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ture. It is evident that any optical measurement of flame temperature will yield definite and useful information concerning some aspects of the flame and the gases.

A middle-of-the-road course has been followed throughout the present discussion as regards the experimental measurement of the translational temperature. Thus attention has been called to the fact that erroneous temperature readings are obtained in some cases. At the same time an effort has been made to emphasize that the definition of the translational temperature retains its usefulness under all conditions and that this temperature can be measured if not with one method then with another. Unfortunately, it is not possible to give a concise prescription for evaluating the translational temperature under all conditions. An attempt to present a conclusion of this type would be inconsistent not only with the thesis of the present survey but would also conflict with some experimentally observed results.

We do not have *a priori* information concerning the approach to statistical equilibrium in a given combustion flame. In the absence of evidence to the contrary, we are therefore justified in choosing any optical technique for which the equipment is available or which appears particularly interesting for other reasons. In many cases (e.g., the flame of a Meker burner) our first temperature measurement will probably determine the translational temperature. In general, however, it is necessary to verify the equilibrium assumption by demonstrating that concordant results can be obtained by the use of two or more independent techniques. Detailed knowledge of the experimental findings of other investigators will permit the intelligent exclusion of some methods under certain conditions. For example, for a temperature determination in a region of active combustion we might prefer one of the reversal methods to a measurement based on the change of rotational line intensity with quantum number while, at the same time, we would expect absorption-emission pyrometry to be less likely to give large errors than the line reversal method. Nevertheless, it is entirely possible that the translational temperature of the flame under study can be determined equally well by all three methods.

Acoustical Impedance and Absorption Coefficients

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THE determination of the normal coefficient of absorption and acoustical impedance of materials is an important and interesting type of experiment which may be performed in the usual acoustical laboratory by the method of standing waves in a tube.

A loudspeaker may be used to set up standing waves at one end of a tight, heavy tube with the acoustical material at the opposite end as shown in Fig. 1. The normal absorption coefficient is found by measurement of the difference between the maximum H_2 and minimum L_1 intensity in decibels (i.e., H_2-L_1) using a traveling pressure microphone. The resistive and reactive components of impedance are found by measurement of the ratio D_1/D_2 in addition to the above two measurements for the normal absorption coefficient. The distance from the acoustical material to the first excess pressure minimum is D_1, while the distance from the first excess pressure minimum to the second excess pressure minimum is D_2.

Theory

The following formula has been developed[1,2] for the normal coefficient of absorption a_n when

[1] S. L. Brown and M. Y. Colby, *Laboratory manual, electricity and magnetism, light, and sound* (University Cooperative Society, Austin, Texas, 1944), p. 45.

[2] H. J. Sabine, *J. Acous. Soc. Am.* 14, 143 (1942).

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Loudness and Intensity

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NOT more than thirty years ago, physicists attempted to make little, if any, distinction between the concepts of *loudness* and *intensity*. The earliest, most useful, quantitative relationship established between those two concepts is summarized in the Weber-Fechner psychological law[1] which states, in Fechner's words, that "the sensation increases as the logarithm of the stimulus." This law implies, for example, that the ratios of stimuli in a stepped scale of least audible increments are equal to one another in sensation. If this were true, 40 least audible increments would produce twice as much sensation as 20 such increments. Less than twenty years ago, many loudness meters, manufactured under various names, were calibrated on a logarithmic scale and were used to measure loudness levels. By 1928, those interested in acoustic correction in rooms suspected that the logarithmic relationship was not exact. The many experiments performed since 1930 have shown conclusively that loudness is only approximately proportional to the logarithm of the intensity of sound and that the departure in linear relationship is considerable for wide intervals in intensity levels.

Because of the rapidity with which new relationships have been established between loudness concepts and intensity,[2] many of the definitions appearing in our recent college textbooks are faulty. Thirty general physics textbooks, written by different authors, and published since 1928, were examined. Four of these textbooks published prior to 1938 did not use the term *loudness*. Nine authors state that loudness depends on the square of the amplitude, an assumption usually based on the idea that loudness depends upon intensity in some simple way; in fact, a few of the currently used physics textbooks make no essential distinction between *loudness* and *intensity*. Ten authors define loudness in terms of sensation and end with the idea that loudness is proportional to the logarithm of the stimulus. The Weber-Fechner law is occasionally mentioned to justify the mathematical statement. Two authors state that the relation between loudness and intensity is not simple and that loudness depends on pitch also; the reader is referred then to psychologists for further discussion. Four authors define loudness in accordance with the customary usage of the word by specialists in the field of acoustics. Finally, four authors, in preparing later editions, did not revise the faulty definitions and concepts used in their discussion of loudness.

Loudness[3] is defined as the magnitude of the auditory sensation produced by the sound. The measurement of loudness is based upon the mental estimates of many typical observers and is best recorded quantitatively, for the present, by the use of graphs. The two most commonly used graphical representations are (*a*) the loudness *versus* phon[4] scale[5] at 1000 cycle/sec (Fig. 1),[6] and (*b*) the equal-loudness contour scale (Fig. 2). The solid line of Fig. 1 gives a temporarily adopted relation between the change

[1] Fechner, *Elements of psychophysics* (1860).

[2] The definition adopted by the American Standards Association is: "The sound intensity of a sound field in a specified direction at a point is the sound energy transmitted per unit of time in the specified direction through a unit area normal to this direction at the point. The unit is the erg per second per square centimeter but sound intensity may also be expressed in watts per square centimeter." H. A. Frederick, J. Acous. Soc. Am. 9, 60 (1937).

[3] The definition adopted by the American Standards Association is: "The loudness is that subjective quality of a sound which determines the magnitude of the auditory sensation produced by that sound." H. A. Frederick, reference 2.

[4] Adopted as a unit of equivalent loudness level measurement at a meeting of delegates of the International Electrotechnical Commission held in Paris, July, 1937; this committee worked under the auspices of the International Standards Association. Fletcher, Bell. Lab. Rec. 16, 213 (1938).

[5] The solid line of Fig. 1 is taken from a paper by H. Fletcher and W. A. Munson, J. Acous. Soc. Am. 5, 82 (1933). The dotted line is from more recent data of H. Fletcher and W. A. Munson, J. Acous. Soc. Am. 9, 1 (1937). The solid line was adopted for noise measurements by the American Standards Association, Feb. 17, 1936 [J. Acous. Soc. Am. 8, 143 (1936)]. See Geiger, J. Acous. Soc. Am. 11, 308 (1940), for an extension of the data in the Fletcher and Munson table to smaller loudness differences. For an earlier tentative adoption, see also, "Proposed standards for noise measurements," J. Acous. Soc. Am. 5, 109 (1933).

[6] The word "cycles" is often substituted for the correct physical expression, *cycle/sec*, in acoustic literature.

Vibratory Characteristics of Vibrafram

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Introduction

SOME few years ago Mr. Paul M. Heerwagen, a local interior decorator, became sufficiently impressed with the acoustical properties in a room decorated with some pressed fibrous material to start investigating various forms of these materials. They were mounted always so as to have an enclosed air space. Out of this experimentation came acoustical tiles in plain and in decorative patterns, standardized as to surface dimensions and known formerly as the Heerwagen tile, later, as Vibrafram.

The tiles (Fig. 1) used, called E-1, are plain and slightly arched in the center so as to have the slight appearance of a four sided pyramid and may be briefly characterized as similar to an inverted square baking tin. The raised portion of the tile is about twelve inches on a side at the base and approximately 10½ inches at the top. The part that oscillates most in the vertical direction is about 10 inches on a side. It has a half-inch edge for gluing so that a space thirteen inches between centers must be provided for mounting. The trapped layer of air in back of the tile appears essential to produce a high acoustical absorption over a wide frequency band.

Object of the Experiments

The object of the experiments is to determine the cause of the high acoustical absorption. About three years ago when Mr. Heerwagen first brought these materials to our laboratories, the first author gained the impression that the absorption may be due to absorption by vibration and reradiation, somewhat as in Rayleigh resonators, since vibration could easily be detected, and that the material itself could not possibly have been the cause of the absorption. Mr. Fred T. Griffin, a graduate student of our department, two years ago started a series of experiments on tile E-1 to study its vibration characteristics. At that time we were housed in a wooden building with highly reflective walls. The material had to be pushed out of a window for experimentation late in the afternoon when the campus was quiet. In spite of these unfavorable circumstances, his experiments tended to show that the absorption was due to vibration. The effect may be said to be due to a sort of mechanical hysteresis or a nonconformity to Hooke's law because of internal resistances. This differs from materials usually employed for acoustical absorption in that vibratory damping is substituted for a viscous flow of air in a pourous medium.

Theory, as Related to Mechanical Resistance

A perfectly elastic body follows Hooke's law when subjected to a distorting force, and a graph of the stress as ordinates plotted against strain as abscissae will be a straight line. Since there is always some internal resistance, the actual force necessary to cause a given distortion is greater than that which is called for according to Hooke's

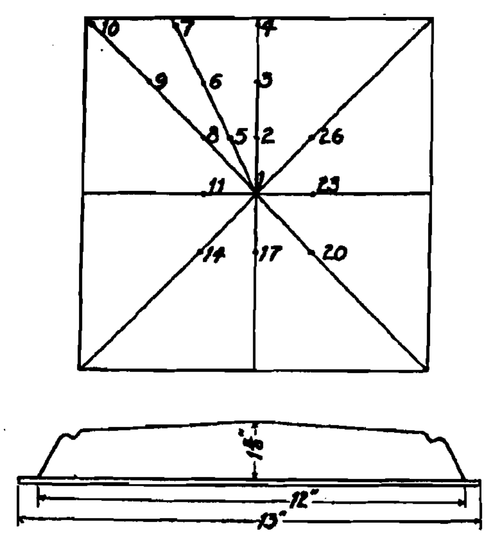

Fig. 1. Top view of "flat" surface of mounted tile (E-1) *above*, and cross section through center *below*.

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from the center position by the collision parameter b, as shown by the arrow in Fig. 5. The charge of equal sign is imparted to the ball by touching it with the van de Graaff generator; that of unequal sign by bringing it into contact with the ground while keeping it in the electric field of the generator.

In the case of small collision parameters b, one observes large deviations of the charged ball from its original direction of motion in the well-known hyperbolic paths. As b increases, the deviation becomes smaller, just as the deflection of electrons or α particles decreases with increasing collision parameter.

3. Model experiment on satellite orbits. When the simple pendulum is long enough ($l>5$m), then the central force of the ball moving round the uncharged van de Graaff generator may be small compared to the force which the charged sphere of the van de Graaff generator exerts on the oppositely charged ball according to Coulomb's law. In that case, the attraction obeys very nearly an inverse square law as does the attractive force on a satellite in the gravity field of the earth. If one tries to make the ball move round the van de Graaff sphere on a circular path, one will usually obtain an ellipse. The greater velocity in the arc of the elliptical path corresponding to the perigee and the smaller one in that corresponding to the apogee, as well as the increase of the velocity for decreasing orbit radius, is clearly seen. When a ping-pong ball slightly weighted with shot is used as a pendulum bob on a thread of about 10-m length, then 10 to 12 revolutions can be observed.

Open Book Examination as a Deterrence to Cheating

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ATTEMPTS at cheating on an examination are perennial possibilities. Occasionally the time-consuming preparations are amazingly and ingenuously made, as witnessed recently in a general physics hourly examination. At that time, information along two lines of inquiry interested me, namely: (1) how much would the cheating help the examinee, if not interrupted, and (2) what more satisfactory method could be used to discourage cheating.

The habit patterns on cheating to counteract low scholastic attainments are reflected in the earlier college years, especially before the less serious students have been eliminated. In nearly 50 years of teaching, the author questions whether there has been any significant change in the number of cheating attempts among the better students who have established themselves successfully in the highly disciplined scientific fields of a university curriculum.

The perusal of previous examination performances of the few students under close observation, coupled with desirable conferences, indicated that a surprisingly small gain in examination grade was made by cheating—sometimes a loss in grade. The observations indicated that perhaps there is not much to be gained by cheating anyway. A method was immediately available for a preliminary check. Since all major hourly examinations of the previous school year (1957–58) were of the objective type with five possible answers, a method for the comparison of examinations conducted on an administered cheating basis with those of the previous school year was available.

All administration of examinations in my lecture sections of engineering physics for the school year 1958–59 were changed to an open book procedure. Reproduction of answers from any neighboring student was the only assistance not permitted. Thus, all students were allowed to use their own initiative to prepare their *cribbing* material to beat each examination. Table I includes most of the tests for which direct comparisons could be made between the usual closed book test and the open book test as described above. All examinations included in the table were administered in the same form without reprinting, or with reprinting because of minor printing corrections, and/or a change in the number of questions by not more than one.

After noting the elaborate preparations some examinees have made for cheating in examinations, the lack of demonstrated gains for all their efforts, as shown in the table, were hardly predictable to me. There appears to be no significant change in the peak, median, or average grades between the open and closed book method of administration. Although similar results were obtained with the longer terminal examinations for the 1958–59 school year, they were not included because a larger number of questions were used in the open book tests and because the time limits were more flexible.

Obviously, the results without more controls have preliminary validity only. They are presented at this time since no further experiments are possible because of my retirement status.

TABLE I. Grade distributions on examinations with a 55-min time limit.

Examinations / Items evaluated	Dynamics of fluids and of solids (E58-20 a,b)		Heat		Sound		Light	
			58-30	59-30	S58-40	S59-40	L58-30	L59-30
	Closed book	Open book	Closed book	Open book	Closed book	Open book	Closed book	Open book
Number of questions on examination	48	48	49	49	42	41	53	54
Number of students[a]	383	37	91	75	91	75	38	53
Average grade	14.3	14.9	25.0	24.1	14.3	13.3	15.1	16.4
Median grade	13	16	25	24	14	13	14	15
Highest grade	37	27	40	39	27	25	32	33
Lowest grade	0	2	10	10	1	2	5	7

[a] No students using the open book test, No. E58-20 a,b, are included in the other open book tests.