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MAKING BEATS VISIBLE

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The production of beats by two vibrating bodies having frequencies almost but not quite the same is a familiar phenomenon. Frequently they are so pronounced that they are easily heard. The piano tuner, after tuning to correct pitch one of the three strings played by any one key, listens for and eliminates any beats produced when the one or the other remaining string is struck along with the first. Two tuning forks or musical bars having identical frequencies will produce distinct beats if one of them is weighted a little.

The cause of beats is well known to all physicists. When simultaneous sound waves agree in phase there is reenforcement and when in opposite phase silence is produced. On account of the persistence of hearing the time of each silence seems much shorter than that of the sound.

Not only do sound waves in the air reenforce or interfere with each other, but they react on the bodies producing the vibrations, causing them to vibrate with greater amplitude when in like phase and less amplitude when in opposite phase. This effect is so pronounced that with the right kind of apparatus one can see the beats and even make them visible by projection to a large audience. Either tuning forks or a stringed instrument like a sonometer or violin may be used.

Two tuning forks with a difference of a few vibrations per second are mounted in a metal block consisting of two halves (one for each fork) so fastened together that one may be rotated over the other a few degrees and clamped solidly in this position. When the two halves of the block are exactly opposite each other the two tuning forks are also directly opposite. When the one half is rotated over the other a few degrees the right hand prong of fork No. 1 will make a small angle with the corresponding prong of fork No. 2. Likewise there may be a similar angle between the left hand prongs of the two forks. If the forks are simultaneously struck with a rubber mallet and the forks held toward a light source or a white or light colored surface, the beats may easily be seen, the two prongs on the right or on the left alternately approaching and receding from each other. If placed in the proper position with reference to a projection apparatus the beats may be seen by a lecture audience. If at the same time the handle of the holder is placed on some resonating surface the beats may be both seen and heard.

To see beats with a stringed instrument use two identical strings. The thicker they are the better. Arrange them in such a way that they cross each other near their middle and that one end of the top one is raised up a little so that the two strings do not touch each other. Tune them to the same pitch. If they are within a few vibrations of each other the beats can be plainly seen where the strings cross. By changing the tension of one of the strings slightly the number of beats can be increased or decreased at will or the beats may be eliminated altogether.

THE THEORY OF THE IMPULSE FUNCTION FOR OSCILLATORY MECHANICAL AND ELECTRICAL SYSTEMS

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Several general methods are available for the representation of the solutions of the equations of oscillatory mechanical and electrical systems. In any particular problem, the choice of the method to be used is largely a matter of convenience. For those problems in which the characteristic frequencies and modes of oscillation are of direct interest, an expansion in terms of normal functions is to be preferred. If one is dealing with a system with continuously distributed physical parameters this leads to expansions in infinite series of functions such as the trigonometric functions (Fourier series and integrals), Bessel functions, Legendre functions, and so on.

For dealing with problems in which the physical data are given in the form of initial conditions, and particularly in cases involving externally applied forces, the method of expansion in normal functions is apt to become very involved, and the series obtained are often only asymptotic in character, if indeed they can be summed in any sense. Following the theory proposed by Heaviside, electrical circuits are often treated by considering that the external voltages applied to the system are resolvable into a sequence of "step-functions." The basic element in this analysis is the *unit function* H (t) which is defined by the properties

$$\begin{aligned} H(t) &= 0 \quad \text{if} \quad t < 0 \\ &= 1 \quad \text{if} \quad t \geqq 0 \end{aligned}$$

Mathematically this procedure may be considered as a resolution by means of Stieltje's integral rather than the Fourier integral. The unit function is taken as the integration element.

For the discussion of mechanical systems it seems more suggestive from the physical point of view to introduce the idea of impulsive forces. An elementary impulse is considered as represented by a force (or electromotive force) of very great magnitude which is