Letters to the Editor.

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The Acoustics of Enclosed Spaces.

THE acoustics of enclosed spaces intended to hold large audiences is now receiving attention, and it is recognised that good conditions for distinct hearing can be obtained only by eliminating the reverberation due to reflection from the walls. Owing to the high velocity of the transmission of sound in nearly all solid bodies, the angle at which total reflection begins is small; for oak wood it is about 6°, and for glass as low as 3°. Unless the wave-front is therefore very nearly parallel to a wall it cannot penetrate and is sent back into the room. The simple and partially effective method of deadening the reverberation by covering the walls with a highly porous material, or woven stuffs, is difficult to apply in large spaces, and a more hopeful solution of the problem seems to me to lie in the discovery of a substance that can be used for the exterior lining of walls and has a velocity of transmission not far different from that in air.

Unfortunately our knowledge of the velocity of sound in different materials is very scanty. I am not aware that the acoustical properties of the substances most commonly used in buildings, such as stones, brick, and mortar or plaster of Paris, have ever been examined. My suggestion is to look for a suitable material which is transparent to sound and can be backed by highly porous matter which will absorb the transmitted vibration. If necessary, a series of alternate layers may be introduced. In referring to the tables of Landoldt-Börnstein I find that the substance which has a velocity of transmission for sound nearest to that of air is cork. This might be taken as a starting point for further investigation, but there are great gaps and inconsistencies in the tables.

It is to be remarked that at nearly normal incidence, so long as no total reflection takes place, the posterior surface of the wall diminishes very considerably the intensity of the reflected sound. This is illustrated by the analogous problem in the theory of light. Applying the relevant equations (A. Schuster, "Optics," p. 71) to normal incidence we find for the reciprocal of the intensity of a wave transmitted through a wall: $1+\pi^2(1-\mu^2)^2e^2/\lambda^2$, where e is the thickness of the wall, λ the wave-length in air, and μ the refractive index. It is here assumed that the thickness of the wall is small compared with the wave-length measured inside the wall, which will nearly always be the case. For wood the refractive index is about ·1, and for stone it will probably be of the same order of magnitude. Applying the equations and assuming the wave-length to be 250 cm. in air, representing a frequency of 130, we find that a wall one metre thick would transmit 86 per cent. of the incident sound at normal incidence, and this would be increased to 98·5 per cent. if the thickness be reduced to 10 cm. Apart from absorption, it is to be expected that stone walls are fairly transparent to sound falling normally upon them. But, as has been said at the beginning, sound incident at angles slightly inclined to the normal is totally reflected.

Some interest attaches to the cognate problem of avoiding the transmission of sound from one room to another. I am not referring to the construction of sound-proof spaces of comparatively small dimensions, such as telephone boxes, where the use of absorbing materials is permissible. But we are all familiar with rooms, more especially in hotels, where everything that is said in one room can be overheard next door. This is generally ascribed to the thinness of the walls. Apart from absorption, which is not likely to be very appreciable in a homogeneous material, no large diminution of the intensity of the transmitted sound should be expected from a moderate increase in the thickness of the walls. The above example shows what may be expected from theory. When we deal with bricks and mortar, or lath and plaster, the want of homogeneity may cause a considerable amount of scattering, and this would help in making the increased thickness more effective.

Unless my information as to our present knowledge is insufficient, it would appear that experimental investigation of the acoustical properties of materials, with regard to absorption, scattering, and the rate of transmission, are much needed at the present time. Such investigations may also have a theoretical interest, as they would include experiments on sheets, the thickness of which bears a much smaller ratio to the wave-length than we are accustomed to deal with in optics.

ARTHUR SCHUSTER.

Some Spectrum Lines of Neutral Helium derived theoretically.

IT is well known that, owing to the prohibitive nature of the general problem of three (or more) bodies, Bohr's quantum theory has proved so far to be unable to account for any spectrum lines but those forming a series of the simple Balmerian type, *i.e.*

$$\nu=\kappa^2N\left(\frac{1}{n^2}-\frac{1}{m^2}\right),$$

where N is the familiar Rydberg constant given by $2\pi^2me^4/ch^3$, and κ the number of unit charges contained in the nucleus, or the atomic number. Apart from X-ray spectra of the higher atoms, for which κ is replaced empirically by a smaller and not necessarily a whole number (Moseley, Sommerfeld), and where the requirements of precision are not high, this simple type of formula covers, as a matter of fact, only the spectra of atomic hydrogen ($\kappa=1$) and of ionised helium ($\kappa=2$), which, having been deprived of one of its electrons, presents again the same problem of two bodies as the hydrogen atom. Accordingly, the known spectrum series of He^+, the ultraviolet Lyman series, the principal or Fowler's series, and the Pickering series, are all of the simple Balmer type, with $n=2$, 3, 4 respectively.

The neutral helium atom, however, with its two electrons, emits an entirely different spectrum consisting in all of more than a hundred lines (Prof. Fowler's latest report contains, pp. 93-94, a list of 105 lines), some apparently "stray" lines, others arrayed empirically into series strongly deviating from the Balmer type, but all alike baffling modern theoretical spectroscopists. In fact, not a single one of these one hundred or so observed lines has, to my knowledge, been accounted for theoretically, the mere desire of attempting this being paralysed by the insuperable difficulty of the three-bodies problem. This is particularly so in the case of lithium ($\kappa=3$) and the higher atoms.

Now, it has occurred to me that, in the absence of a general solution (in finite form, of course), it may be worth while to try some special solution of that classical problem.

At first a sub-case of Lagrange's famous solution of 1772 suggested itself, namely, the collinear type of motions, in which the three bodies, in our case