This invention relates to musical instruments such as pianos and the like, comprising vibratory tone-producing elements together with hammers and keys therefor, and it particularly pertains to a novel string and hammer combination which is especially suited for use with piano-type instruments in which an electrical pickup is employed to convert the mechanical vibrations of the vibratory elements into electrical signals which are thereupon amplified and reconverted into sound waves.

In the past it has been customary in the construction of pianos to mount the strings on the chassis or frame of the instrument in position to be struck by hammers also mounted on the frame and operated by keys on the keyboard of the instrument. This has been true not only in conventional types of pianos but also in instruments intended for electronic reproduction of the tones produced by the strings. Instruments embodying this form of construction are necessarily large and heavy as well as costly because of the length of the strings required, the space needed for the hammer mechanism, and the hammer mechanism, and the presence of the iron frame or plate.

Herefore, the only significant difference between a conventional piano and an electronic piano involved the placement of a pickup in close proximity to the piano strings so as to enable the mechanical vibrations of the strings to be translated into electrical signals.

The type and mode of construction which we have devised for our electronic piano and which will hereinafter be described in connection with the drawings which accompany and form a part of this application, is in sharp contrast to this conventional form of construction and greatly reduces the size and cost of the instrument while producing clear and pleasing tones which may be amplified to any desired sound level by means of electronic amplifying apparatus. The principle upon which our instrument operates marks a radical departure from the prior art so that the instrument which we have produced is entirely new and not merely a modification of existing and already known piano constructions. In our design, the vibratory elements are preferably planar strings though, of course, other elements such as reeds may be substituted therefor if desired, are mounted directly on the keys as are also the hammers which strike against the elements to excite them into vibration. Hence, our entire instrument is incorporated in the keyboard, each key of which constitutes a unitary tone producing element that may be removed as a unit from the instrument in the manner of a conventional piano key. While the mounting of the strings upon the keys necessitates the use of strings which are much shorter than in the conventional type of piano, we have found that by providing an action having reduced attack so that the amplitude of vibrations of the strings is much less than in a conventional piano, a highly pleasing and satisfactory tone may be obtained from the short strings. Satisfactory quality of tone is obtained by using helical strings which give the effect of a much longer string and enable satisfactory tone quality and stability in pitch to be achieved from relatively short strings having reduced tension thereon. Various other novel features of forms and methods of construction and design have been incorporated in our instrument, such as provision of individual pickups in the keys with plug-in connections between pickups of adjacent keys to connect them into the electrical circuit, novel means for compensation for stray hum appearing in the pickups, a novel method of magnetizing the instrument strings, a novel shape for the striking face of the hammer which simplifies and reduces the cost of the hammer, and other features which will appear as the description proceeds.

The prior art over which the present invention is an improvement is represented by French Patent No. 990405 issued to the joint inventor Ferdinand Machalek on June 6, 1951, and Czechoslovakian application Serial No. P-1239-49, filed in Czechoslovakia in April 1949, by the joint inventor Ludmilla Machalek.

It is an object of our invention to provide a simplified hammer, string and key arrangement for an electronic piano.

Another object of our invention is to provide an instrument in which both the vibratory elements and the hammers are mounted on the keys.

Another object of our invention is to provide a keyed musical instrument in which each key has mounted thereon a string, a hammer and an electrical pickup for translating the vibrations of the string into electrical signals.

Another object of our invention is to provide a musical instrument having a key on which are mounted a hammer and a helical or coiled string.

Another object of our invention is to provide helical or waved strings of novel design for a musical percussion instrument.

Another object of our invention is to provide a keyed instrument having a string moving with the key and a hammer placed in the path of the string for attack thereon, the hammer being moved away from the string after attack so as to prevent damping of the vibrations in the string.

Another object of the invention is to provide an action for an electronic piano which is characterized by reduced attack of the hammer on the string.

Another object of the invention is to provide a novel design of striking surface for a piano hammer.

Another object of the invention is to provide novel means for interconnecting the individual pickups mounted on the several keys so that a particular key may be quickly and easily removed from the keyboard of the instrument.

Another object of the invention is to provide an electronic stringed instrument in which either a piano effect or an organ effect may be obtained as desired.

Another object of our invention is to provide novel means for balancing out any stray hum picked up by the electrical pickup apparatus of a musical string instrument.

Another object of our invention is to provide a novel method for magnetizing the strings of the musical instrument in the vicinity of the pickup.

Another object of our invention is to provide a novel method of transmitting the music produced by our instrument to a remote location.

Further objects, and objects relating to details of construction and modes of operation, will readily appear from the detailed description to follow. In one instance, we have accomplished the objects of the invention by the apparatus disclosed in the following specification. The invention is clearly defined and pointed out in the appended claims. Desirable forms of construction of the
invention are illustrated in the accompanying drawings, in which:

Fig. 1 is a perspective view of one of the keys of our invention showing the manner in which the string and pickup are mounted on the key.

Fig. 2 is a side elevation of the same key showing it in place on the keyboard of the instrument with the hammer in place thereon, the key being shown in its normal position in this view.

Fig. 3 is a view similar to Fig. 2 but showing the key in a partially depressed position wherein the hammer has just made contact with the string. With the continued depression of the key the hammer will be lifted off the string.

Fig. 4 is an enlarged view showing in detail the shape of the hammer striking face and the manner in which the hammer felt is applied thereto.

Fig. 5 is a top plan view of a key as it appears when removed from the instrument.

Fig. 6 is a side view of a key showing means for causing the string to vibrate in two sections.

Fig. 7 is a diagrammatic view of a pickup with novel means for compensating for stray hum induced therein.

Fig. 8 is a diagrammatic view of the plug-in connections between keys.

Fig. 9 is a diagrammatic view of an alternative means of balancing out hum induced in the pickup.

Fig. 10 is a graph showing the frequency changes produced by different types of strings by a change in the elongation of the strings.

Fig. 11 is a view showing different types of coiled or waved strings.

Fig. 12 is a side elevation of a modified design of key in which a reed is mounted on the key for striking by the hammer.

Fig. 13 is a cross-sectional view taken through a key and the balance rail showing a modified form of interconnecting means between the individual pickups on the various keys.

Fig. 14 is a diagrammatic representation of a radio transmitter and receiver for use in connection with our musical instrument.

As previously stated, it has been common practice in the design and construction of electronic pianos to utilize conventional piano construction for these instruments and to merely amplify the vibrations set up in the strings by means of an electrical pickup placed in close proximity to the strings. In the conventional piano, the action is such that the mechanical linkage between the key and the hammer will considerably amplify the movement of the key and cause the hammer to move very rapidly toward the string when the key is depressed. As a consequence, the hammer strikes the string while traveling at high speed and this, together with the large size and weight of the hammer, causes a large deflection of the string. This initial, large deflection of the string as a result of the sharp hammer blow thereon produces a sound of impact which is only imperfectly reproduced by the soundboard in the conventional piano. That is, the soundboard discriminates against the percussive noise, or at least does not amplify it to the same extent that it does the musical tones, so that the noise thus produced is not sufficiently loud to be objectionable to the auditory senses. When, however, an attempt is made to amplify the vibrations of the strings by means of an electrical pickup device, the vibratory shock produced by the blow of the hammer on the string is amplified to the same extent as the musical vibrations of the string. This has the effect of over-emphasizing the noise due to the percussive blow of the hammer and the result is very disagreeable and not pleasing to the ear. Attempts have been made to overcome this difficulty by limiting the signal handling ability of the input stages of the electronic amplifier connected to the pickup to thereby limit the amplitude of the signal produced by the blow of the hammer on the string. This has not been found desirable for the reason that such clipping of the signal causes distortion which itself results in unsatisfactory reproduction. With our novel form of key action, however, which operates on the principle of reduced attack, that is, striking the string a light blow with greatly diminished speed, no precautions need be taken to deamplify the noise due to percussion since the impact of the hammer against the string is not sufficient to produce a large deflection of the string which will be reproduced as noise when amplified. Consequently, a very pleasing piano sound of true piano quality is obtained. The vibrations of the strings are picked up and amplified. As will be more fully appreciated as the description proceeds, this opens up an entirely new approach to the problem of producing a compact, inexpensive electronic piano-type instrument which produces clear, vibrant tones of a pleasing character. Also, depending on the location of the pickup with relation to the pivot point of the key, either piano or organ-type sound effects may be produced.

In addition to employing the principle of reduced attack, we prefer to place the piano strings of the instrument directly on the keys so that an extremely compact and simple form of instrument is obtained. Also, we prefer to mount the hammers directly on the keys since this further simplifies the construction and makes each key a complete musical unit in itself.

The construction and mode of operation of our novel key, string and hammer mechanism is best understood by reference to Figs. 1, 2 and 3 of the drawings. As therein shown, the keys 30 are each fitted with a balance pin 21 which serves as a pivot for the key on a balance rail 22. The keys 30 may be made of wood or cast metal which is preferably, though not necessarily, given the shape shown in the drawings. The key herein shown is a “white” key, it being understood that a similar principle of construction may be applied to the “black” keys of the instrument.

The balance rail 22 is fastened to a keyboard frame or chassis 23 which, at its rear edge, is fitted with a key rest rail 24. The rear end of each key is provided with a flat face 25 which is adapted to bear against a strip of felt 26 on the rail 24 when the key is in its normal, undepressed position as shown in Fig. 2. The keys are urged into the positions shown in Fig. 2 by reason of the fact that the center of gravity of the keys is behind the balance rail end of the key and drives them toward the position shown in Fig. 2 when released. Each key is also provided at its forward end with a depending oval pin 28 which is received and guided by an elongated slot 29 provided in the forward end of the balance rail 23. A strip of felt 30 is provided on the balance rail beneath the forward ends of the keys to cushion the blow of the keys when they are depressed. Likewise, a felt washer 31 is placed on each balance pin 21 so as to lie between the key and the balance rail 22 and to cushion the key thereon. The balance pin 21 is received in an enlarged hole 32 provided in the balance rail into which the lower end of the pin extends. The upper end of the hole 32 terminates in a hole of reduced diameter 33 slightly larger than the pin 21 which provides a pivot for the pin. Strips of felt 34 are preferably mounted in the lower end of the hole 32 on either side of the pin 21 so as to prevent sideways displacement of the pin while permitting longitudinal displacement thereof.

As shown in Figs. 1 to 3, inclusive, each key is fitted with a steel piano string 40 which is suitably mounted on the top face of the key. At its forward end, the string 40 is fastened to a hitch pin 41 while the rear end of the string is fastened to a tuning pin 42. Intermediate the pins 41 and 42 at the forward and rear ends of the keys are agraffes 43 and 44. In this instance, take the form of splined pins having slotted heads for receiving the piano string. By turning the tuning pins 42, the tension
on the strings 40 may be varied as necessary to produce tones of the desired pitch. While a string of conventional type has been shown in the drawings, it is to be understood that a helical or waved string to pull the nail is preferred. This alternate type of string may take either the form of a close-wound helix as shown in Fig. 11a, an open-wound helix as shown in Fig. 11b, or, a coiled wave string as shown in Fig. 11c. In any case, the string may be wrapped with soft wire as illustrated in Fig. 11d to increase its mass and thereby lower the frequency or pitch of the string.

We prefer helical strings on all but the highest notes of the piano since such strings not only provide improved quality of tone under conditions of reduced tension but also maintain their tuning much better than ordinary strings. This is illustrated by the graph in Fig. 10 on which is plotted the change in frequency per unit of elongation for straight strings, helical open-wound strings and helical close-wound strings. In each case the amount of elongation of the string being considered is 0.1 inch. For the straight string, as indicated by the line 45 on the graph, the frequency, or pitch, will change 1100 cents (the frequency difference between any two adjacent pitches on the scale like 100 cents) or nearly 1 octave for a 0.1 inch change in elongation. As indicated by line 46 on the graph, the pitch of the open-wound helical string will change 154 cents for a 0.1 inch variation in elongation, while, as shown by line 47, the close-wound helical string will change its pitch only 35 cents for a corresponding variation in elongation. Hence, it is much easier to maintain the tuning of either close-wound or open-wound helical strings than it is to maintain the tuning of straight strings.

To obtain the best results from the coiled strings or waved strings, the outside diameter of the helix or wave should not be greater than 3/16 of the speaking length of the string. With helices of larger diameter, longitudinal vibrations may be created which will react unfavorably on the quality of the tone produced by the string.

In addition, for best performance, we have found that the weight of such strings should be less than 0.5% of the pull thereon for bass strings and more than 0.5% of the pull for treble strings. This latter requirement arises from the need for a large number of harmonics in the bass strings and few or no harmonics in the treble strings. Hence, the bass strings should be long, i.e., they should have a large length to diameter ratio, while the treble strings should be short, i.e., they should have a small length to diameter ratio. Also, the bass strings should have a high pull to weight ratio while the treble strings should have a small pull to weight ratio. These conditions are succinctly expressed by the foregoing limitations on the length of the string with respect to the outside diameter of the helix and the ratio of the weight of strings to the pull exerted thereon for bass and treble strings.

Each key 20 is provided with a hammer supporting bracket 50 to which is secured a bifurcated arm 51 apertured to receive a pin 52 which forms a turning point for the hammer 53. Each hammer is comprised of a hammer shank 54 and a hammer head 55 secured to the rear end of the shank. On the forward end 56 of the shank 54, which will hereinafter be referred to as the hammer butt, is a felt damper 57 which is adapted to bear against the string 40 when the key is in its normal position (Fig. 2). This results from the fact that the hammer head 55 is provided with a flange 58 which is provided on its under face with a bit of felt 59 (Fig. 3) which rests on a pin or spool 60 fastened to a rest rail 61. This rail is pivoted at either end on transverse 62 so that a slight rocking movement may be given to the hammer. A hammer shank 54 is provided with an up end to an arm 64 extending from the rail 61. The rod 63 is connected with the sustaining pedal of the instrument and is elevated when the sustaining pedal is depressed so as to rock the rail 61 counterclockwise as viewed in Fig. 2 to lower the pin 60 slightly and permit the damper 57 to move up off the string 40.

The hammer head 55 is provided with an inclined striking face 70 (see Fig. 4) which is covered with a hammer pad 71. This pad may be made of felt, leather or other suitable cushioning material and may be of uniform thickness along the length of the striking face 70. The pad is preferably glued at the place indicated by reference numeral 72 on the back of the striking face after which it is bent around the toe and glued at 73 to the forward face of the head. The angle of inclination x (Fig. 4) of the striking face 70 with respect to the string 40 at the instant of striking should be within the range of 15° to 30°. With an angle of inclination lying in this range and a pad of substantially uniform thickness, when the hammer strikes the string, the felt will compress and make contact with the string 40 along an appreciable length of the string so as to provide a cushioned attack of the hammer on the string. At the same time, the nose 74 of the hammer provides beneath the felt a point of force concentration on the string so as to suitably depress the string and excite it to vibration. It is also to be noted that in this construction, the felt is glued at 72 to the heel of the striking face behind the portion of the felt which contacts the string so that there is no hardness due to glue beneath that portion of the felt which engages the string.

With the hammer construction shown, a lighter, smaller and less expensive striking implement is provided.

The striking action of the hammer on the string is best understood from a study of Figs. 2 and 3 which show the key in its normal and partially depressed positions, respectively. When pressure is applied to the finger piece 27 of the key, the rear end of the key is gradually raised to a point where the string moves into contact with the hammer as shown in Fig. 3. This is the point of attack of the hammer against the string and the string is thereby set into vibration. As the rear end of the key continues to rise under continued pressure on the finger piece 27, the hammer is rotated clockwise about its turning point 52 due to engagement of the hammer butt 56 with a regulating bar 80. A thin piece of felt 81 is preferably interposed between the bar and the hammer butt to cushion the blow of the butt against the bar. Hence, at the instant the hammer strikes the string, it is smoothly turned about the pivot 52 to lift the hammer from the string and prevent damping of the vibration therein. The flange 58 of the hammer head now moves off the pin 60 and the rounded end of the pin or spool, as the case may be, slides along a friction pad 82 secured to the face of the hammer head. This pad may be made of soft felt or a piled fabric such as mohair. The rounded end of the pin or spool 60 is brought into contact with the friction pad 82 due to the geometry of the key and hammer mechanism. As shown in Fig. 2, the pivot 52 for the hammer follows the path indicated by curved line 83 and moves forward or toward the right relative to the pin 60 as the key is depressed. This brings the end of the pin into contact with the pad 82 as the hammer head rises. Hence, when the key reaches the bottom of its stroke with the forward end of the key bearing against the felt pad 30 on the barrel 66, the rounded end of pin 60 will be in frictional engagement with the pad 82. Also, at this time, the hammer shank 54 will be engaged with a strip of felt 84 extending along the bottom face of the rail 61. This latter engagement prevents any overthrow of the hammer at the end of the upward stroke and effectively locks the hammer in position against the rail 61 and bar 89. Now, as the pressure on the finger piece 27 is released and the hammer permitted to return to its normal position, a frictional piece of the pin against the pad 82 will prevent the hammer head from dropping until after the key has passed the position shown in Fig. 3 so that striking of the hammer
against the string on the return movement of the key is prevented. After the key has returned beyond the position shown in Fig. 3, the hammer moves rearward relative to the pin 69 sufficiently to release the hammer head and permit the hammer to drop with the flange 58 against the pin 69.

The key now completes the final portion of its return movement and the damper 57 on the hammer butt engages the string and dampens the vibrations therein as the surface 25 on the rear end of the key engages the hammer rest pad 26. If sustained vibrations are desired, the suspending rod 63 is elevated slightly so as to lower the pin 69 a small extent and thereby permit the damper 57 to lie slightly above the string.

It may be found desirable to provide a resilient pad 85 on either side of the string beneath the hammer head as indicated in Figs. 1, 2 and 3. These pads will take up a portion of the blow of the hammer and prevent undue deflection of the string when it strikes against the hammer on the up stroke of the key. Alternatively, the pads 85 may be made sufficiently thick and of suitable hardness, to prevent the hammer from striking the string at all, vibrations being set up in the string by the impact of the keys. The pads may be made of felt, rubber, plastic, or, in case it is desired to prevent striking of the hammer against the string, some harder material such as wood may be employed.

From the foregoing description it will be noted that the attack of the hammer on the string is greatly reduced as compared with a normal piano action. That is, the speed of striking of the string on the key is no greater than the speed of the key itself since the hammer remains at rest while the key with the string thereon rises into contact with the hammer. This results in a considerable improvement in the quality of the tone produced by the strings carried by the keys of our instrument.

The mechanical vibrations of the strings 40 may be translated into electrical signals and amplified electronically so as to enable the faint tones produced by the strings to be reproduced as audible sounds having the desired intensity. For this purpose we prefer to provide an individual pickup unit 90 (Fig. 1) for each of the keys of the instrument. Hence, each key is a self-contained unit provided with string, hammer and pickup which may be removed from the instrument as a unit and replaced by a similar unit as desired. As shown in Fig. 1, the pickup 90 may include a bar magnet 91 to the opposite ends of which are fastened soft iron cores 92 and 93. The core 92 has wound thereon a pickup coil 94. The coil 94 and core 93 are received in vertical holes provided in the body of the key 20. The permanent magnet 91 lies against the bottom of the key and is held in place by a strap 95 passing therethrough and secured to the sides of the key, or by any other suitable fastening means. The upper ends of the cores 92 and 93 lie immediately beneath the string 49 which completes the magnetic circuit between the poles with an air gap between the string and each of the poles. Hence, as the string vibrates, the magnetic flux passing around the circuit will vary, thereby inducing a current in the coil 94. One terminal of the coil is connected to a socket or jack 96 (see also, Fig. 1) mounted in the upper surface of the key. The other terminal of the core is connected to a phone tip or plug 97 which may be inserted in the jack of the adjacent key. In this way, all of the pickups of the instrument may be connected in series so that the combined signals produced thereby will be fed into a suitable amplifying and reproducing means.

Inasmuch as the pickup 90 is located in a fixed position with relation to the string 40, the tone picked up by the pickup will be that of a piano-type instrument in which the pressure noise produced by the hammer striking the string will be reproduced as audible sound. However, since the hammer engages with the string with reduced attack, this percussive noise will be moderate and a true piano tone will be generated by the individual keys.
tious excited in the left-hand section of the string by the hammer 55 will be induced in the right-hand section of the string where they will be translated by the pickup 100 into an undulating electric current.

As illustrated in the various figures of the drawings, the keys 29 are routed out at their forward ends as indicated by the section through the space for the forward end of the string beneath the finger piece 27 of the key. In this way, strings extending over substantially the entire length of the key may be accommodated therein so as to obtain strings of greatest possible length for the low tones.

The common pickups 100 and 101 may, and preferably, be of the design illustrated in Fig. 7 or 9. In each of these designs, means is provided for compensating or balancing out any stray hum or noise which may be picked up by the coils of the pickup. As shown in Fig. 7, the pickup is provided with as many iron cores 120 as there are notes of the piano. The longitudinal axes of the bars 110 are normal to the longitudinal axes of the strings 111 of the instrument. The pickup includes a winding 112 which is passed in a sinuous manner about the cores 110, there being as many turns provided on the cores as is necessary for proper operation of the pickup. The winding 112 is connected through a condenser 113 to an electronic amplifier 114, the output of which is fed into a loud speaker 115. If desired, the bars 110 may be made of soft iron and the portions of the strings lying adjacent the cores may be magnetized by applying direct current to the winding 112 for a brief instant. This D.C. current may be applied to the winding by means of terminals 116, the voltage applied being sufficiently high to cause magnetization of the strings when a D.C. current is applied to the terminals 116 for a brief interval of time.

By virtue of the sinuous form of winding 112 between the cores 110, any stray electromagnetic waves reaching the pickup from an outside source will generate equal and opposite currents in the coil 112 so that the extraneous hum or noise will be balanced out automatically and will not reach the amplifier 114. This is important where weak signals generated in the coil 112 by the vibrations of strings 111 must be amplified to high volume levels. If the cores are magnetized, the polarity thereof should be reversed for the strings so as not to balance out harmonics of equal pitch.

In Fig. 9 is shown another means whereby stray hum or noise from an outside source may be balanced out of the pickup so as not to be introduced into the amplifier. As shown in this figure, the pickup is provided with one or more cores 120 which may be in the shape of a long, rectangular bar of soft iron. The core 120 overlies the strings 121 of the instrument and is provided with a winding 122 of conventional type. Connected in parallel with the core 122 are two or more compensating coils comprising soft iron cores 123 and 124 provided with compensating coils on windings 125 and 126, respectively. The compensating coils 125 and 126 are placed somewhat in the instrument remote from the pickup and are supported so as to be rotatable about axes 127 and 128. Inasmuch as the magnetic axes of the windings 122, 125 and 126 are all normal to the plane of the paper when in the positions shown in Fig. 9, and the axes of rotation of the compensating coils lie in the plane of the paper and are perpendicular to one another, their magnetic axes will be rotated relative to the magnetic axis of the coil 122 when they are turned about axes 127 and 128 to enable setting of the coils to a position in which complete balancing out of any stray hum or noise may be effected.

In this type of pickup, as in the case of the pickup shown in Fig. 7, means may be provided for applying a direct current to the coil 122 for a brief interval for the purpose of magnetizing the strings 121 in the vicinity of the core 120. Thereafter, vibrations of strings will induce signal currents in the coil 122 which may be suitably amplified and reproduced electronically.

In place of the piano strings 40 mounted on the keys 20 of our instrument, it is, of course, possible to utilize other tone producing devices of the vibrating type such as reeds. As shown in Fig. 12, a reed 130 is fastened at one end to a bar 131 mounted on the rear end of the key. The hammer 53 may, in this instance, be similar to the hammers employed with the strings 40, although it is preferable to change the form of the striking surface as indicated in Fig. 10. The hammer 132, like the hammers 53, is provided with a damper 133 which is adapted to rest on the free end of the reed when the key is in its normal position so as to dampen vibrations of the reed when the key returns to its normal position after being depressed. Of course, sustained vibrations may be permitted by rotating the rest rail 134 slightly to lower the outer end of the pin 135 to an extent sufficient to remove the dampening force of the damper 133. A pickup 136 similar to the pickup 91 may be mounted directly on the key to translate the vibrations of the reed into electrical signals which may thereafter be amplified and reproduced as audible sounds. As shown in Fig. 12, the key 129 may be routed out as at 137 to provide space for the reed 130 on the key.

In Fig. 13 of the drawings is shown a modified construction of the readily disconnectable connections between the pickups of the individual keys which may be used in lieu of the arrangement shown in Fig. 8. As herein shown, each key 140 is provided with a pair of balance pins 141 which are received in openings 142 provided in a balance rail 143. Received in an annular recess at the upper end of each opening 142 is a coil spring 144 in the form of a toroid through which the balance pins 141 may pass and with which they make electrical contact. As shown in Fig. 3, one of the pins 141 on each key is connected by a conductor 146 with one terminal of the pickup coil 145, while the other pin 141 of the key is connected by a similar conductor with the other terminal of the coil. The coils 144 are connected by conductors 147 with similar coils for adjoining keys on either side of the key 140 so that when all of the keys are in place on the balance rail 143 the pickup coils 145 will be connected in series to form a complete circuit.

In the use of our device as a practice instrument where it is desirable that the music be heard only by the student playing the instrument, or by the student and his or her music instructor, we propose to deliver the electric signal from the electronic pickup device to a small, low-powered radio transmitter located in or near the instrument for transmission to a remote, crystal-type radio receiver adapted to power a set of earphones as shown in Fig. 14. In this way no wire connections from the instrument to the earphones are required, so that complete freedom of movement is permitted to the user of the earphones while listening to the music. In Fig. 14, the pickup device 150 is connected to the input of a radio transmitter 151 provided with an electromagnetic radiator 152. The waves thus emitted are received by the aerial or coil 153 of a radio receiver which is tuned by a condenser 154 to the frequency of the transmitter. The incoming signal is detected by a crystal element 155 and supplied to earphones 156 worn by the listener. Alternatively, the signal emitted by the transmitter and detected by the receiver could, of course, be amplified and utilized to power a loud speaker or a sound recording apparatus located at a distance from the musical instrument.

We are aware that various changes may be made in the construction of our electronic piano without departing from the spirit of our invention and, therefore, we claim our invention broadly as set forth by the appended claims.
Having thus described our invention, what we claim as new and useful and desire to secure by United States Letters Patent is:

1. A musical instrument having a keyboard, keys pivotally mounted on said keyboard, a string and hammer mounted on each of said keys with the hammer disposed above the string, a rest for holding each hammer elevated away from its associated string when the key is in its normal position, and means connected to the key for moving the hammer out of contact with the string after said key is moved from normal position to strike said string against the hammer.

2. The musical instrument of claim 1 in which the string is of helical form throughout its entire speaking length.

3. The instrument string of claim 2 wherein the outside diameter of the helix is less than 1% of the speaking length of the string and the weight of the string is less than 0.5% of the pull exerted thereon, for bass strings, and more than 0.1% of the pull thereon, for treble strings.

4. The musical instrument of claim 2 wherein each string for treble notes is in the form of an open helix with the outside diameter of the helix equal to or smaller than twice the diameter of the wire.

5. The musical instrument of claim 2 wherein the string is wrapped with soft wire to increase the mass of the string.

6. The musical instrument of claim 1 in which the string is of a coplanar wave form throughout its entire speaking length.

7. The musical instrument string of claim 6 wherein the treble strings are so formed that the distance between the tops and bottoms of the waves is equal to or smaller than twice the diameter of the wire.

8. A musical instrument comprising a depressible key, a piano string moving with said key, and a hammer lying in the path of said string for engagement thereby when the key is depressed.

9. The musical instrument of claim 8 in which a part of the key is routed out for providing a space to receive one end of said string.

10. The musical instrument of claim 8 wherein said hammer is biased toward said string, and including means connected to the key for holding said hammer removed from said string when the key is in its undepressed position.

11. The instrument of claim 10 in which said hammer is pivoted on said key in position above said string by means for permitting the hammer to attack said string at a relative speed not exceeding that of the key when the key is depressed.

12. The musical instrument of claim 11 wherein said hammer includes a shank pivoted intermediate its ends on said key, and a damper on the butt end of said shank.

13. The musical instrument of claim 8 including a damper on said hammer and means for engaging the damper with said string when the key is in its normal position.

14. The musical instrument of claim 13 wherein said damper is movable to a non-damping position in which said damper is held disengaged from said string with the key in its normal position.

15. A musical instrument having a key, a balance pin mounted on said key, and a balance rail having an enlarged upper terminating in a portion of reduced cross section slightly exceeding that of the pin therein for receiving said pin.

16. A musical string instrument comprising a key movable from a normal position to a depressed position, a string mounted on said key to produce a musical note when struck, a hammer pivoted on said key intermediate its ends for attacking said string at a speed not exceeding that of the key at the moment of striking when the key is depressed, and means provided on the key situated on said key beside said string and beneath said hammer for absorbing a portion of the impact of the hammer on the string.

17. A musical string instrument comprising a key movable from a normal position to a depressed position, a string mounted on said key to produce a musical note when struck, a hammer pivoted on said key intermediate its ends for attacking said string at a speed not exceeding that of the key when the hammer is depressed, and means situated on said key beside said string and beneath said hammer for absorbing a portion of the impact of the hammer on the string.

18. The instrument of claim 17 wherein said means absorbs all of the impact of the hammer, said string being indirectly vibrated by the impact of the hammer on said means, and wherein said means is located at the conventional striking line.

19. A musical string instrument comprising a key movable from a normal position to a depressed position, a string associated with said key to produce a musical note when struck, a hammer pivoted on said key intermediate its ends and biased towards said string for attacking the string at a speed not exceeding that of said key when the key is depressed, and means to absorb the impact of the hammer away from said string, and means coupling with said hammer to lift it off the string after it has attacked the string upon depression of the key.

20. A musical string instrument comprising a key movable from a normal position to a depressed position, a string associated with said key to produce a musical note when struck, a hammer pivoted on said key intermediate its ends and biased toward said string for attacking the string at a speed not exceeding that of said key when the key is depressed, a hammer rest for holding said hammer away from said string, and a stationary bar connecting one end of said hammer to lift it off the string after it has attacked the string upon depression of the key.

21. The musical instrument of claim 20 including means for engaging said hammer on the side of the pivot opposite said one end of said hammer upon full depression of said key to prevent overthrow of the hammer by said stationary bar.

22. A musical percussion string instrument comprising a keyboard frame including a balance bar, a key pivoted intermediate its ends on said balance bar, a string mounted on said key with its opposite ends fixed to the key, a finger piece on one end of said key, a hammer pivoted on the other end of said key and biased toward said string for contacting the string when the key is depressed, and a rest for maintaining said hammer spaced from said string when the key is in its normal position, said string acting to engage the hammer and move it off the rest when the key is depressed.

23. The instrument of claim 22 wherein said hammer includes a shank pivoted intermediate its ends on said key, and including a damper on the butt end of said shank, and means for moving said rest relative to said key so as to cause said damper to be moved away from the string with the key in its normal position.

24. The instrument of claim 23 including a stationary bar adapted to engage the butt of the hammer shank immediately after the hammer has attacked the string so as to lift the hammer off the string upon continued depression of the key.

25. The instrument of claim 24 including a rail adapted to engage the hammer on the side of the pivot opposite the butt upon full depression of the key so as to prevent overthrow of the hammer by said stationary bar.

26. A musical percussion string instrument comprising a key pivoted intermediate its ends, a string mounted longitudinally thereon with its opposite ends fixed to the key, a finger piece on one end of said key, a hammer pivoted on the other end of said key for attacking the string when the key is depressed, a rest for maintaining
said hammer spaced from said string with the key in its normal position, said string moving relative to said rest to engage the hammer and move it off the rest when the key is depressed, a stationary bar coating with said hammer to lift it off the string during continued depression of the key, and means for preventing said hammer from reengaging said string during return of the key to its normal position.

27. The instrument of claim 26 wherein said last-mentioned means includes coating elements on said hammer and on said rest for preventing return movement of said hammer from said key, a hammer fixed beyond the position where the string engaged the hammer on depression of the key.

28. A musical instrument comprising a depressible key, a reel mounted on said key, a hammer mounted on said key suspended above said reel, and means provided on the key to maintain said hammer stationary when the key is depressed to enable the reel to strike the hammer and thereby be set into vibration.

29. The instrument of claim 28 including means on said hammer to dampen said reel when the key is in its undepressed position.

30. The instrument of claim 28 including means for moving said hammer away from said reel after the key has engaged the hammer.

31. A musical instrument comprising a depressible key, a reel mounted on said key, a hammer mounted on said key above said reel, an electrical pickup mounted on said key beneath said reel, and means provided on the key to cause said reel to be set into vibration by said hammer when the key is depressed and thereby produce an electrical signal in said pickup.

32. A piano hammer having a beveled striking face whose angle of inclination with respect to the string at the instant of impact lies within the range of from 15° to 30°.

33. The hammer of claim 32 including a hammer felt of substantially uniform thickness secured to the striking face of said hammer.

34. The hammer of claim 33 wherein the thickness of said felt is from 25% to 50% of the length of the striking face of the hammer.

35. The hammer of claim 33 wherein said felt is bent around the toe of said hammer and secured to the front face of the hammer above the toe.

36. An electronic piano comprising a depressible key, a string mounted longitudinally thereon with its opposite ends fixed to the key, a hammer pivotally mounted on said key above said string, means provided on the key for causing said hammer to attack said string when the key is depressed, and an electrical pickup moving with said key for translating the mechanical vibrations of the string into corresponding undulations of electric current.

37. An electronic piano comprising a plurality of depressible keys, a string mounted on each of said keys, a hammer mounted on each key above the string adapted to be struck by the string on the key when the key is depressed, an electrical pickup mounted on each of said keys adjacent said string for translating the mechanical vibrations of the string into an electric signal, a hammer mounted on the key above the string for striking said string, and connections between pickups of adjacent keys for enabling all of the pickups to be connected in series.

38. An electronic piano comprising a depressible key, a string associated with said key to produce a musical note when struck, an electrical pickup positioned adjacent said key for translating the vibrations of the string into an electric signal, a hammer mounted on the key above the string for striking said string, and connections between said key and said hammer for causing said hammer to attack said string at a speed not exceeding that of the key when the key is depressed.

39. An electronic piano comprising a keyboard frame, a plurality of depressible keys pivoted on said frame, a string mounted on each of said keys with the opposite ends thereof affixed to the key, a hammer mounted above the string operatively connected with each of said keys to attack the string on the key at a speed not exceeding the speed of the key when the key is depressed, and an electrical pickup mounted on said frame and extending across all of the keys in proximity to the strings mounted thereon.

40. The piano of claim 39 wherein said pickup is positioned adjacent the pivots of said keys so that the distance between the pickup and the strings will remain substantially constant in all positions of the keys whereby the percussive amplitude of the hammerers attacking the strings will be picked up and amplified to produce a piano effect by the instrument.

41. The instrument of claim 39 wherein said pickup is located at a position remote from the key pivots and spaced away from the keys so as to lie at a substantial distance from the strings when the keys are in their normal positions and close to the strings when the keys are depressed, whereby the percussive amplitude caused by the hammerers attacking the strings will not be reproduced so that an organ effect will be provided by the instrument.

42. An electronic piano comprising a keyboard frame, a depressible key pivoted intermediate its ends on said frame, a string on the key having its ends fastened to the opposite ends of said keys, a nodal bar on said key touching said string at its midpoint so as to divide the string into two equal sections, a hammer mounted on the key above the string for attacking one of said string sections when the key is depressed, and an electrical pickup disposed adjacent the other of said string sections for transforming the mechanical vibrations of the string into electrical signals.

43. An electronic piano comprising a series of tone-producing strings, a pickup extending across said strings for transforming the mechanical vibrations of the strings to electrical signals, said pickup including a coil and a magnetic core, and means for balancing out stray hum picked up on the coil of said pickup including a plurality of compensating coils located at a distance from said strings and each rotatable about an axis disposed at right angles to its magnetic axis and to the magnetic axis of said pickup coil.

44. The piano of claim 43 wherein the axis of rotation of one of said compensating coils is located at right angles to the axis of rotation of another of said compensating coils.

45. An electronic piano comprising a series of tone-producing strings, a pickup extending across said strings for transforming the mechanical vibrations of the strings into electrical signals, said pickup including a core for each of said strings, each core being disposed with its axis at right angles to the string, and a coil winding comprised of a continuous conductor wound in and out in a sinuous manner between said cores from one end of said pickup to the other and back again to form a winding in which any stray hum or noise induced in the winding from an outside source will be balanced out due to the equal and opposite currents induced in said coil to thereby provide a hum-free pickup.

46. The piano of claim 45 wherein each of said cores is a permanent magnet and the polarity of alternate cores is reversed.

47. A musical instrument comprising a plurality of depressible keys, a vibratory, tone-producing element mounted on each of said keys, a hammer mounted on each of said keys above a tone-producing element for setting its associated element into vibration when the key is depressed, and an electrical pickup mounted on each of said keys for translating the mechanical vibrations of said elements into an electric signal, said pickups each including a coil, and a magnetized core for said coil disposed with at least one of its poles adjacent to said element.
48. The electronic piano of claim 47 wherein pickup coils on alternate keys are wound in opposite directions, and the polarity of the cores is reversed on alternate keys so as to cause stray hum to be balanced out in said pickups without eliminating signals of the same frequency and phase in the different strings.

49. A musical instrument comprising a key, a balance rail, means for pivoting said key on said balance rail including a balance pin, an electrical pickup on said key, an electrically conductive circuit external of said key and means provided on said key for connecting said pickup to said circuit including said balance pin.

50. A musical instrument comprising a series of vibratory, tone producing elements, electrical pickup means for transforming the mechanical vibrations of said elements into electrical signals, said pickup means including a core having a pole thereon lying adjacent one of said elements and a coil surrounding said core, means for amplifying the signals produced by said pickup means, an isolating condenser between said pickup means and said amplifying means, and means for temporarily supplying direct current to said coil to magnetize said element in the vicinity of the pole on said core.

51. The method of preparing an electronic musical instrument having an iron core and coil type of pickup for use comprising the steps of mounting said pickup in place in the piano with the core thereof adjacent a string of the piano, connecting said coil to a source of direct current, and thereafter disconnecting said coil from said current source when the string has become magnetized.

52. The method of utilizing the electrical signals produced by an electronic musical instrument comprising the steps of delivering said signals to the input of a radio transmitter located adjacent the instrument, transmitting the signals on a radio-frequency carrier wave to a receiver located at a distance from the transmitter, demodulating the radio-frequency wave at the receiver, and applying the resulting signals to an electro-mechanical device.

53. The method of utilizing the electrical signals produced by an electronic musical instrument comprising the steps of introducing said signals into the input of a radio transmitter located near the instrument, transmitting the signals on a radio-frequency carrier wave to a crystal detector receiver located at a distance from the transmitter, and applying the signals from the receiver to an earphone device for reproducing the music of the instrument.

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