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A. DVORAK ET AL

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TYPEWRITER KEYBOARD

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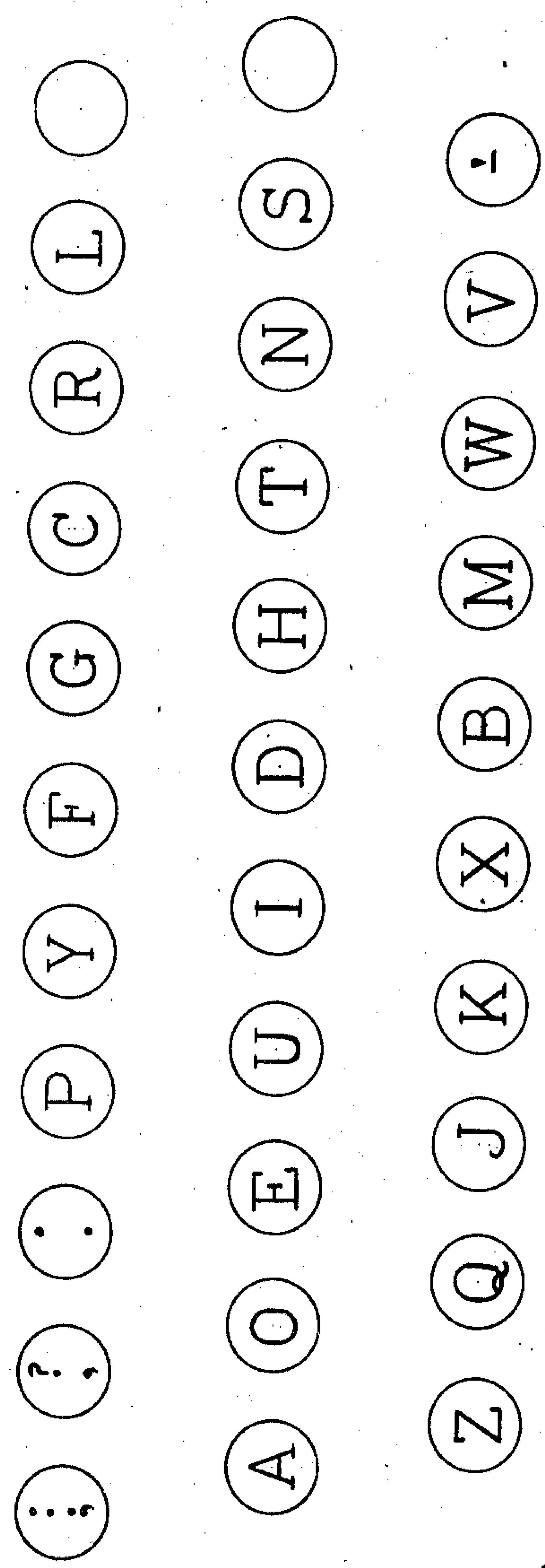


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## TYPEWRITER KEYBOARD

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Our invention relates to the spacial arrangement of the keys in a typewriter keyboard.

It has for its general objects (1) the provision of a scientific plan of arranging the keys which will decrease the possibility of typewriting errors, (2) facilitating increase of operating speed by eliminating awkward sequences, (3) assisting increase of speed because of fewer errors, (4) lessening the fatigue of the typist, because of fewer interruptions due to errors, because of better arrangement of the keys for typing the sequences most frequently used, and the rhythmical flow of typing induced thereby, and because of more evenly distributed labor for the individual fingers and the two hands.

The general objects may be summed up by saying that we desire to produce an arrangement of the keys (having in mind the letter-sequences found in the most commonly used words of a language) such that the automatic rhythm of the operator, passing from one key to another in a continuous flow of word-wholes and phrase-wholes, best fits the mechanical rhythm of the typewriter.

It is a further object to provide such an arrangement of the keys which will require no change in the typewriter mechanism or in the relative spacing and position of all the keys of the keyboard considered as a whole, and which can be readily effected upon any standard typewriter now made by the simple interchanging of type and key cards or labels.

Other objects, particularly such as relate to the positioning of certain keys with relation to others, or the selection of positions for certain keys or groups of keys, will appear as this specification progresses.

Previous attempts to improve the present so-called "universal" keyboard have been confined, so far as we are aware, either to arbitrary rearrangements of letter-keys, without regard to their relationship to all other keys, or to studies of the tapping of isolated letter-keys and the counting of isolated finger loads and isolated letter errors. Such factors are of importance only to the veriest beginner who has not mastered the spacial pattern of the whole keyboard. With a person who has in any appreciable degree mastered this spacial pattern, typewriting proceeds in unified sequences or overlapping key-strokes identified as words and phrases. Words are stroked as wholes, and the typist is usually unaware of the individual letters. Successful typing is the more or less relaxed following, by the typist, of such sequences (word patterns) with the typewriter. A keyboard arrangement must be based upon the requirements of the sequential stroking, the even, uninterrupted flow of which we can designate "rhythm". To count isolated letter strokes, then, does violence to the facts, for typewriting is not a sum of separate tappings by each finger.

As an example, consider that if an expert, capable of well beyond one hundred net words a minute, should attempt one-letter copy, measurements would show his speed to be absurdly slowed to approximately twenty words a minute. The isolated letter-stroke, as the alleged unit of typewriting, thus makes even experts appear ridiculous. Gatewood ("Individual Differences in Finger Reactions", E. L. Gatewood, Psychological Review Monograph Supplements, vol. 28, No. 4, 1920), in simple tapping experiments, shows that single-finger tapping is slower and less accurate than two-finger serial tapping. Nearly one-half of an expert's one-letter time would be saved on two-letter copy. Nearly one-fifth of the two-letter time would be saved on three-letter copy, and so on, improving through to six- or seven-letter sequences. Typewriting, like reading moves not by individual letters, but in word-wholes or phrase-wholes.

That typewriting succeeds because a succession of letter strokes is faster than any stroke made separately, that without this overlapping of the strokes typing becomes a futile tapping, has hitherto not been generally understood. Accordingly, our new method of keyboard revision launches itself for study of sequences and of the possibilities for speed and accuracy gained by increasing the number of sequences stroked by opposite hands, or by remote fingers, or by the first and second adjacent fingers of the right hand.

Typewriting is a complex process, depending upon all the shifting variables of differing typists, motions, machines, and surroundings. To control variables of typing motions involves keeping delicate balances between tension and relaxation, eliminating unnecessary movements, using the shortest, most direct motion paths, at the least possible energy-cost and feeling-cost. To increase the advantages mechanically that accompany fast motions, takes as few stops and starts as possible. Hence unavoidable finger waits are partly compensated by hovering lightly over keys. Typing motions, moreover, are correct when made in whatever way best fits them together. This is termed "play for position". As a finger gets away from a key, the next finger is already in position and stroking. These prompt plays for position and overlappings between strokes permit faster timing and rhythm; anything, such as incorrect or awkward position of the keys in the keyboard, which interrupts or slows down this rhythm, contributes to errors, to slower stroking, and to fatigue.

The stroking unit, accordingly, is not an isolated key-stroke, but embraces a complete interval of time between two successive strokes. This time is set by the skill of the typist. A separate interval between the release of one key and the engaging of another is set by the machine. The rhythm of the machine must fit into the rhythm of the typist's stroking. The critical point is the finger's unnoticed and unfelt arrest as it strikes the keys. This must be the shortest pause that can be held and yet preserve the succession of strokes. Nearly all motion disappears into the release of the finger from the key. The serial nature of key stroking depends upon this exact balance between the slight interval required by the machine and the longer interval required by the typist's fingers. Into a rhythmic pattern of sequence timing the flexible, changing key strokes are thrown in orderly succession. Automatic conditioning of the timing drops each even imprint in its proper place. There are no isolated finger strokings, but rather, sequences. Each sequence is a definite pattern of successive overlapping strokes.

Upon the present keyboard even two-letter sequence times vary widely. The discrepancies between the minimal times required in stroking certain sequences of keys as compared with other sequences of keys, are chiefly due to the unavoidable delays inherent in certain spacial arrangements upon the keyboard. For example, measurements show these unavoidable delays increase as the spacial arrangements change from (1) a sequence in the same bank involving fingers of opposite hands, to (2) a sequence located in upper and lower banks yet still involving fingers of opposite hands, to (3) a sequence involving adjacent fingers of the same hand, to (4) a sequence located in upper and lower banks and involving fingers of the same hand, to (5) a sequence employing the same finger. Relative times of such unavoidable delays within digraphs on the present "universal" keyboard are illustrated respectively, as follows: (1) *ei*, 2 time-units; (2) *em*, 4 time-units; (3) *es*, 5 time-units; (4) *on*, 10 time-units; (5) *de*, 11 time-units. According to measurements reported, an expert's sequence times may vary from the equivalent of 70 words a minute for *de* to 224 words a minute for *nd*. The fastest two-letter sequences or digraphs are written in familiar phrases by fingers of opposite hands, or remote fingers on the same hand, or first and second adjacent fingers on the right hand.

Assuming an average speed of 130 words a minute, such two-letter sequences or digraphs in a familiar phrase like *this is the* may exceed 170 words a minute. Continuing the illustration, if the total minimal time required for each digraph be taken, as in measurements of digraphs written at an average expert speed equivalent to 130 words a minute, the relative times are, for example, *dk*, employing opposite hands, 145; *jl*, employing remote fingers of the same hands, 122; *jk*, employing adjacent fingers, 115; *jj*, tapping with the same finger, 85; *um*, reaching with the same finger, 70. Strokes with the same finger are thus found to be the poorest sequences in typing. According to measurements reported, simple tapping with one finger of *jj* may take .14 second; with the second stroke one bank away, as *jm*, .16 second, and across two banks of keys, as *um*, .17 second. The pace is usually slowed, but less so, when adjacent fingers are used.

Sequences (1) and (2) above, involving fingers of opposite hands, are seen to be rapid, and easy to stroke. Sequence (3), involving adjacent fingers of the same hand, is not rapid, even with the first two fingers, as *er*, and frequently is difficult and slow of execution if it involves different banks, as *nk*, or fingers other than the first two, as *as* or *wa*. Sequence (4), involving upper and lower banks in the same hand, as *ny*, *im*, may be termed a hurdle. These are invariably slow and difficult, as are reaches, sequence (5), movements by a single finger laterally, or from one bank to an adjacent bank, as *ft*, *rt*.

The latter sequences, (4) and (5), and generally sequence (3), except as it involves the first two adjacent fingers, of the right hand especially, may be termed awkward sequences, because their stroking does not fit into the rhythm of the typist so well as other more easily executed sequences, involving different hands, or remote fingers on the same hand. Such awkward sequences are (1) time-consuming, (2) productive of errors, (3) unduly fatiguing, and (4) interrupt the rhythm. These awkward sequences we have designed our keyboard to avoid, so far as possible, and have reduced the frequency of such awkward sequences to about 3%, while in the "universal" keyboard such awkward sequences are 28% of all frequencies.

Any sequence involving a single-finger reach (by one finger alone) is extremely slow, because there can be no play for position, or overlapping of strokes. The "universal" keyboard, however, has a number of such reaches, as *ik*, *ju*, *rt*, *fr*, *de*, *lo*, of comparatively high frequency of occurrence. Certain of these, because of their high frequency, become familiar, and the error count is kept down, but the other three objections noted in the preceding paragraph are still present. Hurdles by one finger alone are even more objectionable, yet a number of high frequency one-finger hurdles are found in the "universal" keyboard, as *ce*, *ny*, *my*, *nu*, *mu*.

Scarcely less objectionable than single-finger reaches and hurdles are those requiring the use of adjacent fingers. These, too, can be classified as naturally awkward. The "universal" keyboard has such adjacent-finger reaches as *aw*, *se*, *sc*, *as*, *we*, *er*, *ge*, *hi*, *ui*, *ol*, *io*, *po*, *pl*, *nk*, *ef*, *dr*, *dv*, *et*, and such adjacent-finger hurdles as *ex*, *cr*, *ct*, *be*, *ev*, *in*, *im*, some of them, as *er*, *as*, *se*, *we*, *in*, *et*, *ev*, for instance, being of very high frequency. In the "universal" keyboard 21% of all frequencies are the awkward adjacent-finger reaches or hurdles, whereas our keyboard, to be explained hereafter, reduces this to 2%. Remote finger hurdles such as *xt*, *no*, *mo*, *mp*, are found in the "universal" keyboard to the extent of 3% of all frequencies, whereas our keyboard reduces these remote finger hurdles to .2%. Of all awkward sequences, single-finger and adjacent-finger reaches and hurdles, the frequency in the "universal" keyboard is 28%, as we have explained above, and in our keyboard do not exceed 4%, being nearer 3%. The elimination of such sequences saves time, lessens errors, lessens fatigue, and preserves the rhythm.

It has not been recognized heretofore that sequences in one hand are slower than those involving two hands. Having discovered this to be the case, it follows that rapid successive stroking can best be maintained if the successive strokes are in alternate hands. This is not because of any purpose to even up the loads upon the two hands, but rather is based upon the consideration of maintaining the rhythm, for this latter in itself is the best assurance of lessened fatigue. We have discovered the desirability of distributing the keys to the two hands, in such manner that the stroking of common sequences involves the use of alternate hands, insofar as possible. Being in opposite hands, reaches and hurdles are automatically eliminated.

Likewise, we have discovered, and employ as a factor in determining the location of the keys, that sequences in one hand (which cannot be wholly avoided) are most satisfactorily made when stroked from an outer finger inwardly. It is easier to tap in rapid succession from the fifth finger to the index finger, than the reverse. In our keyboard the common sequences necessarily falling in one hand are, so far as possible, stroked from an outer to an inner finger. Sequences which involve high frequency in each direction, as *er, re,* are separated, and the letters given to different hands.

The present keyboard has three banks of keys which contain all the letters of the English alphabet and the commonly used punctuation marks. The hands are guided with relation to the home row, that is, the middle bank. We have discovered the necessity, to avoid breaks in rhythm even in common sequences, of forming as many such sequences as possible in the home row. This avoids dropping to the lower bank and returning therefrom, which is very slow, and stepping up to the upper row and recovering, which is somewhat faster but still slower than sequences in the home row. As a result, we have been able to locate letters accounting for 70% of the total letter frequency in the home row.

The rhythmical flow of complete sequences may be momentarily checked by an error. A single key stroke is felt chiefly, if at all, as such a misdirected stroke or error that temporarily blocks the rhythm of typing patterns. Errors are to be attacked only in their original line or phrase or word or shorter sequence setting. This is further shown in the fact that most false strokes are clean, effective strokes—*to the wrong keys*. The following are samples of interference by more dominant sequences. For *that* the typist wrote *the* (2 seconds delay) *t*. For *spectacle* the typist wrote *spec* (.4 second delay) *tab* (1.2 seconds delay) *le*. For *poet's* the typist wrote *powe* (.6 second delay) *t* (.3 second delay) ' (.4 second delay) *s*. For *own heaven* the sequence *our* first interfered with a belated correction *w* and the omission of *n* from the pattern, as follows: *ou* (.5 second delay) *w* (.4 second delay) space (2 seconds) *heaven*. In these samples the more dominant sequences *the, table, power, our* result in substitution, omission and addition of strokes.

Moreover, the more dominant digraphs appear to hold down errors and facilitate speed despite handicaps of the present haphazard keyboard. The first finger patterns, for example, are dominated by the terrific frequencies of *th, on, an, he, in, nd, ha, at, en*. Because of these keystrokes, *t, h, n*, participate in very dominant, common sequences their relative efficiency is high despite keyboard handicaps. Similarly, on the left hand, the *a* and *e* and *t* strokes are dragged above the usual inefficiency by participating in very dominant, common digraphs such as *an, ha, at, ea, ar, as, er, re, he, ed, en, es, ea, le, de, ve, th, at, nt, ti, to, it, st, rt.*

Our studies of more than 11,000 errors by student typists on the 1,000 most common words of Ayres' list ("A Measuring Scale for Ability in Spelling"—L. P. Ayres—Russell Sage Foundation, New York, 1915, pp. 12–20) demonstrate that a relatively small number of word-sequences, frequently typed to be sure, is responsible for a large portion of all typewriting errors. Whereas low-speed college beginners during eight weeks of practice piled up 28% of these errors upon the most common 50 everyday words, second year students actually heaped up 44% of like errors. This proportion of errors, in short, increased after eight weeks, one year, and two years of training, from 28% to 41%, to 44%, respectively. On the most common 300 words, the proportion of errors increased from 67% to 73%, to 77%, respectively. In fact, the second year students actually made more errors on the first 25 words of the Ayres' list. Such a dilemma exposes the positive handicap of the present keyboard.

We have collected the 300 word-sequences most often mistyped. The combined errors of these sequences amount to 75% of all the typing errors found in our study of the typing of the thousand commonest words. In fact, 200 words account for 60%, while 100 words alone account for 45%. All but seven of these 100 words are simple monosyllables. Correct typing of these 100 words would have reduced errors on all common words by 45%. Examples of words characterized by frequent use in copy and excessive errors or difficulty on the present keyboard, are: also, are, away, do, ever, every, find, found, give, good, great, have, is, it, like, look, many, must, never, number, only, people, place, should, take, than, thank, their, then, there, these, think, those, time, to, well, what, when, which, while, with, work, would, write.

The handicaps inherent in the present so-called "universal" keyboard can now be summarized by ten criteria. In general, the very factors operating to produce errors also operate to reduce speed, as follows:

(*a*) Many common sequences, in general, requiring a difficult and awkward serial arrangement of finger-motions.

(*b*) Many digraphs typed with the same finger, whereas digraphs typed with different fingers are faster, due largely to improved play for position and overlapping of keystrokes.

(*c*) Many digraphs consisting of hurdles across banks by the same finger, with time wasted in the get-away, hurdle and pre-position.

(*d*) An excessive number of sequences in the same hand, whereas digraphs employing opposite hands are faster.

(*e*) An excessive number of sequence in the left hand, whereas right hand sequences are usually faster.

(*f*) Many digraphs employing adjacent fingers, notably in hurdles across banks, whereas most adjacent finger digraphs are slower than combinations utilizing remote fingers or opposite hands.

(*g*) The assigning of approximately 30% of the digraphs to include the lower bank, which is exceedingly slow.

(*h*) The assigning of approximately 86% of the digraphs to include the upper bank, which is excessive and tends to reduce the speed.

(i) The assigning of only 51%, approximately, of the digraphs to include the faster home row.

(j) The arrangement of key-locations on the "universal" keyboard with little or no reference to the adaptability of hand skills to the sequence patterns of the written language.

A study of language patterns reveals a very striking fact. Spoken or written language is based on a framework built up of a relatively small number of words, arranged in many patterns. For example, less than 3% in some 80,000 words used in 500 telephone conversations are different words. Little auxiliary verbs, such as *is*; pronouns, such as *you*; prepositions, such as *on* or *to*; conjunctions, such as *and*; articles, like *the*, are only 5% of the different words used. Mostly these are monosyllables. Yet they make up 57% of all these 500 telephone conversations, as counted by French. Their framework supports the longer, more varied, less frequent words, which convey most of the meaning. Although their role is somewhat lessened in written language, it is these common words which materially set the digraphs to be typed. According to a scientific word count, for example 69 words represent one-half of written English; 640 words represent four-fifths of written English. Typing patterns are based upon this framework of a relatively small number of words which support the longer, more varied, less frequent words. Into this framework the typist's motions are to be fitted with the aid of improved keyboard relations.

An intensive study of the frequency with which different sequences appear in written English is the basis for the scientific arrangement of the keyboard which we propose. The total frequencies of usage of digraphs, trigraphs, four-, five-, and six-letter sequences studied, exceed 75,000,000.

A scientific word count in written English shows the predominance of certain sequences over others, to the extent:

That 11 digraphs or two-letter combinations make up 25% of the usage of the millions of digraphs counted;

That 34 digraphs make up 50%;

That 57 digraphs make up 75%;

That 137 digraphs make up 90%;

That 22 trigraphs or three-letter combinations make up 25%;

That 104 trigraphs make up 50%;

That 46 four-letter combinations make up 25%;

That 208 four-letter combinations make up 50%.

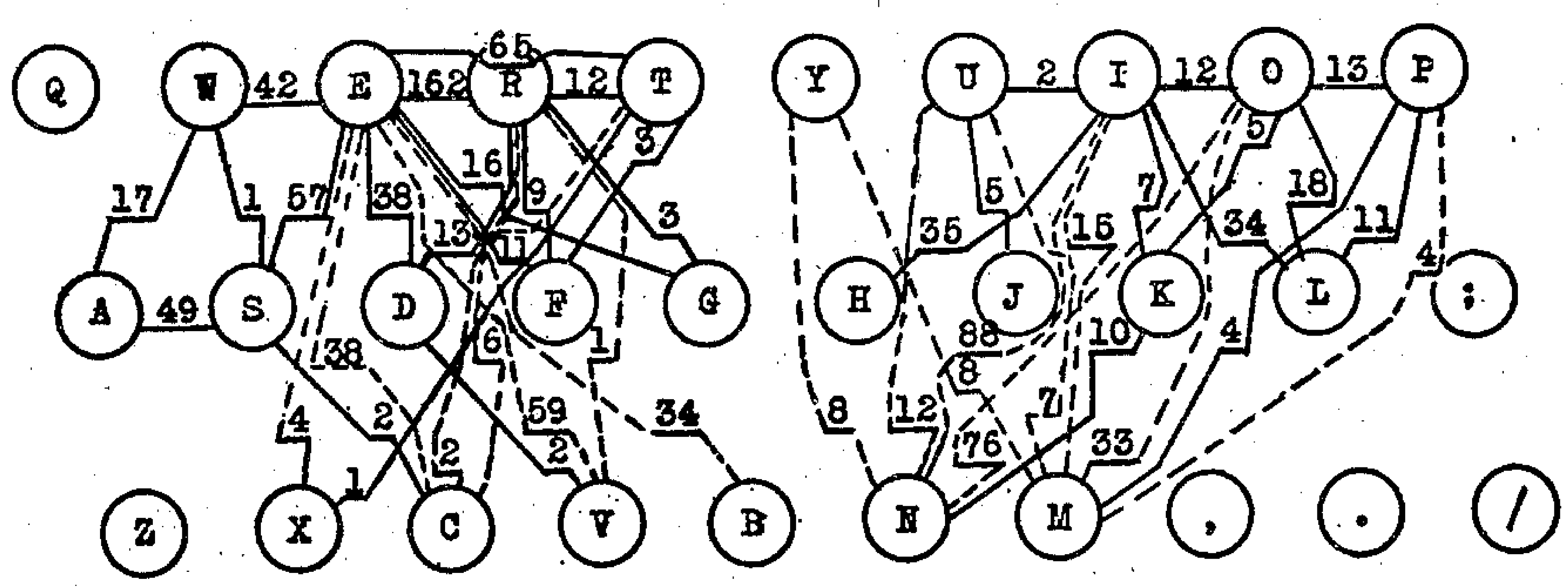
To facilitate the revision of the typewriter keyboard, a master sheet of common digraphs is constructed as follows:

*Table 1.—Relative frequencies of common digraphs arranged to reveal probable degrees of interference arising from each tentative key location.*

| | | | | | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| ab 8 | ac 11 | ad 19 | ae | af 3 | ag 4 | ah | ai 7 | aj | ak 6 | al 29 | am 12 | an 90 | ao | ap 4 | aq | ar 41 | as 39 | at 54 | au 1 | av 21 | aw 1 | ax | ay 21 | az |
| ba 4 | bc | bd | be 34 | bf | bg | bh | bi 2 | bj | bk | bl 5 | bm | bn | bo 10 | bp | bq | br | bs | bt | bu 12 | bv | bw | bx | by 4 | bz |
| ca 17 | cb | cd | ce 22 | cf | cg | ch 20 | ci 3 | cj | ck 4 | cl 4 | cm | cn | co 21 | cp | cq | cr 1 | cs | ct 6 | cu 1 | cv | cw | cx | cy | cz |
| da 11 | db | dc | de 18 | df | dg | dh | di 11 | dj | dk | dl 2 | dm | dn | do 11 | dp | dq | dr 1 | ds 1 | dt | du 1 | dv 2 | dw | dx | dy 1 | dz |
| ea 25 | eb | ec 16 | ed 20 | ef 5 | eg 3 | eh | ei 9 | ej | ek 1 | el 13 | em 10 | en 43 | eo 1 | ep 5 | eq 1 | er 85 | es 21 | et 27 | eu | ev 8 | ew 5 | ex 4 | ey 6 | ez |
| fa 4 | fb | fc | fd | fe 6 | fg | fh | fi 7 | fj | fk | fl | fm | fn | fo 27 | fp | fq | fr 9 | fs | ft 3 | fu 4 | fv | fw | fx | fy | fz |
| ga 4 | gb | gc | gd | ge 13 | gf | gh 9 | gi 5 | gj | gk | gl 2 | gm | gn | go 14 | gp | gq | gr 2 | gs | gt | gu 1 | gv | gw | gx | gy | gz |
| ha 66 | hb | hc | hd | he 117 | hf | hg | hi 35 | hj | hk | hl | hm | hn | ho 20 | hp | hq | hr 2 | hs | ht 5 | hu | hv | hw | hx | hy | hz |
| ia 2 | ib 1 | ic 12 | id 8 | ie 4 | if 11 | ig 6 | ih | ij | ik 2 | il 23 | im 11 | in 81 | io 9 | ip 3 | iq | ir 9 | is 40 | it 48 | iu | iv 8 | iw | ix | iy | iz |
| ja | jb | jc | jd | je | jf | jg | jh | ji | jk | jl | jm | jn | jo | jp | jq | jr | js | jt | ju 6 | jv | jw | jx | jy | jz |
| ka | kb | kc | kd | ke 9 | kf | kg | kh | ki 5 | kj | kl | km | kn 5 | ko | kp | kq | kr | ks 1 | kt | ku | kv | kw | kx | ky | kz |
| la 12 | lb | lc | ld 14 | le 28 | lf 1 | lg | lh | li 11 | lj | lk | lm | ln | lo 11 | lp | lq | lr | ls 2 | lt | lu 1 | lv | lw 1 | lx | ly 13 | lz |
| ma 18 | mb 2 | mc | md | me 40 | mf | mg | mh | mi 4 | mj | mk | ml | mn | mo 10 | mp 3 | mq | mr 2 | ms 1 | mt | mu 6 | mv | mw | mx | my 8 | mz |
| na 2 | nb | nc 9 | nd 72 | ne 23 | nf 1 | ng 33 | nh | ni 7 | nj | nk 5 | nl 2 | nm | no 32 | np | nq | nr | ns 4 | nt 24 | nu 1 | nv | nw | nx | ny 8 | nz |
| oa | ob 1 | oc 1 | od 5 | oe | of 35 | og | oh | oi 3 | oj | ok 3 | ol 7 | om 23 | on 44 | op 7 | oq | or 51 | os 8 | ot 26 | ou 98 | ov 6 | ow 19 | ox | oy 1 | oz |
| pa 8 | pb | pc | pd | pe 9 | pf | pg | ph | pi 1 | pj | pk | pl 11 | pm 1 | pn | po 6 | pq | pr 8 | ps | pt 3 | pu 2 | pv | pw | px | py 1 | pz |
| qa | qb | qc | qd | qe | qf | qg | qh | qi | qj | qk | ql | qm | qn | qo | qp | qr | qs | qt | qu 3 | qv | qw | qx | qy | qz |
| ra 5 | rb | rc 1 | rd 12 | re 77 | rf | rg 1 | rh | ri 13 | rj | rk 2 | rl 2 | rm 2 | rn 5 | ro 14 | rp | rq | rs 12 | rt 7 | ru 2 | rv 1 | rw 1 | rx | ry 15 | rz |
| sa 10 | sb | sc 2 | sd | se 36 | sf | sg | sh 16 | si 13 | sj | sk 1 | sl | sm | sn | so 21 | sp 1 | sq | sr | st 31 | su 7 | sv | sw 1 | sx | sy | sz |
| ta 10 | tb | tc | td | te 38 | tf | tg | th 144 | ti 24 | tj | tk | tl 3 | tm | tn | to 59 | tp | tq | tr 5 | ts 1 | tu 5 | tv | tw 2 | tx | ty 3 | tz |
| ua | ub 1 | uc 6 | ud | ue 3 | uf | ug 4 | uh - | ui 2 | uj | uk | ul 13 | um 1 | un 11 | uo | up 6 | uq | ur 42 | us 20 | ut 23 | uv | uw | ux | uy | uz |
| va 1 | vb | vc | vd | ve 51 | vf | vg | vh | vi 5 | vj | vk | vl | vm | vn | vo 1 | vp | vq | vr | vs | vt | vu | vw | vx | vy | vz |
| wa 16 | wb | wc | wd | we 37 | wf | wg | wh 19 | wi 32 | wj | wk | wl | wm | wn 2 | wo 12 | wp | wq | wr 4 | ws | wt | wu | wv | wx | wy | wz |
| xa | xb | xc | xd | xe | xf | xg | xh | xi | xj | xk | xl | xm | xn | xo | xp 1 | xq | xr | xs | xt 1 | xu | xv | xw | xy | xz |
| ya | yb | yc | yd | ye 4 | yf | yg | yh | yi | yj | yk | yl | ym | yn | yo 57 | yp | yq | yr | ys 3 | yt 1 | yu | yv | yw | yx | yz |
| za | zb | zc | zd | ze | zf | zg | zh | zi | zj | zk | zl | zm | zn | zo | zp | zq | zr | zs | zt | zu | zv | zw | zx | zy |

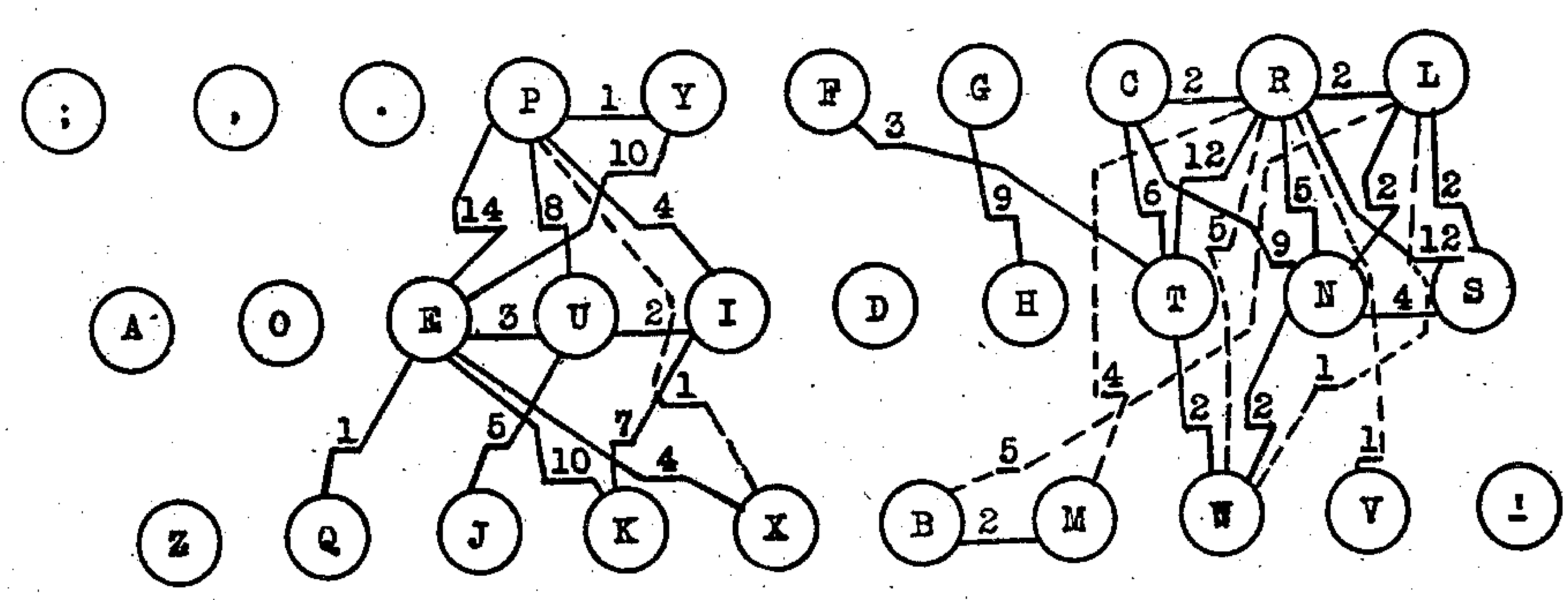
In the light of these digraph frequencies, a chart of the present "universal" keyboard is presented in Table No. 2, and a chart of the new improved keyboard is presented in Table No. 3, in the arrangement shown in the drawing. In this improved keyboard the proportion of digraphs participating in the lower bank of keys has been reduced to approximately 8%; the proportion of digraphs participating in the upper bank, to approximately 22%. In these two equivalent charts the relative frequencies of digraphs are noted between the two keys involved. Those which are stroked by a single finger, or by partly ineffective adjacent fingers, or which require hurdles across a bank, are readily to be found. The charts thus map to an approximate degree much of the interference to be expected from keyboard relations. Upon the present "universal" keyboard the proportion of these less effective digraphs is approximately 28% of all digraph usage. Upon our new keyboard the proportion is approximately 3% of all digraph usage.

*Table 2.—Chart of present "universal" keyboard with relative frequencies of digraphs stroked by awkward hurdles and reaches*




| | Left hand | | Right hand | | Total | |
|---|---|---|---|---|---|---|
| | No. | Frequency (10,000's) | No. | Frequency (10,000's) | No. | Frequency (10,000's) |
| Same finger: | | | | | | |
| Hurdles | 2 | 39 | 4 | 35 | 6 | 74 |
| Reaches | 6 | 66 | 3 | 30 | 9 | 96 |
| Adjacent fingers: | | | | | | |
| Hurdles | 5 | 105 | 2 | 103 | 7 | 208 |
| Reaches | 11 | 436 | 7 | 117 | 18 | 553 |
| Remote fingers: | | | | | | |
| Hurdles | 1 | 1 | 3 | 113 | 4 | 114 |
| Total | 25 | 647 | 19 | 398 | 44 | 1,045 |

*Table 3.—Chart of new typewriter keyboard with relative frequencies of digraphs stroked by awkward hurdles and reaches*




| | Left hand | | Right hand | | Total | |
|---|---|---|---|---|---|---|
| | No. | Frequency (10,000's) | No. | Frequency (10,000's) | No. | Frequency (10,000's) |
| Same finger: | | | | | | |
| Hurdles | 1 | 1 | 1 | 1 | 2 | 2 |
| Reaches | 5 | 22 | 6 | 26 | 11 | 48 |
| Adjacent fingers: | | | | | | |
| Hurdles | 0 | 0 | 1 | 5 | 1 | 5 |
| Reaches | 6 | 44 | 7 | 37 | 13 | 81 |
| Remote fingers: | | | | | | |
| Hurdles | 0 | 0 | 3 | 10 | 3 | 10 |
| Total | 12 | 67 | 18 | 79 | 30 | 146 |

While certain of the letters should not be otherwise located, to accomplish the advantages we have in view, the positions of certain others are optional, and even in the controlling letters positions of certain ones can be interchanged. Those which should not be changed are *e, t, o, a, h, n, i,* and *s,* given in the order of their frequency of use. All these are found in the home row, the vowels in one hand and the consonants in the other. To group all vowels in the home row, and in one hand, it is preferable that *u* be included with the others, and for advantage in effecting combinations of high frequency it is desirable that *d* be likewise included in the home row, though this displaces *r* and *l,* of somewhat greater frequency.

In order that high-frequency consonants shall be opposite the vowels with which they combine, and to group the most generally used consonants for operation by the more facile right hand, *r, l, w, f, m, c, b, g,* and *v,* in order of their relative frequency, are located in the upper and lower banks of the right hand. *y* and *p,* falling respectively between *f* and *m,* and between *g* and *v,* are assigned to the left hand, because it facilitates the stroking, by opposite hands, of sequences of high frequency, as *ly, ry,* and *pr.* The location of these two letters, however, is not free from doubt, and especially they might be reversed in position. So, too, might *f* and *g* be reversed in position without material loss of facility.

The remaining letters, *k, j, x, q, z,* are of infrequent occurrence, and are assigned to the lower bank of the left hand. To avoid the awkward single-finger sequence *ex,* which would occur if the letters were arranged in order of their relative frequency, the *x* is displaced from the *e,* and *k* and *j,* of greater frequency, but less frequently combining with *e,* are displaced outwardly. The *q,* combining chiefly with *u,* is struck by a different finger. Bearing in mind these considerations, it is clear that the order of the letters *z, q, j, k, x,* might be changed, and especially that *z* and *q* could be interchanged without increase of difficulty.

Punctuation marks are positioned in accordance with their frequencies relative to each other and to the letters.

For left-handed persons it may be preferable to reverse the keyboard, but this is to be understood as within the limits of our invention. Furthermore, for languages other than English the position of the particular letters will be widely varied, but arranged according to the principles which we have explained, it will still be found most suitable for the particular language involved. In the drawing it will be observed that certain keys are left blank, and these may be employed for the marks peculiar to a given language, such as the accent mark in French and the umlaut in German or for such other characters as may be deemed desirable.

Our keyboard arrangement has the following advantages:

1. The keys are arranged in a manner based on a scientific count of sequence frequencies in the words used in written language.

2. Fewer common sequences require a difficult and awkward serial arrangement of finger motion (3% as compared with 28%).

3. Fewer digraphs are typed with the same finger (1.3% as compared with 4.6%).

4. Fewer digraphs consist of hurdles across banks by the same finger (.05% as compared with 2%).

5. A reduced number of sequences is in the same hand.

6. A reduced number of sequences is in the left hand.

7. A reduced number of digraphs involves both the fifth and fourth fingers only of both hands (1% as compared with 3%).

8. Fewer digraphs employ adjacent fingers, notably in hurdles across banks (.1% as compared with 5.5%).

9. Fewer digraphs employ awkward adjacent-finger reaches and hurdles (2.3% as compared with 20.4%).

10. Remote-finger hurdles constitute about .2% of all frequencies as compared with 3%.

11. Less than 20% (about 16%) of digraphs are assigned to include the lower bank (as compared with 30%).

12. Less than 40% (about 35%) of the digraphs are assigned to include the upper bank (as compared with 86%).

13. Approximately 67% of all digraphs are stroked with opposite hands, as compared with 48%.

14. Approximately 96% of the digraphs are assigned to include the home row (as compared with 51%).

15. Approximately 45% of the digraphs are confined to the home row only (as compared with 7%).

16. Such digraphs as include different fingers in the same hand are in the main arranged for movement from outer to inner fingers.

17. The arrangement of key locations on the keyboard is made with reference to the adaptability of hand skills to the sequence patterns of the written language as determined by scientific, statistically adequate sequence-counts.

What we claim as our invention is:

1. A typewriter keyboard in which the upper bank contains the letters disposed for operation by individual fingers as follows: in the upper bank, *p* and *y,* the first finger of the left hand; *f* and *g,* the first finger of the right hand; *c* the second finger; *r* the third finger; and *l* the fourth finger, all of the right hand; in the home row, *a* the fourth finger; *o* the third finger; *e* the second finger; *u* and *i* the first finger, all of the left hand; *d* and *h* the first finger; *t* the second finger; *n* the third finger; *s* the fourth finger, all of the right hand; in the lower bank, *z* the fourth finger; *q* the third finger; *j* the second finger; *k* and *x* the first finger, all of the left hand; *b* and *m* the first finger; *w* the second finger; and *v* the third finger, all of the right hand.

2. A typewriter keyboard having letters arranged in three rows, in which letters are disposed for operation by individual fingers of one hand as follows: by the first finger, *p* and *y* in the upper row, and *u* and *i* in the home row; by the second finger, *e* in the home row; by the third finger, *o* in the home row; and by the fourth finger, *a* in the home row; and in which letters are disposed for operation by individual fingers of the other hand as follows: by the first finger, *f* and *g* in the upper row, *d* and *h* in the home row, and *b* and *m* in the lower row; by the second finger, *c* in the upper row, *t* in the home row, and *w* in the lower row; by the third finger *r* in the upper row, *n* in the home row, and *v* in the lower row; and by the fourth finger, *l* in the upper row, and *s* in the home row, the remaining letters being disposed in the lower row of said keyboard.

3. A typewriter keyboard having letters arranged in three rows, in which letters are disposed

for operation by individual fingers of one hand as follows: by the first finger, *p* and *y* in the upper row, *u* and *i* in the home row and *k* and *x* in the lower row; by the second finger, *e* in the home row and *j* in the lower row; by the third finger, *o* in the home row; and by the fourth finger, *a* in the home row; and in which letters are disposed for operation by individual fingers of the other hand as follows: by the first finger, *f* and *g* in the upper row, *d* and *h* in the home row, and *b* and *m* in the lower row; by the second finger, *c* in the upper row, *t* in the home row, and *w* in the lower row; the remaining letters being disposed for operation by the third and fourth fingers of the two hands.

4. A typewriter keyboard comprising three rows of keys, the keys in the middle or home row bearing the letters *a, o, e, u, i, d, h, t, n,* and *s*; the keys in the upper row bearing the letters *p, y, f, g, c, r,* and *l*, so located that the letters *u, i, p* and *y* are struck by the first finger of the left hand, *e*, by the second finger, *o*, by the third finger, *a*, by the fourth finger, and the letters *d, h, f,* and *g* are struck by the first finger of the right hand, *t*, by the second finger, *n*, by the third finger, and *s* by the fourth finger; and the letters *c, r,* and *l* by the second, third, and fourth fingers of the right hand; the keys in the lower row bearing the letters *q, j, k, x, b, m, w, v,* and *z*, so located that the letters *b* and *m* are struck by the first finger, *w* by the second finger, and *v* by the third finger, all of the right hand.

5. A typewriter keyboard comprising three rows of keys, the keys in the middle or home row bearing the letters *a, o, e, u, i, d, h, t, n,* and *s*; the keys in the upper row bearing the letters *p, y, f, g, c, r,* and *l*, so located that the letters *u, i, p,* and *y* are struck by the first finger of the left hand, *e*, by the second finger, *o*, by the third finger, *a*, by the fourth finger, and the letters *d, h, f* and *g* are struck by the first finger of the right hand, *t*, by the second finger, *n*, by the third finger, and *s* by the fourth finger, and the letters *c, r,* and *l* by the second, third, and fourth fingers of the right hand; the keys in the lower row bearing the letters *q, j, k, x, b, m, w, v,* and *z*, so located that the letters *m* and *w* are struck by the first and second fingers, respectively, of the right hand.

6. A typewriter keyboard comprising three rows of keys, the keys in the middle or home row bearing the letters *a, o, e, u, i, d, h, t, n,* and *s*; the keys in the upper row bearing the letters *p, y, f, g, c, r,* and *l*, so located that the letters *u, i, p* and *y* are struck by the first finger of the left hand, *e*, by the second finger, *o*, by the third finger, *a*, by the fourth finger, and the letters *d, h, f,* and *g* are struck by the first finger of the right hand, *t*, by the second finger, *n*, by the third finger, and *s*, by the fourth finger; the keys in the lower row bearing the letters *q, j, k, x, b, m, w, v,* and *z*, so located that the letters *m* and *w* are struck by the first and second fingers, respectively, of the right hand.

7. A typewriter keyboard arranged in three rows, in which the letters *e, u* and *i* are disposed in the home row for operation by the first two fingers of one hand, and the letters *p, y, j, k* and *x* are disposed in adjacent rows for operation with the same fingers by a reach from the home row, and the letters *a* and *o* are disposed in the home row for operation by the third and fourth fingers of the same hand; the letters *d, h* and *t* are disposed in the home row for operation by the first two fingers of the other hand, and the letters *f, g, c, b, m,* and *w* are disposed in adjacent rows for operation with the same fingers by a reach from the home row; the letters *n* and *s* are disposed in the home row for operation by the third and fourth fingers of such other hand, the letters *r, l* and *v* are disposed in adjacent rows for operation with the same fingers by a reach from the home row; and the remaining letters are disposed in the lower row of said keyboard.

8. A typewriter keyboard comprising three rows of keys, the keys in the middle or home row bearing the letters *a, o, e, u, i* arranged for operation by the left hand, and the letters *d, h, t, n,* and *s* arranged for operation by the right hand; the keys in the upper row bearing the letters *p* and *y* arranged for operation by the left hand, and the letters *f, g, c, r,* and *l* for operation by the right hand; the keys in the lower row bearing the letters *q, j, k* and *x* arranged for operation by the left hand, the letters *b, m, w,* and *v* arranged for operation by the right hand, and one other of the keys of the lower row bearing the letter *z*.

9. A typewriter keyboard in which the keys are arranged in three banks, wherein the letters are disposed as follows: in the upper bank, in order from end to end, *p, y, f, g, c, r, l*; in the home bank, in order from end to end, *a, o, e, u, i, d, h, t, n, s*; and in the lower bank, *z, q, j, k, x, b, m, w,* and *v*.

10. A typewriter keyboard having the letters arranged in three rows, in which the letters in the home row are arranged consecutively *a, o, e, u, i, d, h, t, n, s*, the upper row contains the letters *p, y, f, g, c, r and l*, and the lower bank contains the letters *z, q, j, k, x, b, m, w* and *v*.

11. A typewriter keyboard having the letters arranged in three rows, in which the letters *a, o, e, u* and *i* are disposed in the home row to be operated by the fingers of one hand, the letters *p, y, e, u, i, j, k, x*, to be operated by the first two fingers of such hand, the letters *f, g, c, d, h, t, b, m,* and *w* to be operated by the first two fingers of the other hand, and the remaining letters to be operated by the third and fourth fingers of the two hands.

12. A typewriter keyboard having the letters arranged in three rows, in which the letters *a, o, e, u* and *i* are disposed in the home row to be operated by the fingers of one hand, the letters *p, y, e, u, i, j, k, x, f, g, c, d, h, t, b, m,* and *w* to be operated by the first two fingers of the hands, and the remaining letters to be operated by the third and fourth fingers of the two hands.

13. A typewriter keyboard having the letters arranged in three parallel continuous straight rows wherein the home row consists of ten successive keys, the vowels *a, o, e, u,* and *i* being arranged in such home row for operation by the four fingers, exclusive of the thumb, of one hand, and of the letters *d, h, t, n, s, r* and *l*, five being arranged in such home row and the other two being disposed in an adjacent row for operation by the four fingers, exclusive of the thumb, of the other hand, and the remaining letters being disposed in the upper and lower rows adjacent to the home row.

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