

De Motu Chordae

Of the Motion of the String · weight, tension, the swinging plumb and the measure of time

1. TRES CAUSAE ACUMINIS

The three causes of pitch: length, pull and thickness

Halve the string and the voice doubles. But hang twice the weight and the voice does not double; it rises by a tritone only, so that four times the weight is needed for the octave. Therefore the pull enters not simply but by its root. Likewise the thick string is slow and the thin is quick, and the same root governs.

$$n = 1 / 2L \cdot \sqrt{(T / \mu)}$$

L the sounding length, *T* the pull in pounds, μ the weight of one length of the cord

Coniectura: I write the rule as a proportion because I can weigh the cord and count its returns against the plumb, though I cannot count so fast as it moves. Where the eye fails, put two motions side by side and compare them; this is the whole method.

2. PERPENDICULUM

The plumb-line as master of tempo

A weight upon a cord keeps its own time and will not be hurried by the width of its swing. Lengthen the cord fourfold and the swing is twice as slow. Hence a singer needs no drummer: a thread and a stone will hold a company together, and the length of the thread is the name of the measure.

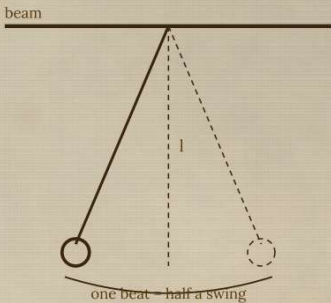


Fig. 1. The plumb upon its beam, drawn at the extremes of one swing. The arc beneath marks the two positions between which a single beat is counted.

$$\tau = \pi \sqrt{(l / g)}$$

one beat, in seconds, of a plumb of length *l* · *g* the fall, 9806 mm in the second squared

A thread of 994 millimetres beats sixty to the minute, which is the pulse of a resting man. All other measures are had by the square: to double the speed, quarter the thread.

3. DE PULSU

The pulse as the first clock, and its dishonesty

Before the thread I used my own wrist, as the physicians do, and found it a liar: it hurries when the music hurries, so that a man beating time by his pulse plays every allegro faster than the last. I have counted it in four men at rest and after climbing the stair.

HOMO	QUIES	POST	ERROR
Painter, 46 yrs	64	96	+50%
Boy, 12 yrs	82	124	+51%
Smith, 30 yrs	58	84	+45%
Old man, 71 yrs	70	98	+40%

Coniectura: therefore the tempo of a piece is not a quantity in the music but a quantity in the body, and every performance is a portrait of the performer's heart. The thread does not care who holds it — which is its whole virtue and the reason no musician will use it.

4. DE PERCUSSIONE

Of the blow, and how long a struck string keeps its voice

A string struck loses its sound not at once but by degrees, and the degrees are not equal: it falls fast at first and then slowly, so that the last quarter of the sound takes half of the time. I have counted the beats of the thread until silence, in a gut and in a wire, over a box and off it.

CHORDA	SONUS	ICTUS
Gut, on the box	3.5 s	3½
Gut, off the box	1.2	1¼
Wire, on the box	11.0	11
Wire, off the box	2.8	3

The box lengthens the wire's voice fourfold and the gut's threefold, yet the box has no strings and cannot sound of itself. *Coniectura:* the belly is a borrower. It takes the motion of the string, which is small and quick, and spends it upon a great deal of air — and the string, being robbed, dies sooner than it would in the naked air. Loudness is therefore bought with duration, and no maker has ever been given both.

5. TABULA TEMPORUM

Table of tempi, with the thread that governs each

MOTUS	ICTUS	FILUM	BRACCIA
Gravis <i>grave</i>	48	1553	2.66
Tardus <i>adagio</i>	56	1141	1.96
Aequus <i>andante</i>	60	994	1.71
Modestus <i>moderato</i>	72	690	1.18
Alacer <i>allegretto</i>	90	442	0.76
Laetus <i>allegro</i>	120	249	0.43
Citus <i>vivace</i>	144	173	0.30
Praeceptus <i>presto</i>	168	127	0.22

ictus are beats to the minute; *filum* the length of thread in millimetres. Note that the hundred and twenty beats between *grave* and *presto* are bought with twelve times the thread — the ear divides evenly what the hand must divide by squares.

6. DE PONDERE CHORDAE

Trial of seven weights upon one gut of 1200 mm

PONDUS	RATIO SONI	INTERVALLUM
1	1.000	unison
2	1.414	tritone, near
2¼	1.500	fifth, exact
4	2.000	octave
6¼	2.500	octave + third
9	3.000	octave + fifth
16	4.000	double octave

Here is the whole secret in one column: the consonances of the weights are the squares of the consonances of the lengths. Nine parts of weight give what three parts of length give. *Coniectura:* nature keeps two books and settles them with a root.

Beware also that the thick gut, being stiff, will not obey the rule at the extremes, and sounds sharper than the number promises. The maker corrects this at the bridge; the calculator cannot correct it at all. *Every instrument is a place where the number is politely disobeyed.*

7. DE CHORDIS INSTRUENDIS

Stringing a lute of six courses, that all may pull alike

If every course is of one thickness, the bass must be slack and the treble near breaking, and the belly is pulled crooked. Therefore let the pull be equal in all and the thickness be given by the note: the gut for the low course as much thicker as its voice is lower.

CHORDA	VOX	CRASSITUDO	TRACTUS
Cantus	g'	0.42 mm	3.2 kg
Secunda	d'	0.56	3.2
Tertia	a	0.75	3.2
Quarta	f	0.94	3.1
Quinta	c	1.26	3.1
Bassus	G	1.68	3.0

Six courses at three kilogrammes each is eighteen upon the bridge, and the belly of a lute is two millimetres of spruce. It holds because the bars beneath it are set as the ribs of a boat are set. *Coniectura:* the instrument is a vessel that carries a load of number instead of grain, and founders in the same manner — slowly, at the joints, and always in winter.

8. DE AERE ET HUMORE

Of weather, which untunes everything

The gut drinks the damp and grows fat and slack; the wire does not, but the wood beneath it swells and lifts the bridge. Hence in a wet week the lute falls and the harpsichord rises, and the two cannot be played together after Tuesday. I have measured a single course each morning for a fortnight against a wire that I keep in oil.

DIES	HUMOR	MUTATIO
Serenus <i>dry</i>	40%	—
Nubilus	62	−12 partes
Pluvius	81	−31
Post pluviam	70	−22
Ventus siccus	35	+9

Thirty-one parts is a third of a semitone: audible to a child, unbearable to a singer, and invisible to the man who built the instrument in a dry workshop in June. *Coniectura:* an instrument is not an object but an agreement between wood, gut and weather, renewed every morning. This is why players are superstitious and makers are not.

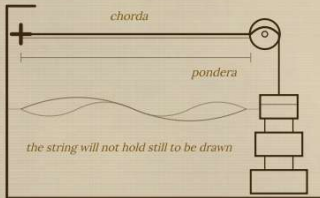


Fig. 2. The gut led over a brass wheel, that the weight may pull true; three weights of one, four and nine parts.

AD MARGINEM

In the margin, beside a sketch of a wheel

Time is a weight falling. Beneath it, in another ink: and music is the only art that spends it honestly.

DE FISTULA AQUAE

A water clock for the choir

A vessel pierced at the foot empties not evenly, for the head of water falls with the level. Keep the head constant by a float and the drip becomes a beat; let the drops strike a plate of copper and the beat becomes audible. Twelve drops to the breve. *Coniectura:* with a wheel and a screw the same drip may turn a page.

PONDERA ET VOCES

Weight hung, and the voice it draws from one string

LIBRAE	VOX	RATIO
1	the ground	1:1
2	fifth above	3:2 †
4	octave	2:1
6	twelfth	3:1
9	fifteenth	4:1
16	nineteenth	6:1

Four times the weight, twice the voice: the sound goes as the root of the pull, not as the pull. I proved it seven times and it did not once lie.

DE FILO PENDULO

Thread length against beats in one Ave Maria

FILUM	ICTUS	RATIO
1 braccio	60	1:1
½	85	√2
¼	120	2:1
2 braccia	42	1:√2
4	30	1:2

The thread keeps better time than any man's pulse, and keeps it whether the weight be lead or wax. Length alone governs. Herein lies a clock without a wheel.

CHORDAE PROBATAE

Strings tried under the same eight pounds

CHORDA	CRASSITUDO	VOX
Gut, thin	½ pt	fifth up
Gut, common	1 pt	ground
Gut, thick	2 pt	fifth down
Wire, brass	1 pt	fourth up

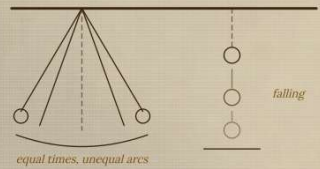


Fig. 3. At the left, four swings of unlike width completed in one time; at the right, a body released three times and drawn where it stood at each beat.

«Nothing sounds that is not first moved, and nothing is moved that is not first pushed.»