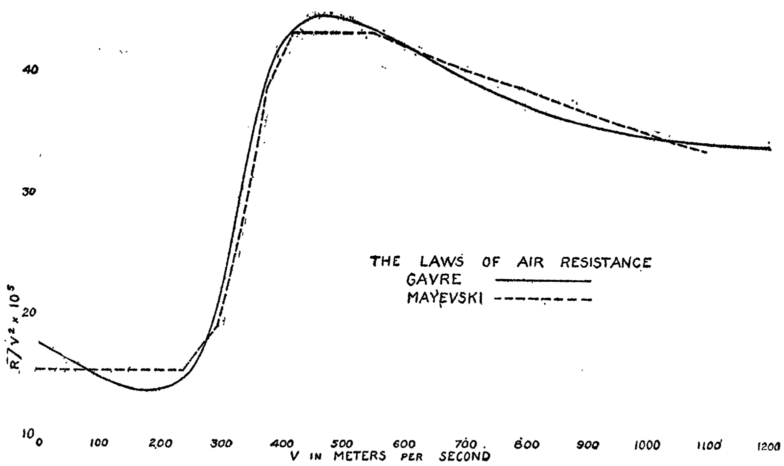

Fig. 1.

the horizontal and uses as a resistance law $R = A_n V^n$, the constants being taken from Bashforth's experimental results.

The method of Gauss, *i. e.*, of using rectangular coordinates, has been used by physicists, to first order differences at any rate, for various computations. In the case of a projectile, if the retardation follows the square law $R = kv^2$, the equations of motion take the well-known form

$$\frac{\partial^2 x}{\partial t^2} = -k\frac{\partial s}{\partial t}\cdot\frac{\partial x}{\partial t},$$

$$\frac{\partial^2 y}{\partial t^2} = -g - k\frac{\partial s}{\partial t}\cdot\frac{\partial y}{\partial t},$$

or

$$\ddot{x} = -kv\dot{x},$$

$$\ddot{y} = -g - kv\dot{y}.$$

If we take as the law of retardation

$$R = cv^2B(vy) = vF(v\cdot y) \quad \text{where} \quad F = \frac{G(v)H(y)}{C}$$

the equations take the form

$$\ddot{x} = -\dot{x}F(v\cdot y),$$

$$\ddot{y} = -g - \dot{y}F(v, y).$$

The change in the retardation due to change in density of the air with height y can be taken account of in the function $H(y)$. As a result of many meteorological observations $H(y)$ may be written

$$H(y) = 10^{-.000045y},$$

y being measured in meters.

In the notation introduced by Professor Moulton $G(v), = vB(v)$, is computed directly from the French tables giving $B(v)$ as a function of v. The form of the function $B(v)$ plotted against v is shown in Fig. 1, and will be called the B curve.

Now if C the ballistic coefficient or penetration coefficient, and the velocity and altitude are known at any time, then $\ddot{x}$ and $\ddot{y}$ are known. If these x and y retardations are constant or nearly so, then the values of the x and y velocities at any later time are known if the time intervals be short. But the retardation depends on the velocity, hence its value for any interval will in general lie between the retardations computed for the velocities at the beginning and end of an interval. One is soon able to approximate to the average—consequently the values of the x and y velocities at the end of the first, and beginning of the second, interval are known. Integration can be performed to find the new x and y and the process can be repeated for the next interval.

After x and y and their first and second derivatives are tabulated for the first four or five short intervals (of $\frac{1}{4}$ or $\frac{1}{2}$ second), first and second differences are tabulated and the computation can proceed in longer time intervals, usually one or two seconds. The formulas for extrapolation are made use of for extending the computation, and the results are checked. Hence a trajectory can be computed taking account of variations of air density with height, and satisfying at all points the assumed law of retardation.

Since the retardation depends on the relative velocity of air and projectile, winds can be allowed for by considering the motion relative to the air at every point. This involves the principal of moving axes. It implies however, that the projectile is a sphere or that the retardation is independent of the angle which the projectile presents to the air, or else that the projectile always turns nose on to meet the air. We know, however, definitely that an air stream of a few miles per hour at right angles to the axis of a projectile may have several times as great a force as the same stream would exert along the axis, and that a spinning projectile can not turn quickly to meet every wind that blows, even though the wind may have but small influence upon the angle at which the air meets the projectile.

It was this method of short arc computation which Professor Moulton applied to the problem of exterior ballistics when he was made head of that branch in the Ordnance Department. For his courage in setting aside the long-established, revered but rather empirical method in use in the War Department, and in introducing a logical, simple method of computing trajectories, and for his energy in initiating and pushing through certain experimental projects, he deserves great commendation. Valuable contributions to the method were made by his associates, notably Bennett, Milne, Ritt. Professor Bennett devised a method which has a number of points of merit. It is the one now used at the Aberdeen Proving Ground. Professor Bliss gave an inclusive method of computing variations in range, altitude and time due to changes in air density, winds, muzzle velocity. Dr. Gronwall greatly simplified and extended the work by Bliss, and made other important contributions. In short, leaving out of account the question as to the correctness of the law of air resistance, the variation of that resistance with the angle of attack of air and projectile, leaving out the motion of precession and nutation which are dependent upon the transverse and longitudinal moments of inertia of the projectile and its rate of spin—leaving out these factors the mathematical basis for finding the trajectory of a projectile is secure.

But the system of forces under which a projectile moves is not the simple one implied by the equations just given. For a projectile is a body spinning rapidly about an axis probably nearly identical with its geometrical axis. It emerges from the gun either with a small yaw, or with a rate of change of yaw, or both. (By yaw is meant the angle between the axis and the direction of motion of the center of gravity.) As in the case of a top, precessional motion results. If the motion is stable, precession accompanied by nutation continues. If unstable, the axis is driven farther from its original direction until the projectile is "side on" to the air, or "base on" to the air. In short, the projectile tumbles. Loss of range and great dispersion are the results.

The condition for stability may be taken the same as that for a top spinning about an axis nearly vertical, viz.,

$$S = \frac{A^2N^2}{4B\mu} > 1,$$

where

A = moment of inertia about the axis of spin

B = moment of inertia about an axis at right angles

N = frequency of spin in radians per sec.

$\mu \sin \theta$ = moment of force about an axis through the C.G. at right angles to the axis of spin, where θ is the yaw *i. e.*, the angle between the axis of the shell and the direction of motion of the center of gravity.

The rate of orientation of the yaw or the precessional velocity is given by

$$\dot{\varphi} = AN \div B(1 + \cos\theta).$$

The relation given for stability, viz., that

$$\frac{A^2N^2}{4B\mu} > 1,$$

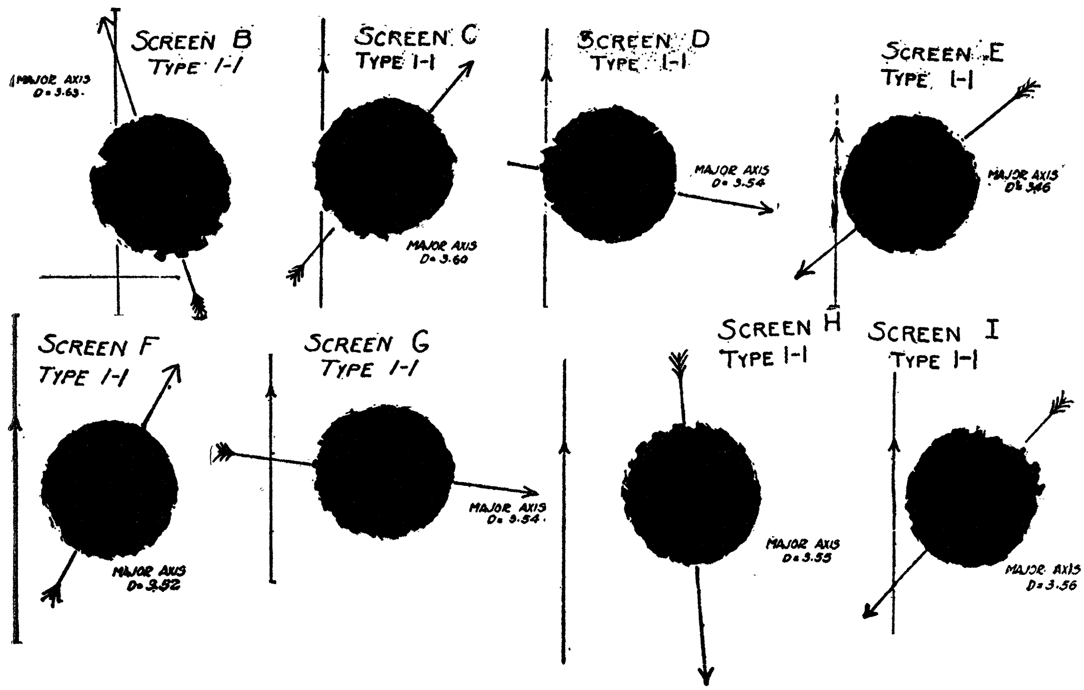

Fig. 2.

is based on the assumption that the torque due to the air is proportional to sin θ. Our air stream experiments throw doubt upon this assumption but the English experimenters, who have made the most complete studies of the rotational motions of projectiles that we know of, seem to confirm it.

These motions of precession and nutation of a projectile can be studied by firing through a number of cardboard screens spaced at equal distances along the line of fire. As has been said, the English have been the foremost investigators in the work. At Aberdeen, under the immediate supervision of Mr. R. H. Kent, a very extended study, following in general the English method, is being made of the stability of projectiles. Cardboard screens are placed at distances of 20 feet from one another for some distance from the gun, then at 100 feet, then at 20 feet again towards the end of the path. A careful study was made of cardboard so as to obtain a kind which would give a clean cut hole. The lantern slide (Fig. 2) shows the variation of the major axis of the hole for eight consecutive 20-foot screens.

It will be seen from Fig. 2 that the major axis of the hole in screens B and C made by the 3.3 inch projectile is about 3.6 inches, and between those screens the angle of the major axis has turned through about 60°. At screens D, E, F, the major axis is about 3.5 inches and it turns rapidly. Here the yaw is a minimum and the rapid motion of the axis is in accord with the theory governing nutation.

If the projectile were moving in a vacuum or if the air forces did not influence the motion, the precessional velocity ϕ' (considered uniform) would be given by

$$\phi' = \frac{AN}{B(1+\cos\theta)} = \frac{AN}{2B}.$$

For the projectile in question $N = 220$ turns per second.

$$\frac{A}{B} = 1/6.$$

Hence $\phi' = 220/12 = 18.3$ turns per second.

Since the muzzle velocity is 2,300 feet per second and the screens are 20 feet apart, this frequency is nearly equal to that of the precessional motion at maximum yaw.

The discussion just given shows what a difficult matter it is to measure the retardation of a projectile by firing through screens. For the retardation must be not only a function of the velocity but also of the yaw. As the latter is periodic there will be a periodic term superimposed on the general term. While the ordinary law may lead one to suppose that the retardation would continually decrease as the velocity dies down it may actually go through the cycle of decrease, increase. For the same reason we may find that the retardation for a shell fired from a gun rifled 1 in 25 may differ from that for the same shell and velocity when the rifling is 1 in 50.

It has been indicated that previous to the introduction of the method of short arc computation by Moulton there had been little change in the field of exterior ballistics in America for several years. In experimental work there had been rather slow progress. That the progress was slow was not so much the fault of the Army as it was due to the non-military policy of the country. When no importance is attached to military affairs by the people we can not expect our army officers to place their service in a position of world prominence.

Recently my attention was called to a letter which may throw light upon one reason for the fact that experimental work was very limited. This letter was written in 1907 from the Ordnance Board to the Chief of Ordnance, requesting that $40 be allowed for experiments in determining the effect on range produced by changing the points or ogives of 50 three-inch projectiles. The experiments were authorized and the money allowed. Trials with only 15 of the 50 projectiles showed that the range was increased from 5,042 to 5,728 yards. It was reported that the coefficient (βc) had been changed from .97272 to .68705. (Note again the extraordinary accuracy in *measuring* this quantity!) The colonel in charge of the experiment deemed further work unnecessary, for he writes (9th indorsement):

> Having established the probable form of the field projectile the board recommends that the remaining 35 experimental shells be made to conform to this design.

However, the Office of the Chief of Ordnance considered that the last word had not yet been said concerning the best form of projectile, and ordered certain other variations to be made in 10 of the remaining 35 projectiles. To provide for this further test it was stated that "a sum of $25 . . . has this day been set aside on the books of this office as a special allotment." (And this was only seven years before the World War started.)

It may be further stated that to this letter authorizing $65 for experimental tests of shells there were 15 indorsements. Those of you who have been in the service will appreciate what this must have meant in the time of stenographers, messengers, filing clerks, and high-salaried officers.

That perfection in the form of projectiles had not been secured was made evident by a series of experiments, rather crude as judged by physical standards, begun at Sandy Hook in 1917, and continued at Aberdeen in 1918. It had been noticed that there was very large dispersion of the shells of the 6-inch gun and the 8-inch howitzer. Various book theories were advanced to account for these dispersions, but finally upon an examination of some recovered shells and as a result of the information obtained by firing through cardboard screens, the true explanation suggested itself. The rotating band on these shells had a raised portion, called a lip, at the rear of the band (Fig. 3). The purpose which this lip was supposed to serve was to act as a choking ring to prevent the escape of the powder blast past the projectile and to seat the projectile at a definite place in the gun. It was seen in the case of the recovered projectiles, and it was evident by the hole formed in the cardboard screen through which the projectile had passed, that these lips were

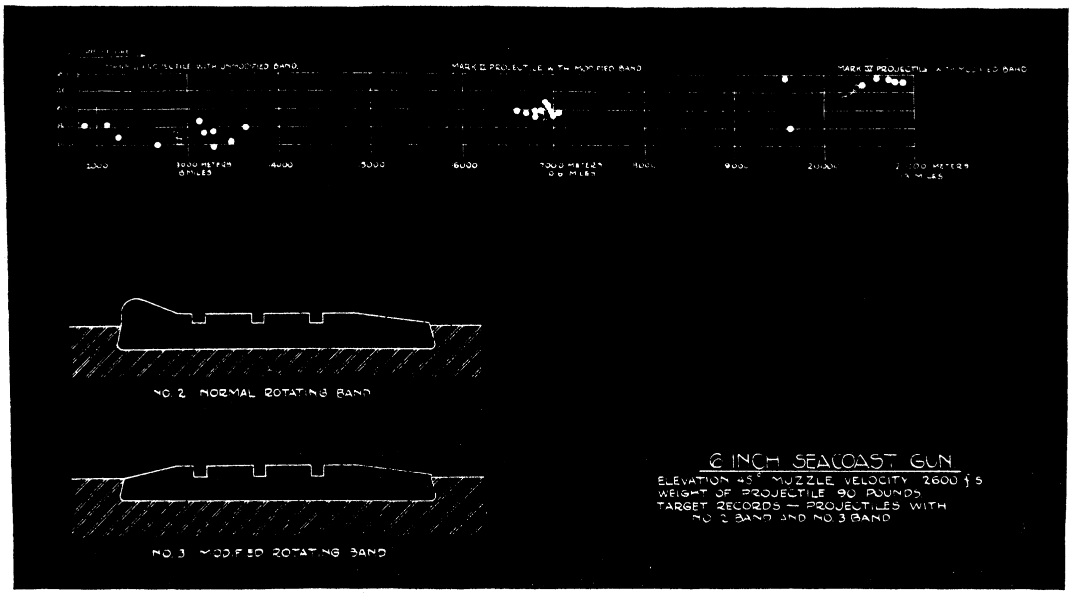

Fig. 3.

partly torn off in the passage of the projectile through the gun. Experiments were then begun in modifying the band. These modifications consisted of machining off the lip as in Fig. 3. The results were very gratifying. The 8-inch howitzer projectile had its range increased by 700 meters and its dispersion decreased in the ratio of 4 to 1, while the 6-inch shell at a muzzle velocity of 2,600 feet per second and elevation of 45° had its range increased from about 12,000 to about 16,000 yards, and its dispersion was divided by four.

A number of experiments of this kind were carried on at Aberdeen, chiefly by Major

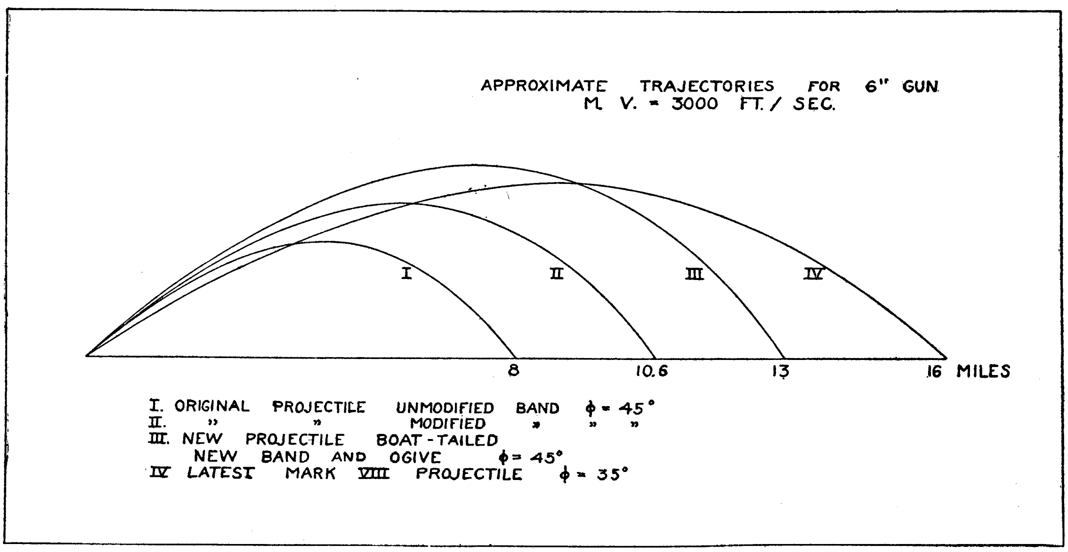

Fig. 4.

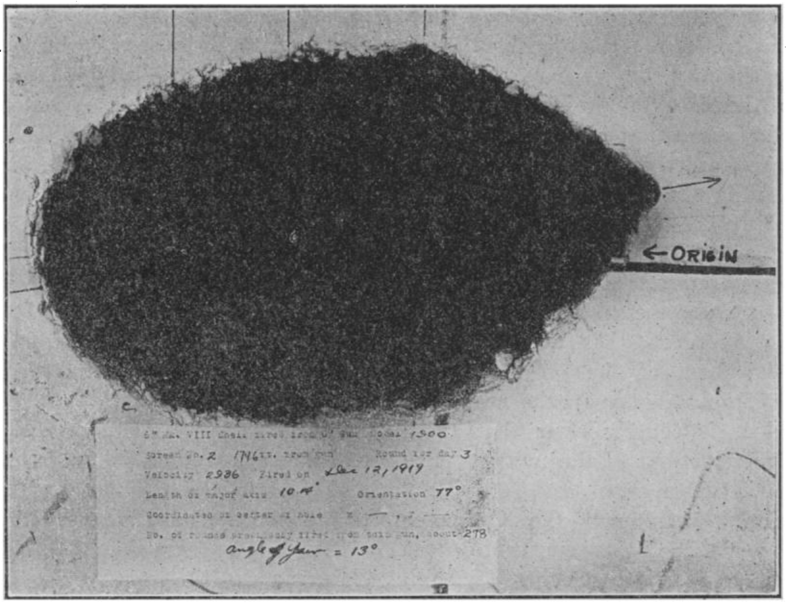

FIG. 5.

Veblen and Lieutenant Alger. In France, similar work was done by Captain R. H. Kent. It is seen that these experiments added greatly to the effectiveness and therefore to the value of the guns in question. The work belongs to physics, notwithstanding the fact that one of these civilian officers was and is a professor of mathematics of the purest quality. That he was able to bring himself temporarily to neglect the fundamental concepts of geometry, in which realm he is one of our foremost thinkers, to enter into the problems of the war with an eagerness for close observation of actualities and a readiness to try out new methods, is very greatly to his credit. He is evidently a physicist by intuition and a mathematician by profession.

It is to be noted (Fig. 4) that between the summers of 1918 and 1919 the range of the 6-inch seacoast gun had been increased from about 14,000 yards to 28,000 yards[2] for a muzzle velocity of 3,000 feet per second, by variations in the form of the projectile suggested by crude experiments. In the case of the last projectile (Mark VIII.) there was rather large dispersion. Had the cardboard test been made it could have been foreseen that there would be this dispersion, for the projectile is evidently not sufficiently stable. In Fig. 5 it is seen that one projectile (6-inch Mark VIII.) has acquired a large yaw not far from the gun. This accounts for the fact that the dispersion for this projectile was large, of the order of 3,000 yards in 28,000.

It may be contended that some of the experiments and tests here recorded are too crude to be classed as belonging to the domain of physics. But let me remind you that Galileo, who may be regarded as the father of our science, climbed the tower of Pisa and let fall two weights, one large and one small, to show that they fell in the same way. We

[2] The range of 14,000 yards for the 6-inch gun is computed for a muzzle velocity of 3,000 feet per second at 45° elevation, basing the computation on the range obtained with a muzzle velocity of 2600 f.s. It ought to be pointed out that the Army had a 6-inch shell which for a muzzle velocity of 2,600 feet per second had a range of 15,000 yards at 15° elevation, but this was a heavy projectile—108 lbs.—while that of the projectile experimented upon was 90 lbs.

have made some progress since Galileo's time. We know that bodies are retarded by the air but we have assumed, on some experimental evidence, in the case of projectiles at any rate except for a constant of proportionality, that they are retarded in the same way. It is evident that in the matter of the laws of air resistance we are not far from the condition that the scientists of Galileo's time were in regard to gravitation.

It is evident from the results of these experiments at Aberdeen that a very slight change in the form of the projectile may make a considerable change in the range obtained. And it is equally clear that those experiments merely touched the matter. The entire subject is still open.

A number of years ago the Ordnance Department made inquiries concerning the possibility of using air streams of high velocity in tests on projectiles. During the war the project was submitted to the National Research Council. It was found that air streams one foot in diameter, with speed of 1,500 feet per second, requiring for their production 5,000 kw., could be furnished by the General Electric Company at their plant at Lynn, Massachusetts. There, with the most loyal support of the Bureau of Standards, and with the effective collaboration of Dr. L. J. Briggs of the bureau the Ordnance Department has conducted experiments[3] which have for their object the determination of the forces of such air streams on projectiles of various forms. Velocities of the air have, so far, varied from 600 up to 1,200 feet per second and temperatures from 0° to 130° C. In these air streams, which are vertical, projectiles of various shapes can be held nose down, and the forces on them and pressures at various points on their surfaces, can be measured. A number of important results have been secured. First, for head-on resistance there is no *one* curve similar to the French *B* curve which gives the law of air resistance for all projectiles. For example, in that law it will be seen by inspection (Fig. 1) that F/v^2 is multiplied by the factor 3 when the velocity changes from 200 to 380 meters per second. In our curves the corresponding factor varies from 1.3 to 4 for the various forms of projectiles. In other words the force exerted on one projectile may be less at one velocity and more at another than the force for the corresponding velocity in the case of another projectile. It follows that there is no "best form" of projectile unless we specify the approximate velocity with which we are dealing.

Second, the results obtained indicate the resistance introduced by the rotating band and show where this band should be placed to produce the least increase of resistance.

Third, it appears that the rapid rise of the *B* curve in the neighborhood of $V = 340$ meters per second is not entirely determined by the velocity of the compressional wave, *i. e.*, by the velocity of sound in the air. In some cases the force of air streams at 130° C. are identical with those at 30° C. (It is understood that the density of the air is standardized, *i. e.*, that the forces plotted are those which an air stream of equal speed and of density 0.001206 gms./cm.^{3} would have exerted.) In other cases, however, the results indicate that the velocity of the compressional wave is one of the factors determining the resistance. The temperature relation seems to be a complicated one and our results are not at all complete on this point.

Fourth, though we have not made quantitative measurements of the variation of force with the angle of attack of air and projectile, we have had some experimental evidence of the large forces which are called into play when this angle changes from "nose on" to oblique. In one case, the force of the air on a fifty pound 4-inch projectile was of the order of 44 pounds, so that there was still about six pounds of down force. When the projectile was being removed from the air stream it was accidently tipped slightly. The air stream forced it farther from the vertical, bent off the steel rod holding it to the balance

[3] Without a knowledge on his part of other inquiries, negotiations for these experiments were carried on and pushed to a conclusion by Major Moulton.

arm and blew the projectile up several feet over a railing into the yard. In another case, when the up force due to the air on a two-inch projectile was only about one third of the weight, *i. e.*, about 1.5 pounds, an oblique action at a slight angle drove the projectile farther from the vertical, finally turned its nose up, bending the steel spindle in the process. It is evident that the oblique forces of air streams on projectiles may be many times the "nose-on" force for corresponding velocities. It is clear then that unless a projectile turns "nose-on" to a wind the method now in use for finding wind corrections are greatly in error.

Enough has been said to show that the fundamental problem of the projectile is not one of mathematics. There are various mathematical methods of handling the problem. The English have a method highly analytical and complete. The French have a method rather tedious for computation but they excel in the graphic representation of results. The Italians still cling to the Siacci method. There are at least three methods in use in America, each one claiming points of merit. The problem is one of experimental science. We must first determine the complete law of air resistance for every probable form of projectile, then we must determine the variation of force as the axis of the projectile changes in direction; the torque about the center of gravity; the precessional and nutational motions under these forces, and the consequent effective lift and drag, as these terms are used in aerodynamics. Mathematicians may then find it necessary, using these known facts, to formulate the differential equations of a twisted trajectory and to evolve methods of integration. But it is quite probable that simple physical methods of integration may be devised.

It is evident even from a superficial study of the matter that a gun is an inefficient engine. An appreciable part of the energy of the powder takes the form of heat and kinetic energy of the gas developed. Of the initial energy of the projectile a large part is used in overcoming the resistance of the air. Perhaps in the warfare of the future we shall not need guns, on land at any rate. Rather we may hoist a carload of projectiles on a dirigible, carry them over the enemy's cities or lines and drop them on carefully selected spots. But if we are to drop projectiles or bombs accurately we must know the laws governing the motion of such bodies.

During the war, Drs. A. W. Duff and L. P. Seig carried on a series of experiments at Langley Field, in which the object was to find by photography the path of a bomb dropped from an airplane. By placing an intense light in a bomb they were able to photograph its path, to measure its velocity at any point, to obtain the speed of the airplane, and the wind velocity. These important results were contributed to the Americal Physical Society at the April meeting.

At Aberdeen, Dr. F. C. Brown, then captain later major in the Ordnance Department, while flying over a shallow body of still water observed the image of the airplane in the water. To a casual observer this would have excited no special interest. But, being a physicist, knowing the meaning of a level surface and a line of force, Dr. Brown saw that he had with him a visible vertical line. However the airplane tossed and pitched the vertical direction could be identified. He made use of this fact in a very skillful way. Attaching to the airplane a motion picture camera he was able to photograph a bomb released from the plane at a height of about 3,000 feet during the whole course of the projectile to the earth. Time can be obtained either from the rate of motion of the camera or from the photograph of a watch placed so that its image also falls on the film. The distance that the bomb has fallen and its orientation in space can be determined from the dimensions of its image. Its angle of lag or its distance behind the vertical line from the plane can be found by measuring the distance between the image of the bomb and that of the airplane. Hence not only the complete trajectory can be found but also the relation of the trajectory at any point with the variation in direction of the axis of the bomb.

It is assumed here that the motion of the airplane has been kept constant. The motion picture film which I shall show, which was kindly loaned to us by the Aircraft Armament Section of the Ordnance Department, will bring out clearly the tossing, pitching motion of the bomb in its course to the earth.

INTERIOR BALLISTICS

In interior ballistics, there are a number of unsolved problems. The first is concerned with the pressure produced in a gun by the exploding charge and its time rate of change.

The ordinary method which has been in use has been to measure the so-called maximum pressure by the shortening produced in a copper cylinder. But experiments have shown that the amount which a cylinder of copper is compressed by an applied pressure depends on the amount of the pressure, the time of application, the previous history as regards tempering, annealing, compression, etc. It is known for example that an application of a pressure of say 36,000 pounds per square inch will give an extra shortening to a cylinder previously compressed to 40,000 pounds per square inch. But the ordinary procedure has been to place in the gun a copper cylinder which had been precompressed to an amount nearly that to be expected. Obviously such a cylinder may indicate a pressure in the gun in excess of 40,000 pounds when in reality it was less. Moreover, the copper cylinder need not indicate the maximum. Rather it indicates a summation of the total effect of the gases upon it. A smaller pressure applied for some time may produce a shortening equal to that due to a larger pressure for a shorter time. Notwithstanding this uncertainty in the behavior of a copper cylinder, that is the kind of gage which has been used to standardize all the powder used in guns. It is clear that we may doubt whether these powders have been standardized at all. What is wanted evidently is a gage which will register the pressure accurately at a certain instant and therefore which will give the complete variation of the pressure with time.

Several gages have been devised which have points of excellence as well as defects. In the Petavel gage the compression of a steel spring was registered on a revolving drum by a light pointer. But the mechanical processes were not well worked out. Colonel Somers improved on Petavel's design in the mechanical details but neglected the optical. For small arms, both mechanical and optical details have been worked out by Professor A. G. Webster. In the gage the spring is a single bar of steel about 5 mm. square and 20 mm. long, which is bent by a plunger fitting into a cylindrical opening through the wall of the gun. Its moving parts have small mass and high elasticity, and it seems capable of giving an accurate record of the changes in pressure even when the whole time is of the order of a few thousandths of a second. But its use appears to be limited to the cases of guns which can be rigidly clamped during the explosion.

In the Bureau of Standards, Drs. Curtis and Duncan have been perfecting a gage which has been used in the large naval guns. Here a steel cylinder compresses a steel spring. During the compression a metal point makes electrical contact with conductors equally spaced. Consequently electrical signals can be indicated by an oscillograph for these equal steps. The time pressure curve is then given if the spring can be properly calibrated. There is however some doubt on this point and there is also uncertainty in electrical contacts and in the friction of the system.

What is needed is a method of calibrating accurately any gage by means of a known rapidly changing high pressure. Such a method has been worked out by the technical staff of the Ordnance Department, but the mechanical and experimental work still has to be done.

I have given you here some applications of the older physics to old and new problems of war. The list even in this limited field might be easily increased. By means of the photography of sound waves from a projectile we may determine many facts concerning its motion, the frequency of its precessional and nutational motions, the nature of its stability or instability. By means of motion pictures taken from an airplane we may determine facts of importance concerning the motion of a rapidly rotating projectile dropped from the plane. The recoil, jump and other motions of guns may be studied by photographic methods. By similar methods the times and positions of high angle shell bursts may be obtained from observational balloons. Gyro stabilizers, microphones, string galvanometers, oscillographs, piezo-electric apparatus, vacuum amplifying tubes, Kenetrons, old and new devices in physics—they all may be used to reduce the problems which I have been discussing to those of an exact science.

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BOARD OF SURVEYS AND MAPS OF THE FEDERAL GOVERNMENT

ON December 30, 1919, the President of the United States by executive order created a Board of Surveys and Maps to be composed of one representative of each of the following organizations of the government:

1. Corps of Engineers, U. S. Army.
2. U. S. Coast and Geodetic Survey, Department of Commerce.
3. U. S. Geological Survey, Department of Interior.
4. General Land Office, Department of Interior.
5. Topography Branch, Post Office Department.
6. Bureau of Soils, Department of Agriculture.
7. U. S. Reclamation Service, Department of Interior.
8. Bureau of Public Roads, Department of Agriculture.
9. Bureau of Indian Affairs, Department of Interior.
10. Mississippi River Commission, War Department.
11. U. S. Lake Survey, War Department.
12. International (Canadian) Boundary Commission, Department of State.
13. Forest Service, Department of Agriculture.
14. U. S. Hydrographic Office, Navy Department.

The individual members of the board were appointed by the chiefs of the several organizations named. The board is directed, by the executive order, to make recommendations to the several departments of the government or to the President for the purpose of coordinating the map-making and surveying activities of the government and to settle all questions at issue between executive departments relating to surveys and maps, in so far as their decisions do not conflict with existing law. The board is also directed to establish a central information office in the U. S. Geological Survey for the purpose of collecting, classifying and furnishing to the public information concerning all mapping and surveying data available in the several government departments and from other sources. The executive order further directs that the board shall hold meetings at stated intervals to which shall be invited representatives of the map-using public for the purpose of conference and advice.

All government departments, according to the executive order, will make full use of the board as an advisory body and will furnish all available information and data called for by the board.

The order of the President rescinds the advisory powers granted to the U. S. Geographic Board by the executive order of August 10, 1906, and transfers those powers to the Board of Surveys and Maps. The executive order of August 10, 1906, reads as follows:

EXECUTIVE ORDER

The official title of the United States Board on Geographic Names is changed to UNITED STATES GEOGRAPHIC BOARD.

In addition to its present duties, advisory powers are hereby granted to this board concerning the preparation of maps compiled, or to be compiled, in the various bureaus and offices of the government, with a special view to the avoidance of unnecessary duplications of work; and for the unification and improvement of the scales of maps, of the symbols and conventions used upon them and of the methods representing relief. Hereafter, all such projects as are of importance shall be submitted to this board for advice before being undertaken.

THEODORE ROOSEVELT

THE WHITE HOUSE,
August 10, 1906