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Stroboscopic Velocities in the Tonoscope

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STROBOSCOPIC VELOCITIES IN THE TONOSCOPE.

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The characteristic equation for stroboscopic velocity is

$$v_s = \left(A - n/m \cdot B\right) D_0 \qquad (1)$$

(see Proc. Iowa Acad. Sci., Vol. XXIV, 1917, p. 222), where v_s is the stroboscopic velocity, A the frequency of the stroboscopic figures, B the frequency of illumination, n/m a fraction at lowest terms, and D_0 the distance of separation of the stroboscopic figures. Eq. (1) may be rewritten,

$$v_s = v - n/m \cdot D_0 B$$

where v is the velocity of the stroboscopic screen. For the tonoscope,

$$v_s = 2 \pi r \left(1 - n/m \cdot B/N\right) \qquad (2)$$

where r is radius of drum, and N is total number of dots around drum in a given row. Let f be the number per second of simple images in a given row passing the tonoscope scale. Then,

$$v_s = f D,$$

where D is distance of separation of simple images. Now $D = D_0/m$ (loc. cit.). Thus,

$$v_s = f D_0 / m = f/m \cdot 2 \pi r/N, \qquad (3)$$

for tonoscope. Equating (2) and (3),

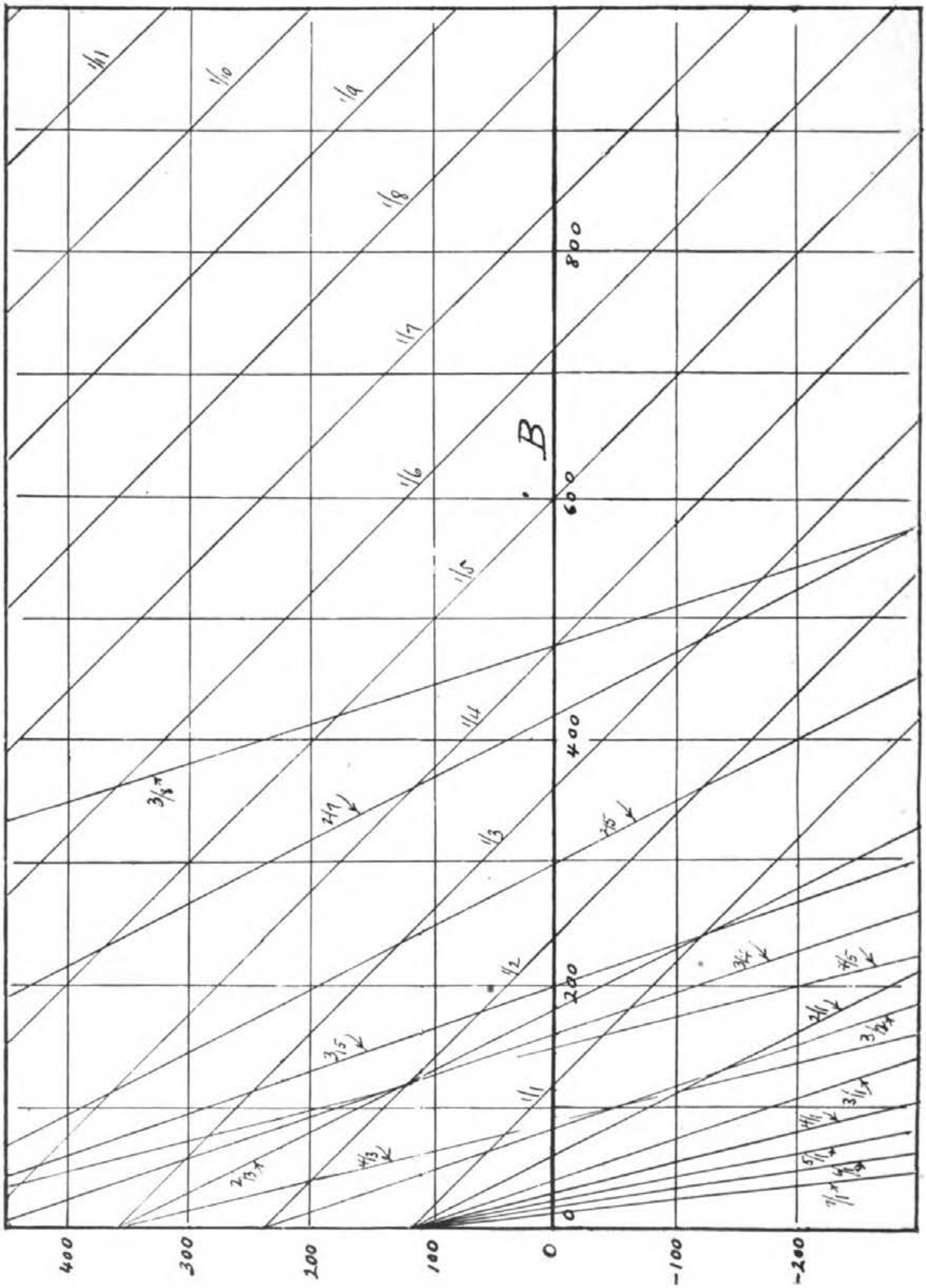
$$f = mN - nB, \qquad (4)$$

an equation that may be regarded as of the form $y = mx + B$. Although f is a frequency rather than a velocity, eq. (4) will be used as a special form to test eq. (1), because of the linear relation, and f will be referred to in this paper as the stroboscopic velocity. The value of v_s is readily found from the value of f by means of eq. (3).

Eq. (4) contains two independent variables, N and B. Two sets of curves are drawn, with N and B respectively constant, and with some of the unlimited number of possible values of n/m. For these two cases (4) is put into the respective forms:

$$f = (m)N + (-nB), \qquad (5a)$$

$$f = (-n)B + (mN). \qquad (5b)$$



f-B Curves, M constant

Thus the curves from (5a) have slope m and y—intercept (—nB), and those from (5b) have slope (—n) and y—intercept (mN). The values of n/m for the comparatively few curves actually drawn are indicated on them.

The meaning of curves from (5a), where B is taken constant for the plotting of the curves, is that if we had a continuous tonoscope drum, instead of a drum with but a single octave, which included values of N from 1 to infinity, the x—intercepts of the straight lines would give the values of N (=n/m·B) for rows stationary by stroboscopic response for the particular value of B, while the f values on the straight lines would give the stroboscopic velocities. For the actual tonoscope we are limited to the tonoscope octave. The visible stroboscopic response for a given value of B is of course limited to segments of such straight line curves, which segments include the zero value for f.

The meaning of curves from (5b), where N is taken constant for the plotting of the curves, is that for a given row (definite value of N) the x—intercepts give the values of B (=m/n·N) which are able to make that row stationary by stroboscopic response, and the other points on the curves give the finite stroboscopic velocity in terms of f as a function of B for that row.

For the curves from (5a), Fig. 1, B is taken equal to 160, so that the value of N_0 for which n/m=1/1, falls within the tonoscope octave. For any other value of B the set of curves would be slipped either up or down along the y—axis, with the angular relations remaining unchanged. The values of n/m most used practically in the tonoscope are: 2/1 (bass voice), 1/1 (where pitch of sounded tone lies within tonoscope octave), 1/2, 1/4 (soprano voice).

Similarly, for the curves from (5b), Fig. 2, N is taken equal to 120, so that the value of N_0 for n/m=1/1, falls within the tonoscope octave. For any other value of N the set of curves is slipped either up or down the y—axis, while the angular relations remain unchanged.

EXPERIMENTAL.

Nine cases, affording five different values of n/m, viz., 1/1, 1/2, 1/3, 2/1, 3/2, are experimentally investigated by observation on the tonoscope. The curves, Fig. 3, for these cases are drawn from eq. (5a), and the small circles indicating points on the curves give experimental values. The agreement between

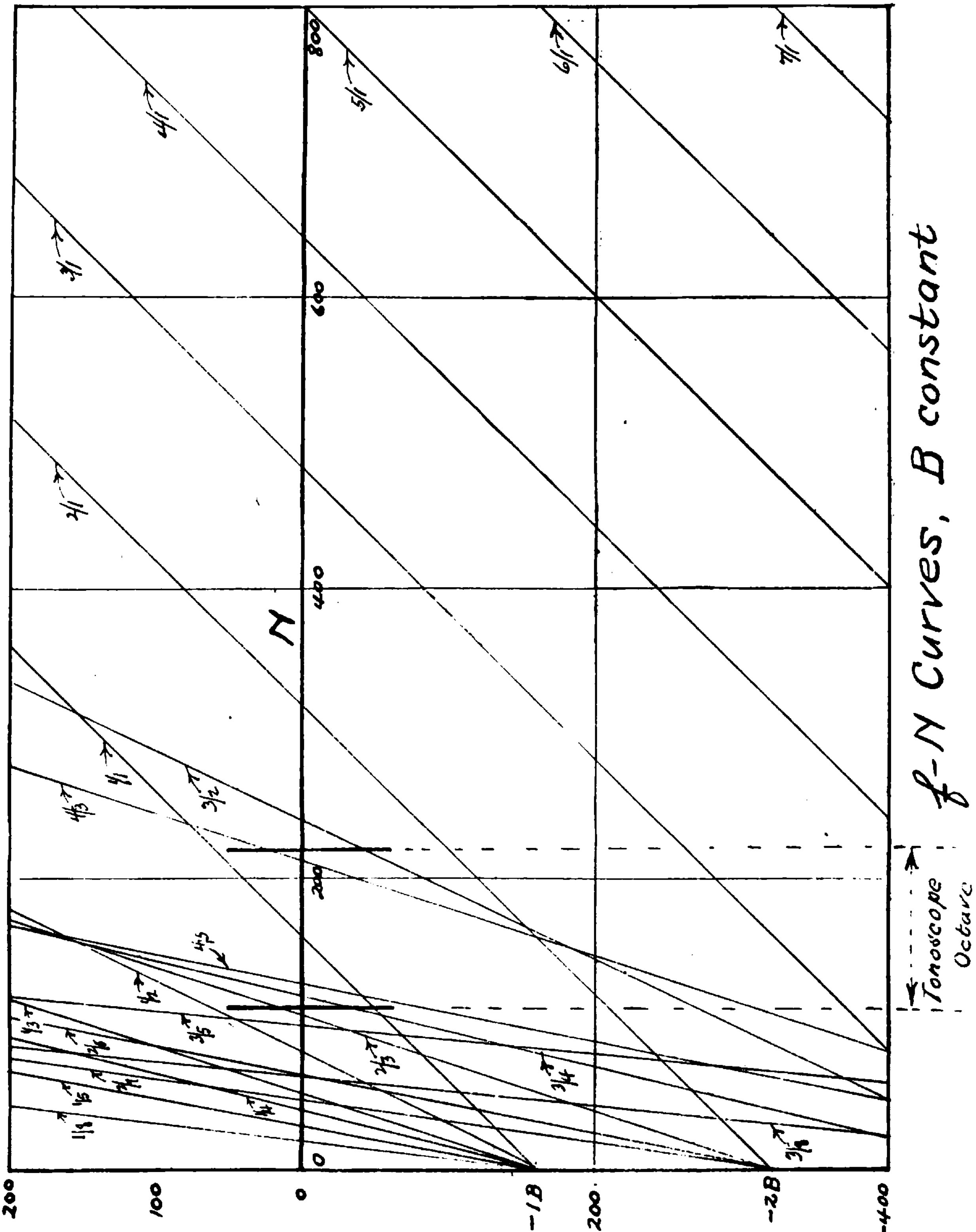

f-N Curves, B constant
Tonoscope Octave
N
800
600
400
200
0
200
100
0
-1B
-200
-2B
-400

Fig. 2.

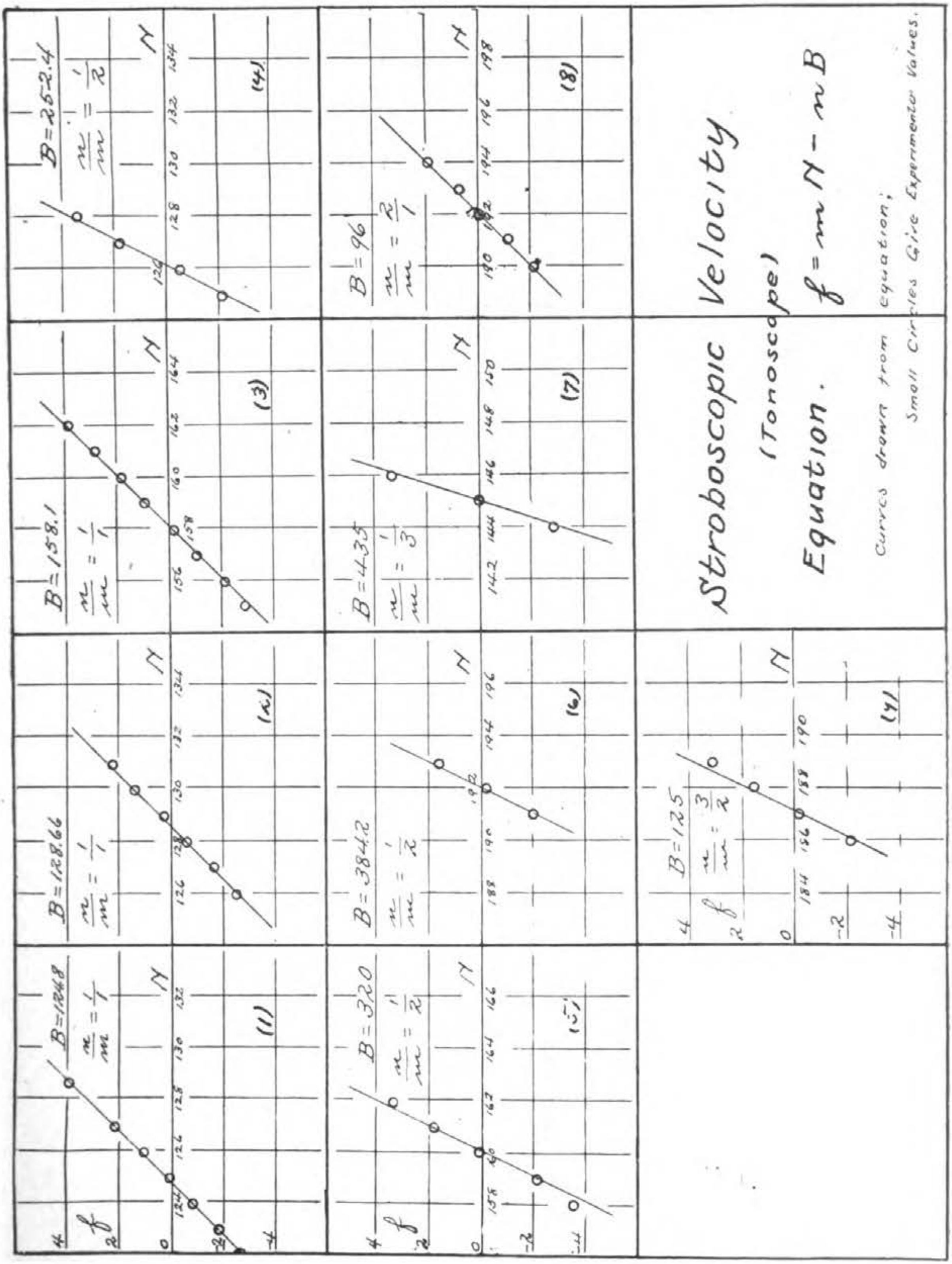

Stroboscopic Velocity (Tonoscope) Equation.
f = m N − n B
Curves drawn from equation; Small Circles Give Experimental Values.
B = 252.4
B = 158.1
B = 128.66
B = 96
B = 43.35
B = 384.2
B = 320
B = 125
(1)
(2)
(3)
(4)
(6)
(7)
(8)
(9)

Fig. 3.

the equation and the experimental values is good in each of the nine cases. It will be noted that the slope changes with m alone. The data are assembled in Table I. How nearly the linear relation appears to hold is seen from the column of values of the constant, $(f+nB)/N$, which is equal to m the slope, and is derived from the experimental values. The extremely slight variation is regarded as entirely due to observational error, which increases with f.

CONCLUSION.

Secondary regions of stroboscopic response present during a reading on the tonoscope, particularly when a fork is used, are thus seen to be in accord with the demands of equation (1), or its special form (4), rather than due to harmonics. That is, a pure tone will produce secondary responses in addition to a primary response. By "primary response" is here meant the region of rows of dots in response containing the stationary, or nearly stationary row that is being read, which region has one of the values of n/m already mentioned for voice pitch readings on the tonoscope. However, there appears to be nothing to prevent a harmonic from producing its own primary and secondary regions of stroboscopic response, provided either that it has sufficient energy itself to actuate the manometric flame, or other device for changing the frequency of the sounded tone into luminous frequency, or that such device possesses on its part unlimited sensitiveness to sound vibrations. Mathematically, at least, the condition exists of a fundamental producing a primary (term restricted here to $n/m=1$) and an unlimited number of secondary stroboscopic responses, and each one of all its possible harmonics simultaneously doing the same thing.

In conclusion of this paper, thanks are due Dean C. E. Seashore, head of the Department of Psychology at the State University, for his kind permission to make this experimental test of the stroboscopic velocity equation with the tonoscope, and for use of forks belonging to that department.

TABLE I.

(f'=total number of simple images counted in t secs., by stop watch)

FORK (B)	N	f'	OBSERVER	t	f	f(av.)	$\frac{f+nI}{N}$
124.8	122	20	D	7.4	2.70	....	......
....	....	20	D	7.2	2.77	(—)2.73	1.0008
(1)	123	10	D	5.6	1.78	....	......
....	....	20	D	11.4	1.75	(—)1.76	1.0008
....	124	8	D	10.2	0.78	....	......
....	....	8	D	10.2	.78	(—)0.78	1.0000
....	125	....	D	Slow	motio	n up	......
....	126	10	D	9.0	1.11	....	......
....	....	10	D	8.6	1.16	....	......
....	....	10	D	8.8	1.13	1.13	0.9992
....	127	15	D	7.0	2.14	....	......
....	....	16	D	7.2	2.22	....	......
....	....	20	D	9.4	2.12	....	......
....	....	15	D	7.0	2.14	2.15	.9992
....	128	Motion	too rapi	d for	accur	ate count	......
128.66	125	30	D	10.2	2.94	Count	......
....	....	30	F	9.6	3.12	uncertain	......
(2)	....	31	D	10.8	2.87	....	......
....	....	30	F	10.0	3.00	(—)2.98 (?)	... ..
....	126	30	F	13.0	2.31	....	......
....	....	20	D	7.8	2.56	....	......
....	....	30	F	12.0	2.50	....	......
....	....	30	D	11.6	2.58	....	......
....	....	30	F	12.0	2.50	(—)2.49	1.0007
....	127	20	F	12.2	1.63	....	......
....	....	20	D	12.0	1.66	(—)1.64	1.0000
....	128	10	F	15.0	0.66	....	......
....	....	10	F	15.0	.66	....	......
....	....	10	D	15.0	.66	(—)0.66	1.0000
....	129	10	D	30.6	0.326	....	......
....	....	10	F	30.0	.333	0.33	1.0000
....	130	20	D	15.0	1.33	....	......
....	....	20	D	15.8	1.26	....	......
....	....	20	F	15.4	1.29	1.29	0.9992
....	131	30	D	13.4	2.24	....	......
....	....	30	F	13.5	2.22	2.23	.9992
....	132	30	D	11.8	2.54	Count	......
....	....	30	F	10.0	3.00	uncertain	......
....	....	30	D	12.2	2.46	....	......
....	....	30	F	10.6	2.83	2.71	......
158.1	155	15	D	5.6	2.67	....	......
....	....	17	D	5.6	3.03	....	......
(3)	....	16	D	5.4	2.96	....	......
....	....	15	D	5.0	3.00	(—)2.91	1.0012
....	156	10.5	D	5.4	1.94	....	......
....	....	12.5	D	5.8	2.15	....	......
....	....	10.0	D	4.8	2.08	....	......
....	....	10.0	D	4.6	2.17	(—)2.08	1.0000
....	157	5	D	4.6	1.08	....	......
....	....	5	D	4.6	1.08	....	......
....	....	6	D	6.0	1.00	(—)1.05	1.0000

TABLE I (Cont.)

Fork (B)	N	f'	Observer	t	f	f(av.)	$\frac{f+nB}{N}$
....	158	0.5	D	4.2	0.12	(—)0.12	1.0000
....	159	5	D	6.2	0.806	....	......
....	....	4	D	4.2	.952	....	......
....	....	4	D	4.0	1.000	0.92	1.0000
....	160	9	D	5.0	1.80	....	......
....	....	9	D	5.2	1.73	1.76	0.9987
....	161	10	D	3.6	2.77	....	......
....	....	10	D	3.4	2.94	....	......
....	....	15	D	5.4	2.77	....	.9993
....	....	15	D	5.4	2.77	2.81	......
....	162	16	D	4.6	3.47	....	......
....	....	17	D	4.2	4.04	....	......
....	....	17	D	4.2	4.04	3.85	.9993
252.4	125	19.5	D	8.6	2.26	....	......
....	....	30.0	F	13.4	2.25	(—)2.25	2.0016
(4)	126	10	D	24.0	0.416	....	......
....	....	10	F	23.0	.434	....	......
....	....	10	D	27.4	.365	....	......
....	....	10	F	23.0	.434	....	......
....	....	10	D	23.0	.434	....	......
....	....	10	F	21.5	.465	....	......
....	....	10	D	23.0	.434	....	......
....	....	10	F	23.0	.434	(—)0.427	2.0000
....	127	14	D	8.4	1.66	....	......
....	....	20	D	12.0	1.66	....	......
....	....	30	F	17.2	1.73	....	......
....	....	25	D	15.0	1.66	....	......
....	....	30	F	17.0	1.76	....	......
....	....	25	D	15.6	1.60	....	......
....	....	25	F	16.0	1.56	....	......
....	....	15	F	9.6	1.56	....	......
....	....	20	D	12.6	1.59	1.64	2.0000
....	128	30	D	10.8	2.77	....	......
....	....	30	F	8.5	3.53	....	......
....	....	30	F	8.8	3.40	3.23	1.9968
320	157	10	F	2.4	4.16	Uncertain	......
....	....	10	F	2.2	4.54	(—)4.35	......
(5)	158	10	F	2.8	3.57	....	......
....	....	10	F	3.3	3.03	....	......
....	....	20	D	5.4	3.70	(—)3.50	2.0031
....	....	25	D	6.8	3.67	....	......
....	159	10	F	4.8	2.08	....	......
....	....	10	F	4.9	2.04	....	......
....	....	10	F	5.0	2.00	....	......
....	....	20	D	9.8	2.04	....	......
....	....	20	D	9.6	2.08	....	......
....	....	20	D	9.8	2.04	(—)2.05	2.0000
....	160	0	F	....	0.000	....	......
....	....	1	D	7.4	.135	0.07	2.0006
....	161	10	F	5.5	1.81	....	......
....	....	15	D	8.2	1.82	....	......
....	....	15	D	7.8	1.91	1.85	1.9987
....	162	10	F	3.0	3.33	....	......

TABLE I (Cont.)

FORK (B)	N	f'	OBSERVER	t	f	f(av.)	f+nB / N
....	....	10	F	3.0	3.33	....	......
....	....	10	F	2.8	3.57	3.41	1.9962
384.2	191	8	D	4.0	2.00	....	......
....	....	7	D	3.6	1.94	....	......
(6)	....	8	D	3.6	2.22	....	......
....	....	6	D	3.2	1.87	(—)2.01	2.0010
....	192	1	D	4.0	0.25	(—)0.25	2.0000
....	193	10	D	6.6	1.51	....	......
....	....	7	D	4.2	1.66	....	......
....	....	5	D	3.2	1.56	....	......
....	....	6	D	3.6	1.66	1.60	1.9989
435	143	10	....	2.8	3.57	Uncertain	......
....	....	10	....	3.0	3.33	....	......
(7)	....	10	....	2.8	3.57	(—)3.49	......
....	144	12	D	4.0	3.00	....	......
....	....	13	D	4.4	2.95	....	......
....	....	8	D	3.2	2.50	(—)2.82	3.0013
....	145	0	....	....	0.00	0.00	3.0000
....	146	10	D	3.6	2.77	....	......
....	....	15	D	5.0	3.00	....	......
....	....	11	....	3.2	3.43	....	......
....	....	10	F	3.1	3.22	....	......
....	....	10	F	3.2	3.12	....	......
....	....	10	F	3.2	3.12	3.27	......
96	190	10	D	4.4	2.27	....	......
....	....	12	D	5.2	2.30	....	......
(8)	....	8.5	D	4.4	1.93	....	......
....	....	8	D	3.8	2.10	(—)2.15	0.9994
....	191	6	D	4.8	1.25	....	......
....	....	8	D	6.6	1.21	....	......
....	....	5	D	4.6	1.09	(—)1.18	.9989
....	192	0	D	...	0.00	0.00	1.0000
....	193	4	....	5.0	0.80	....	......
....	....	5	....	7.0	.71	0.75	.9984
....	194	10	....	5.2	1.92	....	......
....	....	10	....	5.6	1.78	1.85	.9989
125	186	10	D	4.6	2.17	....	......
....	....	9	D	4.0	2.25	....	......
(9)	....	10.5	D	4.8	2.19	....	......
....	....	10	D	4.4	2.27	(—)2.22	2.0043
....	187	1	D	4.0	0.25	....	......
....	......	1	D	4.6	.22	(—)0.23	2.0042
....	188	6	D	4.0	1.50	....	......
....	....	5	D	4.0	1.25	....	......
....	....	7	D	4.2	1.66	....	......
....	....	6	D	3.6	1.66	....	......
....	....	5	D	3.6	1.38	1.49	2.0026
....	189	10	D	3.4	2.94	....	......
....	....	10	D	3.4	2.94	....	......
....	....	10	D	3.0	3.33	3.07	2.0005

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