BEYOND THE THRESHOLD OF HEARING

Humanist culture insists on relating all things to the proportions of man. The Greeks used the "golden mean", or ratio based on an analysis of the proportions of the human figure. For practical purposes everyday objects must be man-sized. The seat of a chair must be the height of a man's calf-length. A door must be higher than 6 feet. Music is confined within the pitch range audible and playable by human beings. Its rhythmic pulse is related to the rate of the human heart, to the rate of breathing, walking or running, its phrase structure to that of human speech and it's phrase duration to the amount of breath available for singing or playing a wind instrument.

Consider a piece of music. It consists of a succession of different sounds following one another in time. Consider a single instant in this succession, such as the final chord. It consists of a juxtaposition of different notes, sounding together simultaneously. Consider one single note of medium pitch seperated out from this chord. It consists of a number of different related components which make up its harmonic spectrum, or wave form. Consider this wave form by observing it on an oscilloscope. It consists of a succession of identically shaped single waves or cycles which represent a pattern of rising and falling air pressure.

These waves radiate in all directions from the sound source like ripples in a pond. The waves move at a constant and uniform speed regardless of their size. The air itself does not move, just as a leaf floating on a pond does not move along, but merely rises up and down on the ripples. The waves reaching the ear take the form of a uniform rise and fall of air pressure upon the ear drum. The speed or frequency of this oscillation is measured in cycles per second. The frequency of middle C on the piano is about 260 c.p.s. Let the length of the waves be decreased. If the waves move at a constant speed regardless of size, then more of them will strike the ear every second. The frequency will be more and the note will sound higher. Let the length of the waves be increased. If the waves move at a constant speed regardless of size, then fewer of them will strike the ear every second. The frequency will be less and the note will sound lower. The three factors governing pitch are related by the formula -

$$\text{Frequency} = \frac{\text{velocity}}{\text{wavelength}}$$

Sound waves move at a speed of 880 feet per second in air. An organ pipe with an effective length of 2 feet will produce a note of 440 c.p.s.

$$\frac{\text{880 feet per second}}{\text{2 feet}} = \text{440 c.p.s.}$$

This is the frequency of orchestral tuning. A. Let the frequency of the single note be increased gradually.

As the note rises in pitch it appears to become quieter until it becomes inaudible above 20,000 c.p.s. Let the loudness or amplitude of the note at 20,000 c.p.s. be increased. It remains inaudible no matter how loud it becomes. Let the frequency of the single note be decreased again to its original pitch. Let the amplitude be increased. At a certain level of loudness, the sound becomes physically painful to the ear. Let the frequency be decreased gradually. As the note falls in pitch it appears to become quieter until it becomes inaudible below 20 c.p.s. Let the amplitude be increased. At a certain level of loudness, the note becomes perceptible as vibrations of objects in the room, and of the walls and floor of the room itself. There is no sensation of audible itch. Let the frequency of the single note be decreased further. The vibration is transformed into a series of single pressure waves. If the wave form is of a particular type described as a square wave these waves will be heard as a series of rapid clicks. If the frequency falls to about 2 c.p.s. it will be transformed into a rhythmic pulse. If a frequency of 2 c.p.s. is fed into the secondary input of a ring modulator, while a complex noise is fed into the primary input, the 2 c.p.s. will be heard as a rise and fall or modulation in the amplitude of the complex noise.

We experience very low sounds almost every day in city street, railway stations, or factories. This threshold region is almost completely untapped as a source of musical material, yet it is not difficult to devise apparatus which could operate at such frequencies.

Sound can be transmitted in almost any medium, though every medium deforms the waveband in its own characteristic way. Loud music heard through the walls of a room has all its high frequencies reduced or attenuated. Our ears are adapted to the particular attenuations produced by the medium of air. Sounds are completely transformed when they are heard under water. Only the very lowest vibrations of the sound of an underground train are transmitted to street level. The low frequency vibrations of explosions, earthquakes and eruptions are transmitted through the ground over a far greater distance than they can be in air. When low frequency vibrations are transmitted through the sea they take the form of rollers, breakers, ground swell and tidal flow.

Sound can be transfered from one medium to another. A microphone converts air waves into fluctuations in an electric current. A transmitter converts these fluctuations into variations in the amplitude of high frequency radio waves. A radio receiver and a loudspeaker reverses the process.

Consider a stretched steel string with a length of 4 feet which vibrates at a frequency of 130 c.p.s. When the string is plucked, the pitch C is heard. The outline of the string appears blurred, and a touch with the fingers shows that it is vibrating very rapidly.

If the string is shortened or tightened, the frequency of this vibration increases, but its amplitude decreases.

If the string is lengthened or loosened, the frequency of this vibration decreases, but its amplitude increases.

Apply the formula:- $\text{frequency} = \frac{\text{velocity}}{\text{wavelength}}$

The wavelength is represented by the length of the string.

The velocity is the actual speed at which the string moves when it is in vibration. Its ability to move is affected by its tightness. Thus, the maximum possible amplitude of its vibration is smaller, the tighter the string becomes.

Consider a stretched steel string with a length of 32 feet which vibrates at a frequency of 16 c.p.s. When the string is plucked, no sound is heard. The amplitude of vibration is very large, and the shape of the string's movement is clearly visible as a rotating movement about the point of rest.

If one end of the string is detached and has a weight hung on it, the string is turned into a pendulum.

Consider a pendulum which swings at a frequency of 2 c.p.s. If the string is shortened, the freq ency of swing is increased. If the string is lengthened, the frequency of swing is decreased.

Apply the formula:- $\text{frequency} = \frac{\text{velocity}}{\text{wavelength}}$

The wavelength is represented by the length of the string.

The velocity is the speed at which the weight of the pendulum moves when it is in motion. This speed is governed by the force of gravity and is therefore a constant factor.

If the pendulum swings along a straight line, it describes an arc, moving back and forth through the midpoint.

If the amplitude is increased it reaches a maximum when the arc becomes a semicircle. The swinging pendulum embodies the principles of all oscillating movement; the movement of arms and legs, the swaying of trees in the wind, the mechanism of clocks.

If the pendulum is given an oscillation at right angles to the first movement, its movement will describe an ellipse when viewed from above.

If the oscillation in both directions is of equal amplitude, the movement will form a circle. When viewed from the side it will always describe an arc. If the oscillation in both directions attains a maximum amplitude, the circle will have a radius equal to the length of the pendulum's string. Viewed from the side it no longer forms an arc. The weight of the pendulum appears to move backward and forward along a horizontal line. At this point the pendulum is poised between two states. It ceases to be an oscillating device and begins to rotate.

It can no longer increase its amplitude, but its frequency and velocity can be increased to almost any extent. It is no longer affected by the force of gravity which is replaced by centrifugal force. Amplitude can only be changed by altering the length of the string.

Apply the formula:- frequency = $\frac{\text{velocity}}{\text{wavelength}}$

Frequency is represented as revolutions per second. Wavelength is the length of the string. Velocity is the speed of the weight moving round its circle.

The rotating centrifuge embodies the principles of all rotating systems in which an orbiting body is held in a circular or elliptical path around another, central body by the opposing gravitational and centrifugal forces: the movement of all stars, planets and satellites. This is the true music of the spheres; the universe is a great vibrating system of resonant chords clashing and resounding against one another.

If the circle described by the rotating centrifuge is given the form of a rim, joined to the centre by a series of wire spokes, it is transformed into a wheel. Consider a wheel with a radius of 2 feet. The frequency and velocity of its revolutions can be increased or decreased to almost any extent. Unlike the centrifuge it retains its shape even when at rest.

Apply the formula:- frequency = $\frac{\text{velocity}}{\text{wavelength}}$

Frequency is represented as revolutions per second. Wavelength is the radius of the wheel. Velocity is the speed of a point on the rim of the wheel.

A wheel is used as a means of transport. Its job is to convert rotating movement into linear movement, or vice versa. Consider the wheel moving along a level road. Consider a point on the rim of the wheel. The frequency with which this point meets the road is the same as the frequency of revolution of the wheel. The distance moved along the road by one revolution will be equal to the circumference of the wheel.

As the wheel moves along, it measures equal distances along the road.

The frequency in time is converted into frequency in space.

The legs of an animal convert oscillation into linear movement.

The needle of a gramophone converts the linear fluctuations in the surface of a gramophone record into fluctuations in an electric current.

The magnetic head of a tape recorder converts linear fluctuations in the magnetic recording tape into fluctuations in an electric current. The vanes of an electric fan convert rotating movement into the linear movement of a draft of air.

The sails of a windmill convert the linear movements of the wind into the rotating movement of the mill wheels, or the oscillating movement of the water pump.

Consider linear movement; it consists of a continuous change of position. Consider rotatory movement; it consists of a circular change of position.

Consider oscillatory movement; it consists of an alternating change of position.

Consider vibration; it consists of a change in the position of molecules.

Consider sound in air; it consists of changes in air pressure.

Consider the tides rising and falling; it consists of changes in the pressure and volume of water in one place.

Consider the rhythm of breathing, the rhythm of sleeping and waking, the rhythm of sexual tension in love making; they consist of changes in the rate of body metabolism.

Consider the cycle of the lunar month, the cycle of the seasons, the cycle of birth, growth, regular pattern of change in various factors, which in time evoke resonant changes in other factors; just as sound in air sets up resonant vibrations in neighbouring solid objects, just as the movements of the moon set up a resonant rise and fall in the level of the sea.

The only barrier standing in the way of accepting the notion that sound vibrations emanate from all things is our insistance upon the idea that sound is only that narrow part of the spectrum of vibrations which can be detected by the ear. An objective examination of physical phenomena shows that this barrier is illusory and that with a certain amount of ingenuity and imagination, it can be overcome.

Technology is the tool which we can use to extend the range of our own senses. The electron microscope and the radio telescope enable us to "see" and "hear" things which are respectively very small or very large and far away. The acoustic microphone, the contact microphone, the ring modulator, the filter are extensions of our ears enabling us to hear sounds on the threshold of our normal sense of hearing. The radio, the telescope, the television are extensions of our senses of hearing and sight across long distances. The tape recorder, gramophone and film camera are extensions of our memories enabling us to experience events in the past. It is now possible to bring together events, phenomena, sounds, images from a limitless number of sources. All that is needed is the imagination to see that these relationships do exist between many different things and to make use of the available tools to realise the vision. This must be the role of the artist in the present day. Technology has brought a limitless field of new experiences within the awareness of our normal senses. It is the job of the artist to write them into a common aesthetic experience.

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