

Chrysalis I
Tuning Table and String Tension Calculations
for
Song of Myself: Intoned Poems of Walt Whitman
Instruments and Music by Cris Forster

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Page 1 shows the tuning — based on the concept of *melodic modulation* — on the left side of Chrysalis I.

Page 2 gives the tension of the strings on the left side of Chrysalis I: Strings 1–41, at 1,522 lbf.

Page 3 gives the tension of the strings on the left side of Chrysalis I: Strings 42–82, at 1,527 lbf.

The total force on the left side equals: $1,522 \text{ lbf} + 1,527 \text{ lbf} = 3,049 \text{ lbf}$.

Page 4 shows the tuning — based on the concept of *melodic modulation* — on the right side of Chrysalis I.

Page 5 gives the tension of the strings on the right side of Chrysalis I: Strings 1–41, at 1,834 lbf.

Page 6 gives the tension of the strings on the right side of Chrysalis I: Strings 42–82, at 1,730 lbf.

The total force on the right side equals: $1,834 \text{ lbf} + 1,730 \text{ lbf} = 3,564 \text{ lbf}$.

The grand total force of Chrysalis I equals $3,049 \text{ lbf} + 3,564 \text{ lbf} = 6,613 \text{ lbf}$, which is approximately equivalent to the average weight of two mid-size sedans at 3,300 lbf each.

* * *

Here are the definitions and descriptions of the symbols in the following four Mathcad worksheets.

x defines a range variable: either 1–41 (as in Strings 1–41), or 42–82 (as in Strings 42–82).

T is the tension of strings, in lbf.

To calculate string tension, I used Equation 2.10 from my book *Musical Mathematics: On the Art and Science of Acoustic Instruments*, Chronicle Books, San Francisco, California, 2010.

B3 := 247 cps, C4 := 262 cps, etc. are the standard note names and frequencies of 12-tone equal temperament rounded to zero decimal places. When a lowercase ‘s’ follows the name of a note it defines the ‘sharp’ version of that note. So, As4 refers to A $\sharp$ ₄, which vibrates at 466 cps.

c is the decimal ratio of one cent: 1.00057779. Since I tuned Chrysalis I in just intonation, I used this constant to raise or lower the standard frequencies of 12-TET by the calculated cent values. I tuned all frequency ratios to the following standard fundamental frequencies: C₃–130.8 cps, C₄–261.6 cps, and C₅–523.3 cps. Also, I calculated all cent values with frequencies rounded to one decimal place. For example, on the left side, Strings 1–3 sound frequency ratio $\frac{13}{9}$ above C₄. Since this ratio vibrates at $261.6 \text{ cps} \times \frac{13}{9} = 377.9 \text{ cps}$, it requires raising F $\sharp$ ₄ by 37 ¢.

With the exception of Strings 18–21 on the left side, and Strings 29–31 on the right side, F indicates a just intoned or non-standard frequency.

L is the length of strings, in inches.

D is the diameter of strings, in inches.

ρ is the mass density of the stringing material, in mica/in³.

For steel: $0.283 \text{ lbf/in}^3 / (386.09 \text{ in/s}^2) = .00073299 \text{ mica/in}^3$. For a definition of the mica mass unit, please see *M.M.*, Chapter 1.

%BrSt is the percentage of the break strength of a steel string. (See *MM.* p. 35.)

Tnsl is the tensile strength of the stringing material. For steel: 350,000 lbf. (See *MM.* p. 35.)

Σ is the sum of the calculated tensions of a given worksheet.

Table 12.1

CHRYSLIS I

Left Side Tuning

Strings: Ratios

1-3:	1/1	(<u>13/9</u>)	377.9 cps	←	"There is that in me....."	<u>Poem 50</u>
4-6:	9/8					
7-9:	6/5					
10-13:	16/13.....	16/9				
	14-17:	20/11				
18-21:	4/1	(<u>4/1</u>)	C ₅ at 523.3 cps	←	"I wish I could translate....."	<u>Poem 6</u>
22-25:	10/9					
26-29:	14/11.....	56/33				
30-33:	3/2	1/1	(<u>3/2</u>)	785.0 cps	←	"I also say....." <u>Poem 18</u>
	34-36:	28/27				
	37-39:	6/5.....	54/35			
	40-43:	5/4	45/28			
	44-48:	6/5	54/35			
		49-51:	7/5			
		52-54:	13/11			
		55-58:	35/33			
<u>Poem 38</u>	"I troop forth....."	→	59-61:	1/1	(<u>7/6</u>)	610.5 cps
			62-64:	20/13		
			65-67:	32/21		
			68-70:	11/9		
			71-74:	7/6		
			75-78:	12/11		
			79-82:	21/20		
<u>Poem 6</u>	"It may be you transpire....."	→	1-3:	1/1	(<u>13/9</u>)	377.9 cps

C.Forster_Chrysalis-I_LS_Tension_1-41.xmcd

$x := 1 \dots 41$ $D := 0.016$ $\rho := 0.00073299$ $c := \frac{1200}{\sqrt{2}}$ $TnsI := 350000$ $B3 := 247$

$C4 := 262$ $Cs4 := 277$ $D4 := 294$ $Ds4 := 311$ $E4 := 330$ $F4 := 349$ $Fs4 := 370$ $G4 := 392$ $Gs4 := 415$

$A4 := 440$ $As4 := 466$ $B4 := 494$

$C5 := 523$ $Cs5 := 554$ $D5 := 587$ $Ds5 := 622$ $E5 := 659$ $F5 := 698$ $Fs5 := 740$ $G5 := 784$ $Gs5 := 830$

$A5 := 880$ $As5 := 932$ $B5 := 988$

$N_x := \frac{L_x}{L_x} :=$ NE_x $F_x :=$

$T_x := (F_x)^2 \cdot (L_x)^2 \cdot D^2 \cdot \pi \cdot \rho$ $T_x =$ $\%BrSt_x := 100 \cdot T_x \div \frac{\pi \cdot D^2 \cdot TnsI}{4}$ $\%BrSt_x =$

1	19.563	1 [#]	Fs4-c ³⁷		1	32	1	46
2	19.500	2 [#]	Fs4-c ³⁷		2	32	2	46
3	19.438	3 [#]	Fs4-c ³⁷	Stringing and Tuning for:	3	32	3	45
4	19.375	4 [#]	Gs4-c ⁴⁰	Song of Myself:	4	40	4	57
5	19.313	5 [#]	Gs4-c ⁴⁰	Intoned Poems of Walt Whitman	5	40	5	56
6	19.125	6 [#]	Gs4-c ⁴⁰	by Cris Forster	6	39	6	55
7	19.000	7 [#]	A4-c ⁵²		7	44	7	62
8	18.813	8 [#]	A4-c ⁵²		8	43	8	61
9	18.625	9 [#]	A4-c ⁵²		9	42	9	60
10	18.438	10 [#]	As4-c ⁴		10	43	10	62
11	18.125	11 [#]	As4-c ⁴		11	42	11	59
12	17.875	12 [#]	As4-c ⁴		12	41	12	58
13	17.563	13 [#]	As4-c ⁴		13	39	13	56
14	17.250	14 [#]	As4-c ³⁵		14	40	14	56
15	16.938	15 [#]	As4-c ³⁵	Left Side	15	38	15	54
16	16.563	16 [#]	As4-c ³⁵	Total Tension of	16	37	16	52
17	16.250	17 [#]	As4-c ³⁵	Strings 1-41:	17	35	17	50
18	15.875	18 [#]	C5-c ⁰	1522 lbf.	18	41	18	58
19	15.500	19 [#]	C5-c ⁰	$\sum_x T_x = 1522$	19	39	19	55
20	15.000	20 [#]	C5-c ⁰		20	36	20	52
21	14.688	21 [#]	C5-c ⁰		21	35	21	49
22	14.313	22 [#]	D5-c ¹⁷		22	41	22	58
23	13.813	23 [#]	D5-c ¹⁷		23	38	23	54
24	13.313	24 [#]	D5-c ¹⁷		24	35	24	50
25	12.875	25 [#]	D5-c ¹⁷		25	33	25	47
26	12.500	26 [#]	E5-c ¹⁸		26	41	26	58
27	12.000	27 [#]	E5-c ¹⁸		27	38	27	53
28	11.625	28 [#]	E5-c ¹⁸		28	35	28	50
29	11.125	29 [#]	E5-c ¹⁸		29	32	29	46
30	10.750	30 [#]	G5-c ²		30	42	30	60
31	10.313	31 [#]	G5-c ²		31	39	31	55
32	9.938	32 [#]	G5-c ²		32	36	32	51
33	9.688	33 [#]	G5-c ²		33	34	33	48
34	9.125	34 [#]	Gs5-c ³⁵		34	32	34	46
35	8.938	35 [#]	Gs5-c ³⁵		35	31	35	44
36	8.688	36 [#]	Gs5-c ³⁵		36	29	36	42
37	8.438	37 [#]	As5-c ¹⁸		37	37	37	53
38	8.313	38 [#]	As5-c ¹⁸		38	36	38	51
39	8.000	39 [#]	As5-c ¹⁸		39	33	39	48
40	7.875	40 [#]	B5-c ¹²		40	35	40	50
41	7.813	41 [#]	B5-c ¹²		41	35	41	49

C.Forster_Chrysalis-I_LS_Tension_42-82.xmcd $x := 42..82$ $D := 0.016$ $\rho := 0.00073299$ $c := \sqrt[1200]{2}$ $TnsI := 350000$ $B3 := 247$
 $C4 := 262$ $Cs4 := 277$ $D4 := 294$ $Ds4 := 311$ $E4 := 330$ $F4 := 349$ $Fs4 := 370$ $G4 := 392$ $Gs4 := 415$ **A4 := 440** $As4 := 466$ $B4 := 494$
 $C5 := 523$ $Cs5 := 554$ $D5 := 587$ $Ds5 := 622$ $E5 := 659$ $F5 := 698$ $Fs5 := 740$ $G5 := 784$ $Gs5 := 830$ **A5 := 880** $As5 := 932$ $B5 := 988$

$N_x := L_x :=$ NE_x $F_x :=$ $T_x := (F_x)^2 \cdot (L_x)^2 \cdot D^2 \cdot \pi \cdot \rho$ $T_x =$ $\%BrSt_x := 100 \cdot T_x \div \frac{\pi \cdot D^2 \cdot TnsI}{4}$ $\%BrSt_x =$

42	7.750
43	7.813
44	7.875
45	8.000
46	8.313
47	8.438
48	8.688
49	8.938
50	9.125
51	9.688
52	9.938
53	10.313
54	10.750
55	11.125
56	11.625
57	12.000
58	12.500
59	12.875
60	13.313
61	13.813
62	14.313
63	14.688
64	15.000
65	15.500
66	15.875
67	16.250
68	16.563
69	16.938
70	17.250
71	17.563
72	17.875
73	18.125
74	18.438
75	18.625
76	18.813
77	19.000
78	19.125
79	19.313
80	19.375
81	19.438
82	19.500

42	B5 ÷ c ¹²
43	B5 ÷ c ¹²
44	As5 c ¹⁸
45	As5 c ¹⁸
46	As5 c ¹⁸
47	As5 c ¹⁸
48	As5 c ¹⁸
49	Gs5 c ⁵⁰
50	Gs5 c ⁵⁰
51	Gs5 c ⁵⁰
52	F5 c ⁵⁶
53	F5 c ⁵⁶
54	F5 c ⁵⁶
55	E5 ÷ c ³¹
56	E5 ÷ c ³¹
57	E5 ÷ c ³¹
58	E5 ÷ c ³¹
59	Ds5 ÷ c ³³
60	Ds5 ÷ c ³³
61	Ds5 ÷ c ³³
62	D5 ÷ c ¹⁷
63	D5 ÷ c ¹⁷
64	D5 ÷ c ¹⁷
65	D5 ÷ c ³⁴
66	D5 ÷ c ³⁴
67	D5 ÷ c ³⁴
68	As4 ÷ c ¹⁶
69	As4 ÷ c ¹⁶
70	As4 ÷ c ¹⁶
71	A4 c ³
72	A4 c ³
73	A4 c ³
74	A4 c ³
75	Gs4 ÷ c ¹³
76	Gs4 ÷ c ¹³
77	Gs4 ÷ c ¹³
78	Gs4 ÷ c ¹³
79	G4 c ²¹
80	G4 c ²¹
81	G4 c ²¹
82	G4 c ²¹

Stringing and Tuning for:
Song of Myself:
Intoned Poems of Walt Whitman
by Cris Forster

Left Side

Total Tension of
Strings 42–82:
1527 lbf.

 $\sum_x T_x = 1527$

	42
42	34
43	35
44	32
45	33
46	36
47	37
48	39
49	34
50	36
51	40
52	30
53	33
54	35
55	31
56	33
57	36
58	39
59	36
60	39
61	42
62	41
63	43
64	45
65	47
66	49
67	52
68	34
69	36
70	37
71	35
72	37
73	38
74	39
75	35
76	35
77	36
78	37
79	35
80	35
81	35
82	35

Left Side

Percentages of
Break Strengths
of Strings 42–82.

	42
42	48
43	49
44	46
45	48
46	51
47	53
48	56
49	49
50	51
51	57
52	43
53	46
54	50
55	43
56	47
57	51
58	55
59	52
60	55
61	60
62	58
63	61
64	64
65	67
66	70
67	73
68	49
69	51
70	53
71	50
72	52
73	53
74	55
75	49
76	50
77	51
78	52
79	49
80	50
81	50
82	50

Table 12.1

(continued)

CHRYSA LIS I

Right Side Tuning

Strings: Ratios

1-3:	1/1	(<u>15/8</u>)	245.3 cps	←	"Something it swings on....."	<u>Poem 50</u>
4-6:	7/5					
7-8:	10/7					
9-10:	19/13					
11-13:	3/2					
14-16:	20/13					
17-18:	11/7					
19-20:	5/3					
21-22:	26/15					
23-24:	16/9					
25-26:	25/13					
27-28:	2/1	(<u>15/8</u>)	490.5 cps			
29-31:	16/15.....	1/1	(<u>4/1</u>)	C ₅ at 523.3 cps	←	"I beat and pound....." <u>Poem 18</u>
32-36:	8/5	3/2				
37-41:	5/3	25/16				
42-45:	10/7.....	3/2		←	"A child said....."	<u>Poem 6</u>
46-49:	260/189	13/9				
50-53:	320/273	16/13				
54-57:	7/6					
58-62:	1/1	(<u>40/21</u>)	498.3 cps			
63-65:	32/21					
66-68:	3/2					
69-71:	27/20					
72-73:	7/5					
74-76:	40/27					
77-79:	5/4					
80-82:	6/5					
<u>Poem 38</u>	"Enough....."	→	1-3:	1/1	(<u>15/8</u>)	245.3 cps

C.Forster_Chrysalis-I_RS_Tension_1-41.xmcd

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1	19.563	1 [#]	B3 ÷ c ¹¹		1		1
2	19.500	2 [#]	B3 ÷ c ¹¹		1	26	1
3	19.438	3 [#]	B3 ÷ c ¹¹	Stringing and Tuning for:	2	26	1
4	19.375	4 [#]	F4 ÷ c ²⁹	Song of Myself:	3	25	19
5	19.313	5 [#]	F4 ÷ c ²⁹	Intoned Poems of Walt Whitman	4	49	19
6	19.125	6 [#]	F4 ÷ c ²⁹	by Cris Forster	5	49	37
7	19.000	7 [#]	F4 · c ⁶		6	48	37
8	18.813	8 [#]	F4 · c ⁶		7	49	36
9	18.625	9 [#]	F4 · c ⁴⁵		8	48	37
10	18.438	10 [#]	F4 · c ⁴⁵		9	50	36
11	18.125	11 [#]	Fs4 ÷ c ¹⁰		10	49	37
12	17.875	12 [#]	Fs4 ÷ c ¹⁰		11	50	37
13	17.563	13 [#]	Fs4 ÷ c ¹⁰		12	48	36
14	17.250	14 [#]	Fs4 · c ³⁴	Right Side	13	47	35
15	16.938	15 [#]	Fs4 · c ³⁴	Total Tension of	14	47	35
16	16.563	16 [#]	Fs4 · c ³⁴	Strings 1–41:	15	46	34
17	16.250	17 [#]	G4 ÷ c ²⁹	1834 lbf.	16	44	33
18	15.875	18 [#]	G4 ÷ c ²⁹	$\sum_x T_x = 1834$	17	44	33
19	15.500	19 [#]	Gs4 ÷ c ²⁷		18	42	31
20	15.000	20 [#]	Gs4 ÷ c ²⁷		19	45	34
21	14.688	21 [#]	Gs4 · c ⁴⁰		20	42	31
22	14.313	22 [#]	Gs4 · c ⁴⁰		21	43	33
23	13.813	23 [#]	A4 ÷ c ¹⁶		22	41	31
24	13.313	24 [#]	A4 ÷ c ¹⁶		23	40	30
25	12.875	25 [#]	As4 · c ²⁰		24	38	28
26	12.500	26 [#]	As4 · c ²⁰		25	41	31
27	12.000	27 [#]	B4 ÷ c ¹²		26	39	29
28	11.625	28 [#]	B4 ÷ c ¹²		27	39	29
29	11.125	29 [#]	C5 · c ⁰		28	36	27
30	10.750	30 [#]	C5 · c ⁰		29	38	28
31	10.313	31 [#]	C5 · c ⁰		30	35	26
32	9.938	32 [#]	G5 · c ²		31	32	24
33	9.688	33 [#]	G5 · c ²		32	68	51
34	9.125	34 [#]	G5 · c ²		33	64	48
35	8.938	35 [#]	G5 · c ²		34	57	43
36	8.688	36 [#]	G5 · c ²		35	55	41
37	8.438	37 [#]	Gs5 ÷ c ²⁷		36	52	39
38	8.313	38 [#]	Gs5 ÷ c ²⁷		37	53	40
39	8.000	39 [#]	Gs5 ÷ c ²⁷		38	51	39
40	7.875	40 [#]	Gs5 ÷ c ²⁷		39	48	36
41	7.813	41 [#]	Gs5 ÷ c ²⁷		40	46	35
					41	45	34

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 $C5 := 523$ $Cs5 := 554$ $D5 := 587$ $Ds5 := 622$ $E5 := 659$ $F5 := 698$ $Fs5 := 740$ $G5 := 784$ $Gs5 := 830$ **A5 := 880** $As5 := 932$ $B5 := 988$

$N_x := \frac{L_x}{L_x} :=$ NE_x $F_x :=$ $T_x := (F_x)^2 \cdot (L_x)^2 \cdot D^2 \cdot \pi \cdot \rho$ $T_x =$ $\%BrSt_x := 100 \cdot T_x \div \frac{\pi \cdot D^2 \cdot TnsI}{4}$ $\%BrSt_x =$

42	7.750
43	7.813
44	7.875
45	8.000
46	8.313
47	8.438
48	8.688
49	8.938
50	9.125
51	9.688
52	9.938
53	10.313
54	10.750
55	11.125
56	11.625
57	12.000
58	12.500
59	12.875
60	13.313
61	13.813
62	14.313
63	14.688
64	15.000
65	15.500
66	15.875
67	16.250
68	16.563
69	16.938
70	17.250
71	17.563
72	17.875
73	18.125
74	18.438
75	18.625
76	18.313
77	19.000
78	19.125
79	19.313
80	19.375
81	19.438
82	19.500

42	Fs5 c ¹⁸
43	Fs5 c ¹⁸
44	Fs5 c ¹⁸
45	Fs5 c ¹⁸
46	F5 c ⁵²
47	F5 c ⁵²
48	F5 c ⁵²
49	F5 c ⁵²
50	Ds5 ÷ c ²⁵
51	Ds5 ÷ c ²⁵
52	Ds5 ÷ c ²⁵
53	Ds5 ÷ c ²⁵
54	D5 ÷ c ¹⁷
55	D5 ÷ c ¹⁷
56	D5 ÷ c ¹⁷
57	D5 ÷ c ¹⁷
58	B4 c ¹⁵
59	B4 c ¹⁵
60	B4 c ¹⁵
61	B4 c ¹⁵
62	B4 c ¹⁶
63	Fs4 c ⁴⁴
64	Fs4 c ⁴⁴
65	Fs4 c ⁴⁴
66	Fs4 c ¹⁷
67	Fs4 c ¹⁷
68	Fs4 c ¹⁷
69	E4 c ⁸
70	E4 c ⁸
71	E4 c ⁸
72	F4 ÷ c ²⁹
73	F4 ÷ c ²⁹
74	Fs4 ÷ c ³²
75	Fs4 ÷ c ³²
76	Fs4 ÷ c ³²
77	Ds4 ÷ c ²⁵
78	Ds4 ÷ c ²⁵
79	Ds4 ÷ c ²⁵
80	D4 c ⁴
81	D4 c ⁴
82	D4 c ⁴

Stringing and Tuning for:
Song of Myself:
Intoned Poems of Walt Whitman
 by Cris Forster

Right Side
 Total Tension of
 Strings 42–82:
 1730 lbf.
 $\sum_x T_x = 1730$

	42
42	37
43	38
44	39
45	40
46	40
47	41
48	44
49	46
50	35
51	39
52	41
53	45
54	44
55	47
56	51
57	54
58	43
59	46
60	49
61	53
62	57
63	35
64	36
65	39
66	39
67	41
68	43
69	35
70	36
71	38
72	42
73	43
74	50
75	51
76	49
77	38
78	38
79	39
80	36
81	37
82	37

Right Side
 Percentages of
 Break Strengths
 of Strings 42–82.

	42
42	28
43	29
44	29
45	30
46	30
47	31
48	33
49	35
50	26
51	30
52	31
53	33
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