

THE VOWEL A^o (AS IN RAW), O (AS IN RODE), U
(AS IN RUDE).

BY LOUIS BEVIER, JR.

MY researches into the nature of the vowels, conducted with the aid of the phonograph, and a recording instrument, have been published from time to time in the *PHYSICAL REVIEW*, giving results for *a*, *a'*, *e*, *i'*, and *i*. Since the publication of the last article, "The Vowel *i* (as in pique)," September, 1904, I have been taking records as opportunity allowed of the series *a'*, *o*, *u*. The results reached are given below. A few preliminary words of explanation are needed.

The vowel *a'* (as in raw) is a sound which in general is uniform in its pronunciation. As ordinarily pronounced, it is a single sound with no important shift of vocal position during its utterance. The results reached therefore by the analysis of *a'*-curves are quite consistent, and accord precisely with what was to be anticipated. In general *a'* is different from *a* (as in father) in a somewhat lower pitch both of the main resonance (1150:1100) and of the secondary resonance (700:650).¹

Hence it is, that if *a* is recorded in the phonograph and the speed in reproduction is reduced the sound issuing is a clear and normal *a'*. If the speed is quickened an *a'* becomes *a* in reproduction, and if still further quickened the result is a species of *a'*, but not a normal one. The reason for this is apparent by comparing the acoustic analysis of *a* and *a'*.²

The vowel *o* is by no means so easy. In the first place, as spoken in America, it is usually a diphthong, beginning with an *o* and ending with an *u* glide. I have attempted to record and analyze the *o* sound simply, but in spite of great care the results with different voices do not show a close correspondence, a fact which greatly

¹ *PHYSICAL REVIEW*, April, 1900.

² Cf. *PHYSICAL REVIEW*, March, 1902.

increases the difficulty of definite description, but which was to have been expected, since recent phonetic studies reveal the same differences and varieties of sound grouped together as *o*'s.

With *u* another difficulty appears. Here there is often added (particularly in feminine utterance) a very high resonance, probably due to the closeness of the lips, which does not properly characterize the *u* sound. And this resonance is no more stationary for *u* than is the characteristic high resonance of *i* for that vowel,¹ but may vary within wide limits or be entirely wanting, without depriving the sound of a satisfactory *u* quality.

The most casual observation by ear, by instrumental registration of lip position, or by acoustic analysis, reveals the fact that *u* may be uttered with varying degrees of closeness and still be heard as *u*. Individuals even pronounce *u* in certain words, with an opening which brings it very near to a close *o*. It is therefore idle to expect that the curves will show as constant a character as the curves of sounds which are themselves more constant.

A comparison of the tables of analyses of *o* and *u* with those of *a*^o and *e*, will show how much greater the agreement in detail is in the case of the "bright" vowels, than in the "dark" vowels which we are now studying.

Passing these generalities I present herewith tables of analyses for *a*^o, *o*, and *u*, as computed from phonograph curves. For explanation of the methods used, I refer the reader to the preceding articles of this series, particularly to the article of Professor Prentiss.²

In the table of *a*^o analyses, it will be observed that generally there is strong resonance at or near a frequency of 1,000 vibrations to the second. This is the chief and most characteristic region of resonance for the *a*^o timbre. On a fundamental of 128 vibrations to the second, VIII. (1,024) will be strong; at 256 it will be IV., at 320 III., etc.

Again there is a marked secondary region of resonance culminating at about 640 to the second. Taking the same chord-tones, we shall find that on a fundamental of 128 to the second V. will be

¹ Cf. PHYSICAL REVIEW, November, 1902.

² PHYSICAL REVIEW, November, 1902.

strongly reinforced, and on a fundamental of 320 II. Comparing this result with the analyses of a , a^o is seen to be a low-pitched a .

One further characteristic must be noted. In the series a - a^e - e - i^e - i , there is seen to be a generally diminishing amplitude in the curves. Thus, save where the fundamental or chord-tone is strongly reinforced, the traces for a^e has less amplitude than a , and so on till for i the trace does not generally travel far on either side of a median straight line. A^o on the other hand gives a trace of great amplitude, the greatest of any of the vowels studied except u . This is plain for the series a , a^e , e , i^e , i by inspection of the sample curves shown.

The reason u shows so large an amplitude is not because its resonance is loudest, but because it is concentrated chiefly in the lowest frequencies, in the chord-tone or first upper partial, where great amplitude does not involve great energy. In the experi-

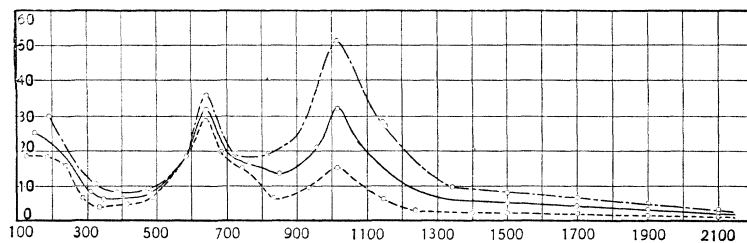


Fig. 1. A^o Resonance Curve.

mental work no effort was made to have the vowels sung with uniform loudness, hence the above comparison is merely a rough and ready test of average.

The analyses of u , which for convenience I discuss next, show some interesting facts. This vowel is to be described acoustically with negative rather than with positive characteristics. The mouth cavity in the normal u -position seems to have no marked resonance higher than about 210 vibrations to the second. In low tones of men's voices, this may be heard as a strong reinforcement of II. *cf.* the first two analyses given in the tables, voices one and four at 113. Obviously however as the chord-tone rises, this resonance will shift from II. to I.

Where the chord-tone lies above, say, 250 vibrations to the

second, the table shows great inconsistencies. This is due in part to inconsistencies of utterance, and in part to the fact that where no

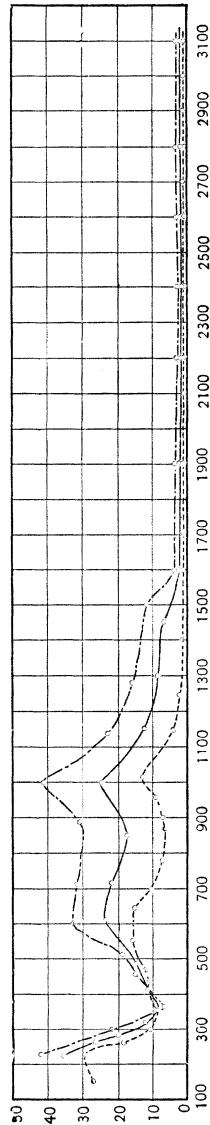


Fig. 2. O Resonance Curve.

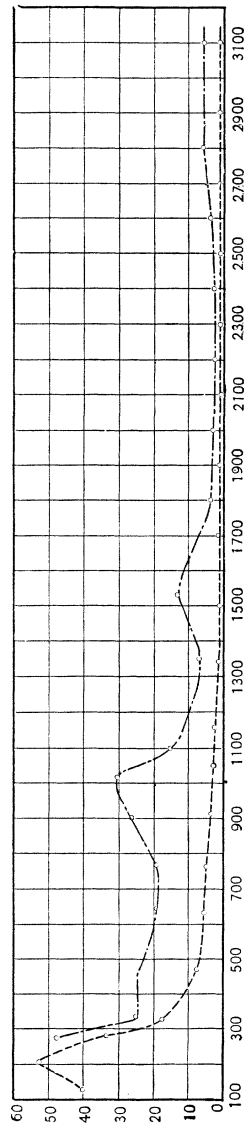


Fig. 3. U Resonance Curve.

resonance frequency is present in decided amplitude, the error due to the favored rates of the phonograph diaphragm is greatly increased.

Though I give the resonance curve therefore as before, I regard only the line for men as of great significance. One fact, however, is shown by the upper line, *i. e.*, the presence in many feminine *u*'s of a high resonance in the neighborhood of 3,000. This is present in some cases in considerable amplitude, so plainly in fact that many of the tones reveal it to the unaided eye at a casual examination. To this I have already alluded. I have not observed this in any of the men's *u*'s. Of course with low fundamental chord-tones, such a high resonance would not be prominent in the trace. Still, were it a characteristic mark of *u*-quality, its presence should be detected and its amplitudes should be capable of measurement. That it is an accidental resonance, whose absence does not impair the true *u*-quality is further shown by the fact, that many women's *u*'s are without it, and that its position is free to shift within considerable limits of pitch. In the resonance-curve computed on averages it raises slightly the end of the line all the way from 2,800 to about 3,300 as is seen in Fig. 3, page 83.

The normal *u* then will have strength in the chord-tone and in the first upper partial on lower fundamentals, and chiefly in the chord-tone on higher ones. The ear identifies it by the absence of marked upper resonances.

The analyses of the *o* curves are not so consistent, and their interpretation presents no little difficulty. If the individual analyses are studied one by one, the range will be found to be very wide, running from a typical and normal *o* to a fully closed *u*. For example, voice 6 at 144 is a good *o*-record, while voice 1 at 144 gives a record which is a normal man's *u*. Intermediate between these extremes all shades seem to be represented.

One reason of this is, I conclude, that there was little uniformity of utterance among the voices tested. The diphthongal character of *o* allows anything to pass with the ear, from *o* to a true *u*. If the waves analyzed were taken from the earlier part of the utterance, the analyses should be more or less like a true *o*, if from the latter part, more or less like a true *u*. I conclude from this that the intermediate examples represent approximately the truth, and a true monophthongal *o* may be described phonetically as follows: It possesses a strong resonance at about 600 to the second, but none

higher, also a resonance heard either as a chord-tone or as a first upper partial at about 225. These two resonances seem to be characteristic. A good example of such an *o* will be seen in voice 4 at 128, or in voice 5 at 288. In the first II. and V. are strongly reinforced, in the second I. and II. These facts are shown in the *o*-resonance curve (Fig. 2, page 83), but since this is computed from averaging all the records analyzed, it shows also a resonance at 1,000, due to the presence of many records which shade toward *a*^o.

If these conclusions are correct, it becomes clear why reproducing a phonographic *u* at an increased speed, or an *a*^o at a reduced speed, will not yield a satisfactory *o*-sound. In view of the inconsistencies of the records analyzed it is desirable that further researches be made with *o*-records, great care being taken in recording normal *o*-sounds, and also in selecting waves for measurement from different parts of the trace for careful comparison. This is of course absolutely essential in the study of diphthongs.

THE VOWEL *a*^o.

| | | I. | II. | III. | IV. | V. | VI. | VII. | VIII. | IX. | X. | XI. | XII. | XIII. | XIV. | XV. | XVI. | XVII. |
|---|-------|------|------|------|------|------|------|------|-------|------|------|------|------|-------|------|------|------|-------|
| | | 113 | 226 | 339 | 452 | 565 | 678 | 791 | 904 | 1017 | 1130 | 1243 | 1356 | 1469 | 1582 | 1695 | 1808 | 1921 |
| 1 | 119.8 | 32.0 | 16.8 | 1.1 | 3.7 | 16.6 | 15.8 | 3.6 | 1.2 | 2.9 | 1.3 | 0.4 | 0.7 | 0.8 | 1.4 | 1.2 | 0.3 | 0.2 |
| 4 | 69.9 | 2.0 | 30.7 | 2.1 | 2.0 | 5.9 | 18.7 | 3.9 | 7.3 | 13.4 | 1.1 | 1.6 | 1.5 | 2.7 | 0.7 | 0.7 | 1.2 | 0.2 |
| | | 128 | 256 | 384 | 512 | 640 | 768 | 896 | 1024 | 1152 | 1280 | 1408 | 1536 | 1664 | 1792 | 1920 | 2048 | 2176 |
| 4 | 156.5 | 6.1 | 11.7 | 2.3 | 2.8 | 10.4 | 20.9 | 3.7 | 16.2 | 11.9 | 1.8 | 0.9 | 2.7 | 0.7 | 2.0 | 1.3 | 1.2 | 0.7 |
| 6 | 47.7 | 8.2 | 23.5 | 0.6 | 1.9 | 30.2 | 2.7 | 5.7 | 10.9 | 4.4 | 1.9 | 0.2 | 2.1 | 1.9 | 1.5 | 1.9 | 1.0 | 1.4 |
| | | 144 | 288 | 432 | 576 | 720 | 864 | 1008 | 1152 | 1296 | 1440 | 1584 | 1728 | 1872 | 2016 | 2160 | 2304 | 2448 |
| 1 | 133.3 | 1.8 | 12.1 | 6.2 | 52.7 | 2.1 | 7.1 | 7.2 | 2.1 | 1.8 | 1.1 | 2.0 | 0.6 | 0.6 | 0.5 | 1.2 | 0.4 | 0.5 |
| 4 | 253.2 | 21.5 | 5.4 | 2.1 | 8.1 | 20.4 | 3.0 | 15.2 | 10.4 | 2.9 | 2.5 | 1.3 | 0.8 | 0.8 | 0.4 | 0.4 | 0.2 | 0.4 |
| 6 | 139.5 | 43.1 | 4.4 | 1.8 | 9.4 | 4.9 | 4.3 | 9.5 | 1.4 | 1.1 | 1.6 | 0.3 | 0.5 | 0.9 | 0.9 | 0.9 | 1.4 | 2.2 |
| | | 160 | 320 | 480 | 640 | 800 | 960 | 1120 | 1280 | 1440 | 1600 | 1760 | 1920 | 2080 | 2240 | 2400 | 2560 | 2720 |
| 1 | 243.3 | 12.5 | 7.6 | 3.8 | 52.6 | 5.1 | 2.3 | 1.4 | 1.2 | 0.9 | 1.0 | 1.1 | 1.2 | 0.6 | 0.9 | 0.9 | 0.5 | 1.9 |
| 4 | 265.6 | 21.2 | 2.2 | 2.4 | 19.4 | 10.6 | 9.3 | 22.2 | 2.2 | 2.8 | 1.5 | 1.5 | 1.2 | 0.6 | 0.8 | 0.4 | 0.7 | 1.1 |
| 6 | 159.0 | 25.1 | 2.3 | 0.4 | 31.1 | 2.3 | 8.2 | 15.5 | 1.1 | 1.7 | 3.2 | 1.5 | 1.6 | 0.4 | 1.0 | 1.0 | 2.8 | 0.8 |
| | | 171 | 342 | 513 | 684 | 855 | 1026 | 1197 | 1368 | 1539 | 1710 | 1881 | 2052 | 2223 | 2394 | 2565 | 2736 | 2907 |
| 1 | 173.6 | 24.9 | 8.8 | 9.2 | 21.5 | 11.1 | 7.5 | 1.7 | 0.9 | 0.6 | 0.6 | 1.1 | 0.3 | 0.3 | 0.6 | 1.0 | 2.8 | 1.4 |
| 4 | 343.9 | 20.5 | 2.4 | 4.8 | 18.6 | 4.0 | 30.2 | 5.2 | 4.8 | 2.9 | 1.4 | 0.5 | 0.8 | 0.4 | 0.5 | 0.3 | 1.1 | 1.6 |
| 6 | 84.6 | 6.4 | 6.3 | 13.9 | 7.2 | 8.9 | 16.9 | 2.7 | 4.1 | 1.4 | 1.5 | 2.7 | 2.4 | 2.5 | 6.5 | 10.2 | 5.6 | 0.8 |

¹ Where the percentages do not sum up exactly to 100 it is because the computation included upper partials higher than those printed. In no cases are the omitted figures large enough to affect the statement of facts.

| | | I. | II. | III. | IV. | V. | VI. | VII. | VIII. | XI. | X. | XI. | XII. | XIII. | XIV. | XV. | XVI. | XVII. |
|----|-------|------|------|------|------|------|------|------|-------|------|------|------|------|-------|------|------|------|-------|
| 1 | | 113 | 226 | 339 | 452 | 565 | 678 | 791 | 904 | 1017 | 1130 | 1243 | 1356 | 1469 | 1582 | 1695 | 1808 | 1921 |
| 6 | 55.0 | 42.2 | 11.5 | 10.2 | 2.8 | 12.7 | 0.9 | 1.6 | 0.8 | 0.8 | 1.3 | 1.1 | 1.3 | 1.8 | 1.8 | 1.1 | 0.8 | 1.1 |
| | 89.2 | 15.3 | 39.8 | 9.2 | 15.3 | 2.6 | 7.6 | 1.0 | 1.2 | 0.8 | 0.8 | 1.0 | 1.0 | 0.2 | 0.8 | 0.6 | 0.3 | 0.3 |
| | | 128 | 256 | 384 | 512 | 640 | 768 | 896 | 1024 | 1152 | 1280 | 1408 | 1536 | 1664 | 1792 | 1920 | 2048 | 2176 |
| 1 | 66.9 | 27.5 | 21.0 | 8.2 | 6.7 | 23.2 | 2.3 | 0.6 | 1.0 | 0.1 | 0.5 | 0.6 | 0.4 | 0.1 | 0.8 | 0.9 | 0.8 | 0.1 |
| 4 | 104.0 | 12.4 | 24.4 | 5.5 | 11.6 | 11.9 | 10.1 | 7.4 | 3.8 | 2.4 | 1.4 | 1.5 | 0.9 | 1.1 | 0.1 | 0.4 | 0.1 | 0.6 |
| | | 144 | 288 | 432 | 576 | 720 | 864 | 1008 | 1152 | 1296 | 1440 | 1584 | 1728 | 1872 | 2016 | 2160 | 2304 | 2448 |
| 1 | 132.0 | 53.3 | 20.8 | 11.3 | 4.2 | 2.5 | 0.5 | 0.2 | 0.2 | 0.5 | 0.5 | 0.6 | 0.1 | 0.5 | 0.5 | 0.2 | 0.5 | 0.5 |
| 6 | 249.7 | 17.7 | 4.2 | 11.4 | 20.6 | 0.4 | 7.8 | 15.6 | 1.8 | 3.8 | 0.8 | 2.1 | 1.4 | 1.3 | 1.0 | 1.7 | 2.7 | 0.8 |
| | | 160 | 320 | 480 | 640 | 800 | 960 | 1120 | 1280 | 1440 | 1600 | 1760 | 1920 | 2080 | 2240 | 2400 | 2560 | 2720 |
| 1 | 145.1 | 69.3 | 9.2 | 5.4 | 5.0 | 3.1 | 0.6 | 0.7 | 0.4 | 0.6 | 0.3 | 0.8 | 0.6 | 0.6 | 0.1 | 0.5 | 0.4 | 0.6 |
| 4 | 257.3 | 34.7 | 7.9 | 6.1 | 22.2 | 3.3 | 9.2 | 5.4 | 1.9 | 0.6 | 1.2 | 0.6 | 0.3 | 0.8 | 0.5 | 1.0 | 0.2 | 0.1 |
| | | 171 | 342 | 513 | 684 | 855 | 1026 | 1197 | 1368 | 1539 | 1710 | 1881 | 2052 | 2223 | 2394 | 2565 | 2736 | 2907 |
| 1 | 152.0 | 18.5 | 25.7 | 11.1 | 25.6 | 1.6 | 2.5 | 1.0 | 1.0 | 0.7 | 0.3 | 0.6 | 0.7 | 0.6 | 1.4 | 0.9 | 1.6 | 1.8 |
| 4 | 164.5 | 28.6 | 5.8 | 17.4 | 9.2 | 9.0 | 12.4 | 4.5 | 1.4 | 1.4 | 0.7 | 0.8 | 0.7 | 0.8 | 0.4 | 0.7 | 0.9 | 1.7 |
| 6 | 357.1 | 12.9 | 7.9 | 17.2 | 6.7 | 8.5 | 28.2 | 0.8 | 1.9 | 0.2 | 1.9 | 1.6 | 3.0 | 3.2 | 1.3 | 1.5 | 1.5 | 1.7 |
| | | 192 | 384 | 576 | 768 | 960 | 1152 | 1344 | 1536 | 1728 | 1920 | 2112 | 2304 | 2496 | 2688 | 2880 | 3072 | 3264 |
| 1 | 143.0 | 30.8 | 17.6 | 12.0 | 19.9 | 2.0 | 2.5 | 1.5 | 1.0 | 2.1 | 0.8 | 0.2 | 0.4 | 0.7 | 1.2 | 1.2 | 1.0 | 2.7 |
| 4 | 261.2 | 14.4 | 4.0 | 18.9 | 11.8 | 11.6 | 19.2 | 1.8 | 1.8 | 3.1 | 1.4 | 1.1 | 0.7 | 0.4 | 0.9 | 2.5 | 4.2 | 2.2 |
| 6 | 178.3 | 20.0 | 6.3 | 30.1 | 5.2 | 18.7 | 4.8 | 3.2 | 1.8 | 2.0 | 1.9 | 0.8 | 0.1 | 2.1 | 1.7 | 0.7 | 0.4 | 0.2 |
| | | 227 | 454 | 681 | 908 | 1135 | 1362 | 1589 | 1816 | 2043 | 2270 | 2497 | 2724 | 2951 | 3178 | 3405 | 3632 | 3859 |
| 4 | 221.5 | 44.9 | 12.0 | 23.2 | 5.4 | 5.0 | 1.5 | 1.4 | 1.8 | 0.3 | 0.8 | 0.5 | 0.6 | 0.5 | 0.9 | 0.3 | 0.8 | 0.1 |
| 5 | 60.6 | 43.1 | 9.1 | 17.0 | 6.8 | 12.7 | 3.4 | 0.5 | 0.8 | 0.8 | 1.3 | 0.2 | 0.6 | 1.5 | 0.4 | 1.1 | 0.5 | 0.2 |
| 6 | 283.0 | 15.1 | 15.8 | 15.5 | 28.7 | 5.6 | 6.7 | 1.4 | 1.5 | 2.1 | 3.5 | 0.8 | 0.4 | 0.7 | 1.0 | 0.9 | 0.1 | 0.2 |
| | | 256 | 512 | 768 | 1024 | 1280 | 1536 | 1792 | 2048 | 2304 | 2560 | 2816 | 3072 | 3328 | 3584 | 3840 | 4096 | 4352 |
| 1 | 221.7 | 13.3 | 22.0 | 3.1 | 49.0 | 4.2 | 1.7 | 1.2 | 1.2 | 0.5 | 1.3 | 0.4 | 0.1 | 1.3 | 0.2 | 0.3 | 0.1 | 0.1 |
| 4 | 288.1 | 27.6 | 31.1 | 16.9 | 9.8 | 3.4 | 2.9 | 0.7 | 0.1 | 0.6 | 0.7 | 1.6 | 1.1 | 1.4 | 1.1 | 0.5 | 0.3 | 0.2 |
| 6 | 339.6 | 10.5 | 14.8 | 8.2 | 45.5 | 3.0 | 5.1 | 1.1 | 1.9 | 0.9 | 2.9 | 0.8 | 1.4 | 0.7 | 1.9 | 0.6 | 0.4 | 0.3 |
| | | 288 | 576 | 864 | 1152 | 1440 | 1728 | 2016 | 2304 | 2592 | 2880 | 3168 | 3456 | 3744 | 4032 | 4320 | 4608 | 4896 |
| 5 | 47.0 | 30.4 | 20.6 | 12.3 | 9.2 | 8.9 | 4.9 | 3.8 | 2.6 | 0.9 | 0.6 | 1.5 | 1.1 | 0.9 | 0.9 | 0.4 | 0.4 | 0.6 |
| 7 | 42.0 | 16.9 | 18.8 | 11.0 | 16.4 | 8.6 | 1.6 | 3.1 | 2.6 | 1.9 | 9.1 | 2.4 | 3.1 | 1.4 | 1.2 | 0.7 | 0.5 | 0.7 |
| | | 320 | 640 | 960 | 1280 | 1600 | 1920 | 2240 | 2560 | 2880 | 3200 | 3520 | 3840 | 4160 | 4480 | 4800 | 5120 | 5440 |
| 5 | 42.6 | 39.8 | 15.6 | 5.5 | 21.9 | 2.3 | 2.3 | 2.1 | 2.3 | 0.9 | 0.9 | 1.6 | 0.9 | 0.9 | 0.9 | 1.4 | 0.5 | 0.2 |
| 7 | 107.7 | 7.4 | 46.8 | 11.4 | 8.0 | 5.4 | 4.8 | 4.1 | 3.3 | 4.8 | 1.6 | 0.5 | 0.3 | 0.4 | 0.3 | 0.6 | 0.1 | 0.2 |
| 11 | 85.6 | 13.6 | 40.1 | 17.8 | 16.9 | 4.8 | 2.2 | 1.1 | 0.4 | 0.5 | 0.9 | 0.4 | 0.3 | 0.2 | 0.2 | 0.1 | 0.1 | 0.4 |
| | | 342 | 684 | 1026 | 1368 | 1710 | 2052 | 2394 | 2736 | | | | | | | | | |
| 5 | 238.6 | 4.3 | 26.4 | 47.4 | 18.7 | 0.7 | 1.0 | 0.9 | 0.6 | | | | | | | | | |
| 11 | 233.6 | 4.0 | 25.3 | 50.0 | 13.8 | 2.2 | 1.6 | 1.3 | 1.8 | | | | | | | | | |
| | | 384 | 768 | 1152 | 1536 | 1920 | 2304 | 2688 | 3072 | 3456 | 3840 | 4224 | 4608 | 4992 | 5376 | 5760 | 6144 | 6528 |
| 5 | 134.4 | 10.1 | 51.6 | 18.5 | 11.7 | 2.4 | 1.6 | 0.8 | 0.9 | 0.2 | 0.4 | 0.2 | 0.1 | 0.4 | 0.3 | 0.4 | 0.3 | 0.1 |
| 7 | 119.3 | 3.0 | 44.7 | 11.0 | 8.6 | 6.8 | 5.0 | 4.4 | 0.6 | 9.5 | 1.5 | 1.9 | 1.2 | 0.4 | 0.6 | 0.3 | 0.3 | 0.2 |
| 11 | 174.2 | 4.9 | 29.4 | 45.2 | 16.2 | 1.4 | 1.0 | 0.5 | 1.4 | | | | | | | | | |

THE VOWEL *O*, *continued*.

| | | I. | II. | III. | IV. | V. | VI. | VII. | VIII. | IX. | X. | XI. | XII. | XIII. | XIV. | XV. | XVI. | XVII. |
|----|-------|------|------|------|------|------|------|------|-------|------|------|------|------|-------|------|------|------|-------|
| | | 454 | 908 | 1362 | 1816 | 2270 | 2724 | 3178 | 3632 | | | | | | | | | |
| 5 | 121.2 | 17.1 | 62.7 | 12.3 | 2.8 | 1.8 | 2.0 | 0.7 | 0.6 | | | | | | | | | |
| 11 | 104.3 | 15.0 | 50.1 | 25.8 | 1.2 | 1.0 | 2.4 | 3.2 | 1.3 | | | | | | | | | |
| 7 | 382.6 | 18.2 | 52.5 | 9.6 | 2.1 | 2.5 | 11.1 | 2.7 | 1.3 | | | | | | | | | |
| | | 512 | 1024 | 1536 | 2048 | 2560 | 3072 | 3584 | 4096 | 4608 | 5120 | 5632 | 6144 | 6656 | 7168 | 7680 | 8192 | 8704 |
| 5 | 116.4 | 11.6 | 33.6 | 32.1 | 10.3 | 4.4 | 1.4 | 0.4 | 2.1 | 6.7 | 0.9 | 0.5 | 0.2 | 0.7 | 0.1 | 0.1 | 3.3 | 0.5 |
| 7 | 155.6 | 23.7 | 62.7 | 6.5 | 3.1 | 1.2 | 1.5 | 0.6 | 0.7 | | | | | | | | | |
| 11 | 107.1 | 6.4 | 53.1 | 20.3 | 11.8 | 3.3 | 2.4 | 1.6 | 1.1 | | | | | | | | | |

THE VOWEL *U*.

| | | I. | II. | III. | IV. | V. | VI. | VII. | VIII. | IX. | X. | XI. | XII. | XIII. | XIV. | XV. | XVI. | XVII. |
|---|-------|------|------|------|------|------|------|------|-------|------|------|------|------|-------|------|------|------|-------|
| | | 113 | 226 | 339 | 452 | 565 | 678 | 791 | 904 | 1017 | 1130 | 1243 | 1356 | 1469 | 1582 | 1695 | 1808 | 1921 |
| 1 | 130.6 | 17.1 | 41.8 | 8.6 | 1.6 | 3.7 | 7.6 | 1.4 | 1.0 | 2.1 | 0.4 | 2.4 | 1.4 | 1.7 | 0.8 | 0.5 | 0.5 | 0.6 |
| 4 | 109.3 | 8.1 | 52.6 | 12.7 | 5.7 | 3.3 | 3.4 | 0.8 | 1.8 | 0.5 | 0.4 | 1.2 | 1.5 | 0.7 | 0.7 | 0.6 | 1.8 | 1.2 |
| | | 128 | 256 | 384 | 512 | 640 | 768 | 896 | 1024 | 1152 | 1280 | 1408 | 1536 | 1664 | 1792 | 1920 | 2048 | 2176 |
| 1 | 124.8 | 37.6 | 28.6 | 5.2 | 2.4 | 6.5 | 4.0 | 0.4 | 1.9 | 0.4 | 0.6 | 0.6 | 0.6 | 1.4 | 0.8 | 0.2 | 0.6 | 0.9 |
| 4 | 26.7 | 3.0 | 39.1 | 10.0 | 9.0 | 3.7 | 2.7 | 3.4 | 2.6 | 0.8 | 1.5 | 3.4 | 1.9 | 4.9 | 1.9 | 2.2 | 1.5 | 1.2 |
| | | 144 | 288 | 432 | 576 | 720 | 864 | 1008 | 1152 | 1296 | 1440 | 1584 | 1728 | 1872 | 2016 | 2160 | 2304 | 2448 |
| 1 | 274.3 | 63.6 | 16.7 | 2.0 | 2.9 | 1.9 | 3.6 | 1.6 | 0.4 | 1.1 | 0.4 | 0.4 | 0.0 | 0.4 | 0.3 | 0.8 | 0.3 | 0.7 |
| 4 | 225.3 | 54.7 | 19.0 | 8.7 | 1.6 | 2.6 | 3.5 | 1.8 | 0.9 | 0.1 | 0.7 | 1.9 | 0.9 | 1.0 | 0.4 | 0.2 | 0.2 | 1.0 |
| 6 | 312.9 | 59.1 | 18.1 | 7.2 | 0.9 | 1.4 | 3.6 | 2.2 | 0.4 | 0.5 | 1.1 | 0.9 | 0.3 | 0.5 | 1.0 | 1.3 | 0.5 | 0.6 |
| | | 160 | 320 | 480 | 640 | 800 | 960 | 1120 | 1280 | 1440 | 1600 | 1760 | 1920 | 2080 | 2240 | 2400 | 2560 | 2720 |
| 1 | 216.1 | 45.3 | 23.0 | 2.8 | 14.5 | 2.5 | 1.7 | 1.4 | 0.4 | 0.1 | 0.8 | 0.6 | 0.6 | 0.5 | 1.0 | 2.3 | 1.0 | 1.4 |
| 6 | 292.3 | 64.8 | 18.0 | 4.4 | 2.6 | 0.2 | 2.0 | 2.6 | 0.5 | 1.1 | 0.3 | 0.5 | 0.1 | 0.2 | 0.5 | 0.9 | 0.2 | 0.5 |
| | | 171 | 342 | 513 | 684 | 855 | 1026 | 1197 | 1368 | 1539 | 1710 | 1881 | 2052 | 2223 | 2394 | 2565 | 2736 | 2907 |
| 1 | 246.8 | 32.4 | 24.0 | 5.9 | 19.0 | 7.6 | 5.4 | 0.9 | 0.9 | 0.9 | 0.4 | 0.8 | 0.2 | 1.7 | 4.6 | 0.4 | 1.9 | 1.6 |
| 4 | 304.5 | 44.2 | 20.5 | 6.6 | 8.0 | 9.1 | 3.3 | 1.9 | 1.1 | 1.2 | 0.9 | 0.3 | 0.4 | 0.1 | 0.4 | 0.8 | 0.6 | 0.6 |
| 6 | 300.4 | 35.2 | 21.9 | 6.5 | 10.0 | 5.8 | 8.7 | 2.4 | 0.0 | 1.3 | 0.4 | 0.6 | 2.6 | 2.1 | 1.3 | 0.3 | 0.3 | 0.6 |
| | | 192 | 384 | 576 | 768 | 960 | 1152 | 1344 | 1536 | 1728 | 1920 | 2112 | 2304 | 2496 | 2688 | 2880 | 3072 | 3264 |
| 1 | 347.0 | 34.0 | 28.8 | 4.5 | 14.8 | 2.9 | 1.7 | 1.6 | 0.5 | 2.3 | 0.5 | 1.1 | 1.1 | 3.4 | 0.4 | 1.2 | 0.8 | 0.4 |
| 4 | 185.9 | 65.3 | 14.4 | 4.4 | 4.9 | 2.9 | 0.8 | 1.5 | 0.4 | 0.5 | 0.4 | 0.6 | 1.0 | 0.3 | 0.4 | 0.5 | 0.4 | 0.4 |
| 6 | 330.5 | 30.5 | 21.5 | 5.6 | 6.6 | 1.9 | 18.8 | 1.0 | 1.8 | 0.5 | 1.4 | 2.0 | 3.0 | 1.0 | 0.6 | 1.5 | 0.7 | 1.6 |
| | | 227 | 454 | 681 | 908 | 1135 | 1362 | 1589 | 1816 | 2043 | 2270 | 2497 | 2724 | 2951 | 3178 | 3405 | 3632 | 3859 |
| 1 | 554.0 | 74.7 | 3.6 | 14.3 | 1.3 | 1.4 | 0.5 | 1.1 | 0.3 | 0.4 | 0.6 | 0.2 | 0.3 | 0.1 | 0.2 | 0.7 | 0.1 | 0.2 |
| 4 | 442.6 | 70.4 | 7.1 | 8.2 | 5.9 | 1.5 | 1.3 | 0.3 | 0.8 | 0.9 | 0.5 | 1.0 | 0.2 | 0.2 | 0.3 | 0.2 | 0.3 | 0.9 |
| 6 | 197.5 | 54.8 | 22.2 | 7.0 | 2.9 | 2.2 | 1.0 | 1.0 | 2.1 | 4.1 | 0.8 | 0.3 | 0.1 | 0.2 | 0.4 | 0.5 | 0.3 | 0.1 |

THE VOWEL *U*, *continued*.

| | | I. | II. | III. | IV. | V. | VI. | VII. | VIII. | IX. | X. | XI. | XII. | XIII. | XVI. | XV. | XVI. | XVII. |
|----|-------|------|------|------|------|------|------|------|-------|------|------|------|------|-------|------|------|------|-------|
| | | 256 | 512 | 768 | 1024 | 1280 | 1536 | 1792 | 2048 | 2304 | 2560 | 2816 | 3072 | 3328 | 3584 | 3840 | 4096 | 4352 |
| 1 | 455.0 | 41.8 | 13.5 | 19.3 | 2.5 | 2.1 | 2.7 | 0.8 | 1.1 | 5.0 | 1.3 | 4.3 | 2.0 | 1.3 | 0.5 | 0.5 | 0.2 | 1.3 |
| 4 | 191.1 | 66.9 | 8.6 | 12.9 | 3.9 | 1.7 | 0.9 | 1.1 | 0.4 | 0.4 | 0.7 | 0.3 | 0.3 | 0.3 | 0.9 | 0.4 | 0.2 | 0.3 |
| 6 | 181.9 | 56.5 | 14.7 | 17.2 | 3.6 | 1.5 | 1.4 | 0.7 | 1.1 | 0.6 | 0.6 | 0.7 | 0.3 | 0.2 | 0.4 | 0.1 | 0.1 | 0.3 |
| 5 | 72.1 | 74.7 | 0.8 | 4.2 | 3.0 | 0.7 | 0.5 | 1.7 | 0.1 | 1.7 | 1.4 | 3.2 | 2.2 | 1.9 | 1.5 | 1.2 | 0.5 | 0.7 |
| | | 288 | 576 | 864 | 1152 | 1440 | 1728 | 2016 | 2304 | 2592 | 2880 | 3168 | 3456 | 3744 | 4032 | 4320 | 4608 | 4896 |
| 7 | 47.7 | 22.9 | 13.0 | 5.7 | 5.6 | 5.4 | 4.2 | 3.8 | 2.5 | 6.0 | 6.1 | 14.9 | 4.8 | 0.6 | 1.7 | 0.2 | 1.1 | 1.5 |
| | | 320 | 640 | 960 | 1280 | 1600 | 1920 | 2240 | 2560 | 2880 | 3200 | 3520 | 3840 | 4160 | 4480 | 4800 | 5120 | 5440 |
| 11 | 49.2 | 34.9 | 39.2 | 8.9 | 4.0 | 5.6 | 1.8 | 0.4 | 0.8 | 0.6 | 0.8 | 0.4 | 0.2 | 1.0 | 0.8 | 0.2 | 0.2 | 0.2 |
| | | 342 | 684 | 1026 | 1368 | 1710 | 2052 | 2394 | 2736 | 3078 | 3420 | 3762 | 4104 | 4446 | 4788 | 5130 | 5472 | 5814 |
| 5 | 121.9 | 29.5 | 5.3 | 49.2 | 2.4 | 4.4 | 3.5 | 1.1 | 4.6 | | | | | | | | | |
| 7 | 58.7 | 13.8 | 14.8 | 24.3 | 6.5 | 6.3 | 1.5 | 1.9 | 15.3 | 8.5 | 1.4 | 1.0 | 0.7 | 1.0 | 0.7 | 1.2 | 0.7 | 0.4 |
| 11 | 54.5 | 16.0 | 24.2 | 51.5 | 3.1 | 2.2 | 0.4 | 1.3 | 1.3 | | | | | | | | | |
| | | 384 | 768 | 1152 | 1536 | 1920 | 2304 | 2688 | 3072 | 3456 | 3840 | 4224 | 4608 | 4992 | 5376 | 5760 | 6144 | 6528 |
| 5 | 103.7 | 30.1 | 2.0 | 11.3 | 38.5 | 4.8 | 2.2 | 2.4 | 2.3 | 1.0 | 0.8 | 0.5 | 0.7 | 1.0 | 0.7 | 0.8 | 0.3 | 0.6 |
| 7 | 70.6 | 21.1 | 35.6 | 11.3 | 5.2 | 4.8 | 2.4 | 2.0 | 1.7 | 4.5 | 3.5 | 3.4 | 1.1 | 1.4 | 0.1 | 0.3 | 0.8 | 0.8 |
| 11 | 46.8 | 27.2 | 36.3 | 28.4 | 2.1 | 1.5 | 2.1 | 0.9 | 1.5 | | | | | | | | | |
| | | 454 | 908 | 1362 | 1816 | 2270 | 2724 | 3178 | 3632 | 4086 | 4540 | 4994 | 5448 | 5902 | 6356 | 6810 | 7264 | 7718 |
| 5 | 243.9 | 39.4 | 45.0 | 9.1 | 0.4 | 2.3 | 2.7 | 0.2 | 0.9 | | | | | | | | | |
| 7 | 65.4 | 19.4 | 29.7 | 12.3 | 4.3 | 4.4 | 15.6 | 6.6 | 1.1 | 1.9 | 0.6 | 0.9 | 0.6 | 0.6 | 0.5 | 0.5 | 0.5 | 0.5 |
| 11 | 82.8 | 29.7 | 45.8 | 15.5 | 5.7 | 1.4 | 0.6 | 0.9 | 0.4 | | | | | | | | | |
| | | 512 | 1024 | 1536 | 2048 | 2560 | 3072 | 3584 | 4096 | 4608 | 5120 | 5632 | 6144 | 6656 | 7168 | 7680 | 8192 | 8704 |
| 7 | 124.8 | 28.2 | 32.1 | 19.6 | 3.4 | 3.9 | 7.1 | 1.5 | 0.6 | 0.4 | 0.6 | 0.5 | 0.4 | 0.4 | 0.3 | 0.4 | 0.4 | 0.2 |
| 7 | 47.0 | 21.7 | 19.2 | 18.1 | 4.7 | 5.9 | 12.1 | 7.9 | 3.2 | 1.1 | 1.2 | 0.2 | 1.1 | 0.2 | 0.9 | 1.0 | 0.6 | 0.9 |