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Clarendon Press Series

ACOUSTICS

THEORETICAL

PART I

BY

W. F. DONKIN, M.A., F.R.S., F.R.A.S.,

SAVILIAN PROFESSOR OF ASTRONOMY, OXFORD

Oxford

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ADVERTISEMENT.

As this is the only portion of a treatise on Acoustics, intended to comprise the practical as well as the theoretical parts of the subject, which will proceed from the pen of its Author, a few words are required to explain the circumstances under which it now appears.

The Author, the late Professor Donkin, has passed away prematurely from the work. It was a work he was peculiarly qualified to undertake, being a mathematician of great attainments and rare taste, and taking an especial interest in the investigation and application of the higher theorems of analysis which are necessary for these subjects. He was, moreover, an accomplished musician, and had a profound theoretical knowledge of the Science of Music.

He began this work early in the year 1867; but he was continually interrupted by severe illness, and was much hindered by the difficulty, and in many instances the impossibility, of obtaining accurate experimental results at the places wherein his delicate health compelled him to spend the winter months of that and the following years. He took, however, so great an interest in the subject, that he continued working at it to within two or three days of his death.

The part now published contains an inquiry into the Vibrations of Strings and Rods, together with an explanation of the more elementary theorems of the

subject, and is, in the opinion of its Author, complete in itself; his wish was that it should be published as soon as possible; and he was pleased at knowing that the last pages of it were passing through the Press immediately before the time of his death. It is the first portion of the theoretical part.

It was intended that the second portion should contain the investigation into the Vibrations of Stretched Membranes and Plates; into the Motion of the Molecules of an Elastic Body; and into the Mathematical Theory of Sound. Professor Donkin did not live long enough to complete any part of this section of the work.

The third portion was intended to contain the practical part of the subject; and the theory and practice of Music would have been most fully considered. It is exceedingly to be regretted that the Professor did not live to complete this portion; for the combination of the qualities necessary for it is seldom met with, and he possessed them in a remarkable degree. Not even a sketch or an outline is found amongst his papers. He had formed the plan in his own mind and often talked of it with pleasure. It can now never be written as he would have written it.

BARTHOLOMEW PRICE.

11, ST. GILES', OXFORD,
Feb. 16, 1870.

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Eustachian tube on the other, always contain air, but under different conditions. The air in the meatus is liable to be directly affected by every change, however slight and rapid, in the pressure of the external air, with which it is always in free communication; but that within the tympanic membrane, being only occasionally put into communication with the external air by the opening of the Eustachian tube, is not liable to be directly affected by slight and rapid changes, though it takes part in the slower fluctuations shewn by the barometer.

3. The second, or interior, part of the ear is contained within a cavity which is called the *bony labyrinth*, because it is of a complicated form, and is surrounded by bone except in two places. These two places may be compared to windows, looking into the tympanum, but completely closed by membranes, so that neither air nor fluid can pass through them. One of these is called the *oval* and the other the *round* window.

The interior of this bony labyrinth is filled with fluid, in which are suspended membranous bags, following nearly the same form, and themselves containing fluid.

The terminal fibres of the auditory nerve are distributed over the surfaces (or parts of the surfaces) of these membranous bags, and there are special arrangements of which the object appears to be the communication to these nervous fibres of any agitation affecting the fluid.

4. The tympanic membrane is connected with that which closes the 'oval window' by a link-work of small bones contained in the open space of the tympanum, in such a manner that when the former membrane is bulged inwards or outwards by an increase or diminution of the pressure on its external surface, a similar movement is impressed on the latter; and although the fluid within is probably as incompressible as water (of which it chiefly consists), the membrane of the 'round window' allows it to yield by expanding outwards when that of the oval window is forced inwards, and *vice versâ*.

Thus the motion impressed on the tympanic membrane by the external air is communicated to the fluid contained in the labyrinth, and from that to the fibres of the auditory nerve, by

means of the apparatus mentioned above, which need not be further described at present[1].

It is probable also that motion is partly propagated from the tympanic membrane through the air in the tympanum to the membrane of the round window, and so to the fluid.

5. The 'pressure' of the air at any point must be understood to mean, as usual, the pressure which would be exerted on a unit of surface by air of the same density and temperature as at the point in question.

When the pressure at any point varies with the time, the variation may be graphically represented by means of a 'curve

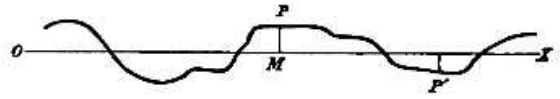

Fig. 1.

of pressure,' in which the abscissa OM of any point P is proportional to the time elapsed since a given instant, and the ordinate MP to the excess of pressure above a standard value, which may be taken arbitrarily. A negative ordinate (as at P') represents of course a defect of pressure below the standard value.

As we shall chiefly have occasion to consider cases in which the *average* (or mean) pressure remains unaltered, it will be convenient to assume that average as the standard value represented by the axis of abscissæ OX.

Changes of density may evidently be represented in the same way by a 'curve of density,' in which positive ordinates represent condensation, and negative ordinates dilatation. The curves of pressure and of density will differ slightly in form, because

[1] A full description, with illustrations, of the structure of the ear, so far as it is known at present, will be found in Helmholtz, p. 198, &c., and in Huxley's 'Lessons in Elementary Physiology,' p. 204, &c., and other recent works on Anatomy and Physiology. But the reader is recommended to study the subject, if possible, with the help of anatomical preparations or models. For the purposes of this treatise, however, nothing is absolutely necessary to be known beyond what is stated here or hereafter in the text.