artistic world of music, great as the individual acquirements of some members as executants may be, is essentially a world of handicraftsmen; practising indeed a very subtle art, but led entirely, according to Aristotle's definition, by rules, and not by laws.

The function of the scientific man is to expand these technical rules of art into the conscious and explained laws of science. How nobly this duty has been performed by Chladni, by Savart, by Wheatstone, and above all by Helmholtz, few artists are aware; nor indeed has there been hitherto any easy mode for their obtaining such information. They have been somewhat in the habit of sneering at the theorist as a "mathematician;" nor is it very remarkable that the other party, like the Dublin fishwife whom O'Connell called a parallelopipedon, should retaliate with even more opprobrious epithets. Hence old threadbare jokes about "catgut-scraping," Lord Chesterfield's contempt of musicians, and the like, which culminate in the epigram on Handel and Buononcini. This century is beginning to recognise that varying styles of musical art are not a mere question of "Tweedledum and Tweedledee," and that the "fiddler," though in an utilitarian point of view unnecessary to the maintenance of life, is highly conducive to education and civilisation. If artists are to maintain the improved position of later years it must be by cordially fraternising with the man of science, for thus only can their art hope to acquire the dignity and generalisation which are the prerogatives of ἐπιστήμη.

It is to be noticed that this view of the case appears to have been taken by many of our best professional musicians; for the list of members which heads either volume of these "Proceedings" is far more remarkable for individual eminence of the names than for their multitude. It is to be hoped that such a conviction will continue to extend. The number of points in which music is conterminous with pure science is considerable, and is daily increasing. Music, moreover, is among the most powerful means we have for cultivating that delicacy of the senses on which all accurate observation depends. It has, as yet, been too apt to fall into the hands of a sect or clique, whose disposition is naturally exclusive, and whose objects have often been the reverse of elevated. But with the great advance which has of late years taken place in general musical knowledge throughout England, and by the fostering care of societies like the present there is ground for anticipation that the science of music may rise to the esteem and consideration as an educator and humaniser which it once held in the writings of Plato, and in the palmiest days of old Greek thought.

W. H. STONE

ON THE RESISTANCE OF THE AIR TO THE MOTION OF PROJECTILES

THE experiments made by Hutton to determine the resistance of the air to the motion of shot were carried out by firing small spherical balls into the receiver of a gun-pendulum. As little confidence could be felt in applying his results to the large service shot at present in use, on the formation of the Advanced Class of Royal Artillery Officers, Woolwich, in 1864, it was thought desirable that a systematic course of experiments should be made with *elongated* shot, and upon a much larger scale. Afterwards, similar experiments were made with *round* shot.

The method of experimenting pursued by Hutton appeared to have been carried to its useful limits, and although a large ballistic pendulum had been constructed for Government, it was practically useless. The chronograph used in the experiments above referred to was invented and constructed for that purpose by the Rev. F. Bashforth, at that time Professor of Applied Mathematics to the Advanced Class, and Official Referee to the Ordnance Select Committee. This instrument is now in the Loan Exhibition, South Kensington.

A complete collection of the "Reports on Experiments made with the Bashforth chronograph, 1865-1870" (marked 84, B, 1941), has been published by Government, at the nominal price of one shilling.[1] It will therefore be sufficient here to state that the first set of experiments was made to test the new chronograph, in which the velocity of the shot varied from about 1,150 f.s. to 1,060 f.s. The resistance of the air was found to vary as the *cube* of the velocity. The next experiments were made with *elongated* shot of equal diameters and different forms of head. The velocities here varied from 1,500 f.s. to 1,090 f.s., and the law of resistance still appeared to be the *cubic*. Lastly, a course of experiments was made with *elongated* and *spherical* projectiles (solid and hollow) of 3, 5, 7, and 9 inches in diameter. The velocities of the elongated shot varied from 800 f.s. to 1,750 f.s., and those of the spherical from 800 f.s. to 2,400 f.s. At a given velocity the resistance of the air varied as the square of the diameter. But when the coefficient of resistance was obtained by dividing the numbers expressing the resistances by the cube of the corresponding velocity, the result was not now constant through these great variations of velocity. This coefficient was found to increase rapidly from 900 f.s. up to 1,050 f.s., and from 1,100 f.s. to 1,300 f.s. it was nearly constant, and for higher velocities it gradually decreased with the increase of velocity. The published reports give a full account of every round fired. Unfortunately it has not hitherto been found possible to express the coefficient of resistance by a simple function of the velocity. Mr. Bashforth has made use of the cubic law in his treatise on the motion of projectiles (1873). The trajectory is divided into arcs, and each arc is supposed to be described, while the coefficient of resistance retains its mean value for that arc.

In a tract on the remaining velocities, &c., of several service shot (1871),[2] Mr. Bashforth stated:—"For ogival-headed elongated shot, the resistance of the air may be said to vary roughly as the *sixth* power of the velocity for velocities 900-1,100 f.s.; to vary as the *third* power for velocities, 1,100-1,350 f.s.; and to vary as the *second* power for velocities above 1,350 f.s."

General Mayevski, Professor of Ballistics to the Academy of Artillery, St. Petersburg, published a work on Ballistics in Russian, in 1870, at the expense of the State. A translation of the more interesting chapters of this work was published in French by the author, in 1872.[3] In the preface to the latter work he states that "Les résultats des expériences faites par M. Bashforth en Angleterre sur les projectiles oblongs ont été déduits des données insérées dans les *Proceedings of the Royal Artillery Institution, Woolwich*, 1868. Les expériences de St. Pétersbourg sur la résistance de l'air au mouvement des projectiles sphériques et oblongs ont été faites par nous en 1868 et 1869, et leurs resultats sont pour la première fois publiés dans notre traité. Afin que les expressions de la résistance représentent, avec une approximation suffisante, les résultats de nos expériences et ceux des expériences anglaises, faites avec des appareils perfectionnés, et que ces expressions permettent en même temps une intégration facile, *quoique par approximation*, des équations différentielles du mouvement, nous avons admis *pour les projectiles sphériques*, dans les limites des vitesses de 530^{ms} à 376^{ms} (1739-1230 f.s.) la résistance de l'air propostionelle au carré de la vitesse, et nous avons exprimé, à partir de la vitesse de 376^{ms} (1230 f.s.) jusqu'aux petites vitesses, la résistance de l'air par un binome dont le premier terme est proportionel à la deuxième puissance de la vitesse, et le second à la quatrième puissance de la vitesse; *pour les projectiles oblongs*, quand leur axe de figure coïncide avec la direction du mouvement, nous

[1] W. Clowes and Son; Allen; Mitchell; Longmans and Co.
[2] London: Spon.
[3] Paris: Gauthier-Villars.

avons admis, dans les limites des vitesses de 510^{ms} à 360^{ms} (1673-1180 f.s.) la résistance de l'air proportionelle au *carré* de la vitesse; dans les limites des vitesses de 360^{ms} à 280^{ms} (1180-920 f.s.) nous l'avons admise proportionelle à la *sixième* puissance de la vitesse, et nous avons exprimé, à partir de la vitesse de 280^{ms} (920 f.s.) jusqu'aux petites vitesses, la résistance de l'air par un binome dont le premier terme est proportionel à la deuxième puissance de la vitesse et le second à la quatrième puissance de la vitesse," &c. (pp. vi., vii.). So that Mr. Bashforth employs one single law, the *cubic*, and makes his coefficient vary to suit the velocity, while General Mayevski varies his law of resistance according to the velocity. But in neither case does the law of resistance admit of direct integration. Mr. Bashforth supplies this defect by extensive tables calculated by quadratures, and granting the cubic law, the results are exact. General Mayevski's integrations are approximations, and require extensive tables also. But there is no dispute as to the amount of resistance encountered by elongated shot in moving through the air. For General Mayevski observes: "Aussi pour compléter les données se rapportant aux projectiles de forts calibres, nous avons profité des tableaux des vitesses décroissantes déduites par M. Bashforth de ses expériences faites en 1868 au moyen de son chronographe; ces tableaux comprennent les vitesses de 518^{ms} à 283^{ms} (1700-930 f.s.), qui correspondent aux trajets de 305 en 305 mètres des projectiles oblongs de 178^{mm}, 203^{mm}, et 229^{mm} (7, 8, and 9 inches), et qui sont obtenues pour le cas où le mouvement des projectiles peut être considéré comme rectiligne. Nous avons calculé d'après les résultats insérés dans ces tableaux les valeurs de la résistance correspondantes à différentes vitesses" (p. 38).

Projectiles Oblongs.

Bouches à feu.	Vitesses v.	Valeurs de ρ'.	Bouches à feu.	Vitesses v.	Valeurs de ρ'.
	ms.			ms.	
C. de 4^{l}	172	0·0151	C. de 203^{mm} ...	329	0·0338
C. 203^{mm}	207	0·0137	C. de 203^{mm} angl.	332	0·0327
C. de 4^{l}	239	0·0148	C. de 229^{mm} angl.	334	0·0332
C. de 12^{l}	247	0·0170	C. de 4^{l}	337	0·0341
C. de 24^{l}	266	0·0160	C. de 178^{mm} angl.	340	0·0334
C. de 203^{mm} ...	282	0·0163	C. de 203^{mm} angl.	345	0·0354
C. de 203^{mm} angl.	287	0·0184	C. de 229^{mm} angl.	355	0·0364
C. de 229^{mm} angl.	291	0·0247	C. de 178^{mm} angl.	358	0·0382
C. de 203^{mm} angl.	300	0·0230	C. de 203^{mm} ...	360	0·0384
C. de 178^{mm} angl.	302	0·0218	C. de 203^{mm} angl.	360	0·0393
C. de 12^{l}	304	0·0221	C. de 4^{l}	401	0·0450
C. de 4^{l}	307	0·0158	C de 203^{mm} ...	409	0·0430
C. de 229^{mm} angl.	316	0·0305	C. de 203^{mm} angl	419	0·0433
C de 4^{l}	317	0·0259	C. de 229^{mm} angl.	420	0·0427
C. de 203^{mm} ...	319	0·0174	C. de 203^{mm} angl.	460	0·0449
C. de 203^{mm} angl.	320	0·0277	C. de 203^{mm} angl.	508	0·0440
C. de 24^{l}	320	0·0299	C. de 178^{mm} angl.	512	0·0443
C. de 178^{mm} angl.	322	0·0270			

It ought to be stated that Hutton's results for spherical shot are very good indeed for velocities above 1200 f.s., while Didion's results, intended to correct Hutton's, were not quite so good. They both failed for lower velocities. It would be interesting to have the resistance of the air to projectiles determined for velocities below 900 f.s. But very considerable difficulties would be met with if the experiments were conducted in the usual manner, for the chronograph is most effective when there is a rapid variation of velocity. In the middle of the range the screens would have to be raised to a considerable height. It would be found difficult to fire shots through them all. If the shot were fired at low initial velocities from the ordinary rifled gun, there might be considerable doubts respecting the steadiness of the shot.

Reference must be made to the collection of scientific memoirs on ballistics by the Comte de St. Robert published in 1872,[1] although they do not supply any new experimental data.

[1] Turin: Vincent Bora.

As it is found impossible to integrate the equations of motion of shot for the simple laws of resistance, of square cube, &c., it appears almost hopeless to search for an expression of the complicated law now known to hold good through a considerable range of velocities. These results would serve as tests of any theory of the resistance of the air; and if any theoretical investigations did satisfy these conditions, then we should have an expression for the resistance of the air to the shot, but it is almost certain that it would be too complicated to be of practical use. B.

A LOCAL MUSEUM

THE population of the parish of Morton, 1871, was 2,099—the chief village, Thornhill, containing about one half of the population of the parish. The parish is situated on both banks of the Nith in the North of Dumfriesshire, Scotland. Yet sparse as is the population, and remote from the great commercial centres as is the district, it is supplied with a museum which well might grace a place of far more wealth and consequence. The building was erected by Thomas B. Grierson, and the collections in the museum were formed by him. The Duke of Buccleuch granted the land on which to build, together with stone. The memorial stone was laid with masonic honours in June 1869. The building, which was from the design of a local architect, is an oblong, consisting of a ground floor and gallery. The gallery is very appropriately supported by six oaks, as brought from the forest, being among the last of the natural woods of Nithsdale.

The *débris* excavated for the foundation has been well utilised by forming a large mound in the surrounding garden, which is faced on all sides by an excellent collection of the minerals and curious stones of the district, and forms a suitable habitat for hardy plants. The garden contains a great variety of flowering plants, of shrubs, trees, and cryptogamous vegetation, and is laid out with considerable art. Large objects, which do not suffer waste by atmospheric causes, such as stone crosses and querns, are placed at intervals in the walks. Great prominence has been given in the collections inside the building to objects which illustrate the history of the country. These include some valuable relics belonging to the Covenanters of the seventeenth century, and to the poet Burns. The collections illustrative of the unpolished and polished stone-period are very valuable. Some beautifully wrought cells and stone-hammers have been yielded by this part of Nithsdale. The bronze and iron collections are very fair. Among the quadrupeds is a skull of the ancient ox which roamed wild less than a century ago in Drumlanrig Parks, and which belong to the same variety as those at Chillingham and Hamilton Palace, which are supposed to be the sole survivors of the ancient Caledonian Urus. Among fish there is an interesting collection, which was the gift of the late Mr. Shaw, illustrative of the natural history of the salmon, and which shows that animal in its various different stages. The late Mr. Shaw threw great light on the development of the salmon, and destroyed some popular delusions concerning it. He was a keeper in the district under the Duke of Buccleuch. The abnormal form of animals are very various, many opportunities having occurred to fill the cases devoted to these from the pastoral and agricultural district around. In the collection of fossils due prominence is given to those belonging to the strata of the south of Scotland, and the industrial departments contain specimens of the manufactures of the country. The museum is free to the public on Saturday, and open for a small sum during the week. School children are admitted along with their teachers gratuitously on application. The proprietor, Dr. Grierson, is most indefatigable in his attentions and explanations to all willing to learn from his collection of objects. The