direction in which the wind is going. The same kind of thing happens with sound-wave fronts when travelling with the wind.

The velocity of any part of a wave front relative to the ground will be the normal velocity of sound + the velocity of the wind at that point. Since the velocity increases as we go upwards the front tends to swing round and travel downwards, as shown in the successive positions *a* 1, 2, 3 and 4, in fig. 14, where we must suppose the wind to be blowing from left to right. But if the wind is against the sound the velocity of a point of the wave front is the normal velocity—the wind velocity at the point, and so decreases as we rise. Then the front tends to swing round and travel upwards as shown in the successive positions *b* I, 2, 3, and 4, in fig. 14, where the wind is travelling from right to left. In the first case the waves are more likely to reach and be perceived by an observer level with the source, while in the second case they may go over his head and not be heard at all.

*Diffraction of Sound Waves.*

Many of the well-known phenomena of optical diffraction may be imitated with sound waves, especially if the waves be short. Lord Rayleigh (*Scientific Papers,* iii. 24) has given various examples, and we refer the reader to his account. We shall only consider one interesting case of sound diffraction which may be easily observed. When we are walking past a fence formed by equally-spaced vertical rails or overlapping boards, we may often note that each footstep is followed by a musical ring. A sharp clap of the hands may also produce the effect. A short impulsive wave travels towards the fence, and each rail as it is reached by the wave becomes the centre of a new secondary wave sent out all round, or at any rate on the front side of the fence.

Let S (fig. 15) be the source very nearly in the line of the rails ABCDEF. At the instant that the original wave reaches F the wave from E has travelled to a circle of radius very nearly equal to EF—not quite, as S is not quite in the plane of the rails. The wave from D has travelled to a circle of radius nearly equal to DF, that from C to a circle of radius nearly CF, and so on. As these "secondary waves ” return to S their distance apart is nearly equal to twice the distance between the rails, and the observer then hears a note of wave-length nearly 2EF. But if an observer is stationed at S' the waves will be about half as far apart and will reach him with nearly twice the frequency, so that he hears a note about an octave higher. As he travels further round the frequency increases still more. The railings in fact do for sound what a diffraction grating does for light.

*Frequency and Pitch.*

Sounds may be divided into noises and musical notes. A mere noise is an irregular disturbance. If we study the source produc­ing it we find that there is no regularity of vibration. A musical note always arises from a source which has some regularity of vibration, and which sends equally-spaced waves into the air. A given note has always the same frequency, that is to say, the hearer receives the same number of waves per second what­ever the source by which the note is produced. Various instru­ments have been devised which produce any desired note, and which are provided with methods of counting the frequency of vibration. The results obtained fully confirm the general law that "pitch,” or the position of the note in the musical scale, depends solely on its frequency. We shall now describe some of the methods of determining frequency.

Savart’s toothed wheel apparatus, named after Félix Savart (1791—1841), a French physicist and surgeon, consists of a brass wheel, whose edge is divided into a number of equal projecting teeth distributed uniformly over the circumference, and which is capable of rapid rotation about an axis perpendicular to its plane and passing through its centre, by means of a series of multiplying wheels, the last of which is turned round by the hand. The toothed wheel being set in motion, the edge of a card or of a funnel-shaped piece of common notepaper is held against the teeth, when a note will be heard arising from the rapidly succeeding displacements of the air in its vicinity. The pitch of this note will rise as the rate of rotation increases, and becomes steady when that rotation is maintained uniform. It may thus be brought into unison with any sound of which it may be required to determine the correspond­ing number of vibrations per second, as for instance the note A3, three octaves higher than the A which is indicated musically by a small circle placed between the second and third lines of the G clef, which A is the note of the tuning-fork usually employed for regulating concert-pitch. A3 may be given by a piano. Now, suppose that the note produced with Savart’s apparatus is in unison with A3, when the experimenter turns round the first wheel at the rate of 60 turns per minute or one per second, and that the cir­cumferences of the various multiplying wheels are such that the rate of revolution of the toothed wheel is thereby increased 44 times, then the latter wheel will perform 44 revolutions in a second, and hence, if the number of its teeth be 80, the number of taps imparted to the card every second will amount to 44×80 or 3520. This, therefore, is the number of vibrations corresponding to the note A3. If we divide this by 23 or 8, we obtain 440 as the number of vibrations answering to the note A. If, for the single toothed wheel, be substituted a set of four with a common axis, in which the teeth are in the ratios 4: 5: 6: 8, and if the card be rapidly passed along their edges, we shall hear distinctly produced the fundamental chord C, E, G, C1 and shall thus satisfy ourselves that the intervals C, E; C, G and C, C1 are 5/4, 3/2 and 2 respectively.

Neither this instrument nor the next to be described is now used for exact work; they merely serve as illustrations of the law of pitch.

The *siren* of L. F. W. A. Seebeck (1805-1849) is the simplest form of apparatus thus designated, and consists of a large circular disk mounted on a central axis, about which it may be made to revolve with moderate rapidity. This disk is per­forated with small round holes arranged in circles about the centre of the disk. In the first series of circles, reckoning from the centre the openings are so made as to divide the respective circumferences, on which they are found, in aliquot parts bearing to each other the ratios of the numbers 2, 4, 5, 6, 8, 10, 12, 16, 20, 2a, 32, 40, 48, 64. The second series consists of circles each of which is formed of two sets of perforations, in the first circle arranged as 4:5, in the next as 3:4, then as 2:3, 3:5, 4:7. In the outer series is a circle divided by perforations into four sets, the numbers of aliquot parts being as 3 : 4 : 5 : 6, followed by others which we need not further refer to.

The disk being started, then by means of a tube held at one end between the lips, and applied near to the disk at the other, or more easily with a common bellows, a blast of air is made to fall on the part of the disk which contains any one of the above circles. The current being alternately transmitted and shut off, as a hole passes on and off the aperture of the tube or bellows, causes a vibratory motion of the air, whose frequency depends on the number of times per second that a perforation passes the mouth of the tube. Hence the note produced with any given circle of holes rises in pitch as the disk revolves more rapidly; and if, the revolution of the disk being kept as steady as possible, the tube be passed rapidly across the circles of the first series, a series of notes is heard, which, if the lowest be denoted by C, form the sequence C, C1, E1, G1, C2, &c. In like manner, the first circle in which we have two sets of holes dividing the circumference, the one into say 8 parts, and the other into 10, or in ratio 4:5, the note produced is a compound one, such as would be obtained by striking on the piano two notes separated by the interval of a major third (J). Similar results are obtainable by means of the remaining perforations.

A still simpler form of siren may be constituted with a good spinning-top, a perforated card disk, and a tube for blowing with.

The siren of C. Cagniard de la Tour is founded on the same principle as the preceding. It consists of a cylindrical chest of brass, the base of which is pierced at its centre with an opening in which is fixed a brass tube projecting outwards, and intended for supplying the cavity of the cylinder with compressed air or other gas, or even liquid. The top of the cylinder is formed of a plate perforated near its edge by holes distributed uniformly in a circle concentric with the plate, and which are cut obliquely through the thickness of the plate. Immediately above this fixed plate, and almost in contact with it, is another of the same dimensions, and furnished with the same number, n, of openings similarly placed, but passing obliquely through in an opposite direction from those in the fixed plate, the one set being inclined to the left, the other to the right.

This second plate is capable of rotation about an axis per­pendicular to its plane and passing through its centre. Now, let the movable plate be at any time in a position such that its holes are immediately above those in the fixed plate, and let the bellows’ by which air is forced into the cylinder (air, for simplicity, being