performance is uncanny and one is in danger of dropping the tube. The vibration of the air within will continue for some moments after the tube is removed from the flame. These vibrations may be made audible by placing the closed end *P* against a resonating body—one's head, a tin can, a light table, or against a wooden blackboard.

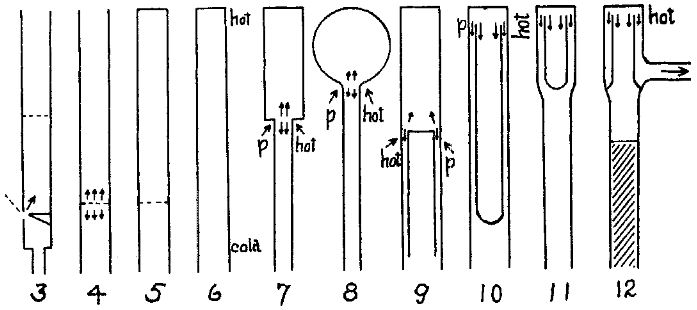
The intensity of the tone emitted by these tubes is dependent upon the temperature difference that is established between the tip *M* and the rest of the tube. The pitch, as previously stated, is determined by the dimensions and is little affected by a change in temperature. It may be of interest to remark that when the body of the tube *NOP*, Fig. 1, is at room temperature, the tube will begin to sing when the tip is heated to about 400° C. When *NOP* is cooled to liquid air temperature, the tube will sing when the tip *M* is maintained at *room* temperature, which makes the temperature difference in this instance about 200° C. By extrapolation it was found that the temperature difference required if it were possible to cool *NOP* to absolute zero would be 80° Kelvin. The pitch of the tone emitted in each of the above examples is correspondingly lowered.

The following physical explanation, in collaboration with Dr. Jakob Kunz, University of Illinois, is offered:

In the organ pipe, energy is supplied by a stream of air which encourages the vibrations in a one-sided way, so that the vibrating column receives an impulse each time when the air moves upward towards the node in the middle of the pipe, Fig. 3, and receives no impulse in the opposite motion. It looks as if a pendulum were kept in oscillation by receiving at one end of its path an impulse always in the same direction. If we were to apply the momentum of the air-jet at the centre of the tube, vibrations of the column would be discouraged.

We can communicate momentum to a vertical open-air column by heating it. If we heat the air in the tube in Fig. 4 by a wire net placed in the lower half of the tube, we shall obtain a uniform current of air upwards. If the air is vibrating, then as it is moving inward its vibration is increased by the momentum of the upward stream of air, but not increased by moving downward. When we place the hot wire net in the middle of the tube it will tend to increase the pressure of the gas when it is a minimum, *i.e.* it will discourage oscillations. The same will happen when we place the net above the middle. In order to encourage oscillations we have to add momentum in a position and at a moment such that the pressure in the node increases more than it would do on account of the oscillations alone. If we put the hot wire net at the lower end of the tube, *i.e.* in a loop, the effect will be very small, or zero. The transfer of heat will depend upon the temperature of the air in contact with the wire net, being greatest when the temperature is lowest. But the temperature in the loop at the lower end does not vary; therefore, the transfer of heat in this position of the gauze does not give rise to oscillations. It tends only to raise the temperature of the gas uniformly. *Heat must therefore be applied between a loop and a node.*

If we cover the upper end of the tube, Fig. 5, with the hot net in the most favourable position, the sound ceases, and if we heat by means of a Bunsen burner the outside at the top, as in Fig. 6, we get no sound. This was considered by Rayleigh as possible (" Theory of Sound," vol. 2, p. 231). But if we change the cross-section of the tube, as in Fig. 7, and heat at *p*, then the tube will emit a sound. The pressure in the upper half of the tube will increase, partly because the air is heated, partly because of the condensations of the air in the node on the top. The air will expand, and now the expansion in the narrow neck is aided by the air being heated by the wall. Here the oscillations are encouraged because each time when the air is expanding by the oscillation the expansion is increased by the heat. In each cycle the vibrating particle receives one push in the right direction. It is this one-sidedness of the action which encourages the oscillations. Moreover, as the heat here has the tendency to increase the pressure near the node, the oscillations will start very readily. A slight modification of this experiment is the glassblower's bulb, Fig. 8, which emits a sound when heated around the neck, *p*. Instead of making the lower part of the tube narrower, as in Fig. 7, we might proceed as in Fig. 9, where the annular area takes the place of the narrow tube in Fig. 8. A modification of this tube is the tube of Fig. 10, which will sound when heated at *p* and is much more sensitive. It is evident from the explanation that this tube will not sing when the lower end of the inner tube is open, because the one-sidedness of the action is destroyed. Slight modifications of Fig. 10 are the tubes represented in Figs. 11 and 12. If we place a hot wire net inside the tubes of Figs. 7, 8, 9, 10, 11, 12, where the hot flame was outside, the tubes will produce a sound. In all cases, in the organ pipe, in Rijke's experiment (Fig. 4), and in the tubes in Figs. 7-12, the oscillations of a column of air are maintained by a one-sided addition of momentum at the right moment and in the right place.



These experiments belong to a large variety of phenomena in which a direct motion is transferred into a periodic motion, or, electrically speaking, where direct current is transformed into alternating current. CHAS. T. KNIPP.

Cavendish Laboratory,
Cambridge,
July 12.

Frequency Demultiplication.

IT is a well-known fact that when a sinusoidal E.M.F. (of the form $E_0 \sin \omega t$) is available, it is a relatively simple matter to design an electrical system such that alternating currents or potential differences will occur in the system, having a frequency which is a whole multiple of the applied E.M.F., *e.g.* 2ω, 3ω, etc. For example, when the E.M.F. $E_0 \sin \omega t$ is applied to a diode-rectifier, the current in the anode circuit will include a component of double frequency, *i.e.* 2ω. This is therefore one method of frequency multiplication. Several other methods could easily be mentioned.

Now we found it is also possible to design an electrical system such that when the above-mentioned

E.M.F., $E_0 \sin \omega t$, is applied to it, currents and potential differences occur in the system the frequencies of which are whole submultiples of the frequency of the applied E.M.F., *e.g.* $\omega/2$, $\omega/3$, $\omega/4$ up to $\omega/40$.

To this end one can make use of the remarkable synchronising properties of relaxation-oscillations, *i.e.* oscillations the time period of which is determined by the approximate expression $T = \pi/2\,C\,R$, a relaxation time (Balth. van der Pol, "On Relaxation Oscillations," *Phil. Mag.*, p. 978, 1926; also *Zeitschr. f. hochfreq. Technik*, **29**, 114; 1927).

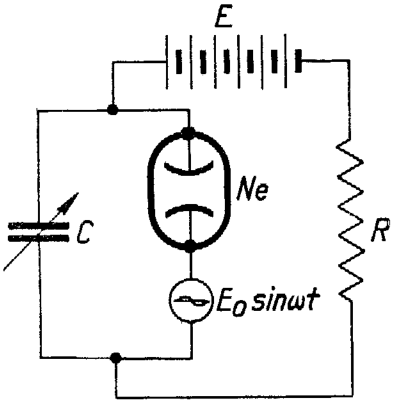


FIG. 1.

Let *Ne* in Fig. 1 represent a neon glow lamp, *R* a resistance of the order of a few megohms, *C* a variable condenser of approximately maximum 3500 cm. capacity and *E* a battery of say 200 volts. In the absence of the E.M.F. $E_0 \sin \omega t$, this system will oscillate with a time period $T = \alpha C R$ where α is a number of the order unity. With the E.M.F. $E_0 \sin \omega t$ present, where E_0 may be of the order of 10 volts (considerably lower voltages also give the same result) it is found that the system is only capable of oscillating with *discrete frequencies*, these being determined by *whole submultiples of the applied frequency*. For example, with $E_0 = 0$, give C a small value such that the natural relaxation frequency of the system is 1000 periods per second. Next apply the alternating voltage $E_0 \sin \omega t$, where ω may be made $2\pi \times 1000$ sec.$^{-1}$, then the system will go on oscillating with a frequency 1000 sec.$^{-1}$. When now the applied $E_0 \sin \omega t$ is left as before but C is gradually increased to a much greater value, it will be found that the system continues to oscillate with a frequency 1000 sec.$^{-1}$. If C is next increased still further, the frequency of the oscillations in the system (as detected, for example, with a telephone coupled loosely in some way to the system) suddenly drops to 1000/2 sec.$^{-1}$, to maintain this value over a certain range of the capacity value. If C is increased still more, the frequency suddenly jumps to 1000/3 sec.$^{-1}$, and so on up to 1000/40 sec.$^{-1}$. In some recent experiments it was found possible to obtain a frequency demultiplication up to the ratio 1 : 1/200. Often an irregular noise is heard in the telephone receivers before the frequency jumps to the next lower value. However, this is a subsidiary phenomenon, the main effect being the regular frequency demultiplication. It may be noted that while the production of harmonics, as with frequency multiplication, furnishes us with tones determining the musical major scale, the phenomenon of frequency-division renders the musical minor scale audible. In fact, with a properly chosen 'fundamental' ω, the turning of the condenser in the region of the third to the sixth subharmonic strongly reminds one of the tunes of a bagpipe.

In conclusion, we give in Fig. 2 the measured time periods (which are thus found to be a series of discrete subharmonics) as a function of the setting of the condenser C. The dotted line in the figure gives the frequency with which the system oscillates in the absence of the applied alternating E.M.F. The shaded parts correspond to those settings of the condenser where an irregular noise is heard. In the actual experiment the resistance R was, for ease of adjustment, replaced by a diode. The experiment, however, succeeds just as well with an ohmic resistance R. Obviously the same experiment succeeds with all systems capable of producing relaxation-oscillations such as described in the papers quoted.

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Eindhoven, Aug. 5.

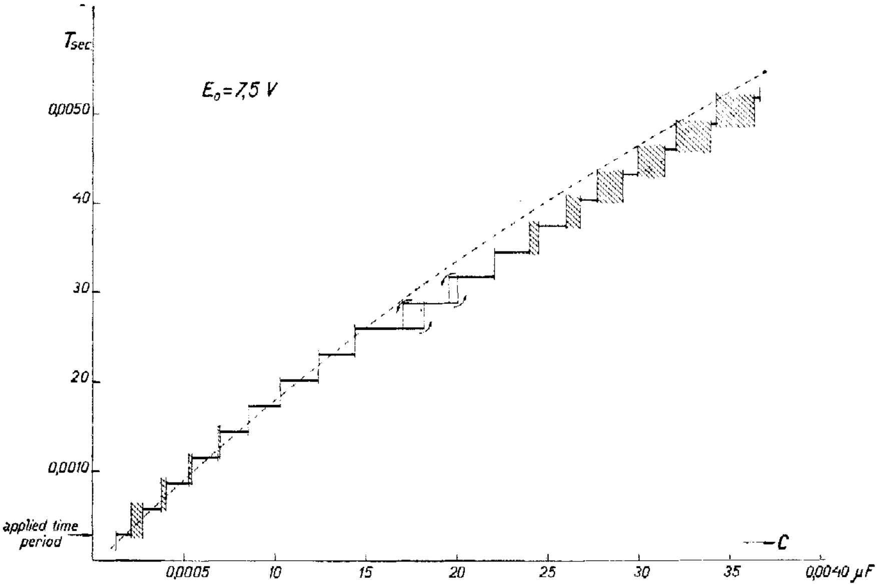

FIG. 2.

Movement in Fluid Dielectrics under Stress.

IT has been suggested to me that I should describe briefly, for the benefit of readers of NATURE who may be interested, some experiments which I showed at the High Tension Conference in Paris a few weeks ago.

In January last, as the result of a suggestion by Mr. G. L. Addenbrooke, who had previously investigated the phenomenon, I was able to demonstrate at the annual exhibition of the Physical Society, and