



JOHN TARTAGLIA
WAVE FUNCTIONS

for Violin, Viola, and Cello




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Premiered December 1, 1996 by Ensemble Capriccio:
Chouhei Min, violin; Korey Konkol, viola; and Mina Fischer, cello

c. 22 minutes

- I. *The Dancing Wu-Li*
- II. *Bell's Theorem*
- III. *Schrödinger's Cat*
- IV. *"Surely, Mr. Feynman... (in memoriam)"*

PROGRAM NOTE:

John Tartaglia's string trio, *Wave Functions*, is a wonderful contemporary example of the connection that has long existed between the weird science of quantum mechanics and the harmonious field of music. The sound waves that make music possible are subject to many of the same mathematical rules as the quantum wave functions that describe the activity of electrons and photons. But John Tartaglia's trio goes far beyond formal similarities to demonstrate that absolute music provides a genuinely appropriate language for expressing the abstract ideas of modern physics.

In the trio's first movement, *The Dancing Wu-Li*, a dark ominous opening warns us, as it were, of the strange unfamiliar world we are entering, where atoms lurk in a nowhere realm of mere possibility until provoked into physical existence by the act of an observer. *Wu-li* comes from the Chinese word for physics, and means patterns of organic change, something nonsensical, or enlightenment—apt descriptions indeed for the chaotic micro world of quantum particles. The movement continues with a kind of dialogue between the void and potentiality, suggesting the unstable circumstances in which particles emerge from nowhere, collide, and then vanish. A waltz appears in which an ordered phrase of notes seems to stop in its tracks, hesitate and retrace its steps, as if reversing itself in time like an anti-electron dancing into the past, far from its electron partner. We can only accept the dance and join in.

The title of the second movement, *Bell's Theorem*, refers to the shocking proof by physicist John Bell that physical reality must be non-local. In other words, two electrons or photons can instantly communicate with and affect each other over great distances without ever exchanging physical signals. Bell's theorem was the death knell for Einstein's long-standing rejection of quantum theory on the grounds that it violates the "local-forces" law of cause and effect. In Tartaglia's somber opening phrases and throughout the movement, we hear the tolling of a bell that is both a musical pun on Bell's name and the mournful proclamation of the death of causality. A later rhythmic, syncopated passage evokes a kind of coordinated ballet, in which all the dancers hypnotically follow the same steps like synchronized marionettes—the perfect musical embodiment of non-local quantum "entanglement."

Schrödinger's Cat is the playful name given to a diabolical thought experiment, devised by Erwin Schrödinger, one of the founders of quantum mechanics, who eventually came to doubt his own theory. Schrödinger wanted to dramatize the ambiguity of certain quantum descriptions, in which a particle apparently can exist in two mutually contradictory states. A photon may be polarized in an upward and a downward direction at the same time, or a hypothetical colored particle can be both black and white. Schrödinger imagines a cat trapped inside a box containing a poison gas apparatus that is triggered by a radioactive mechanism with a 50-50 chance of firing in one hour. At the end of the hour, according to the laws of quantum mechanics, the state of the cat is "half dead and half alive." In the third movement, *Schrödinger's Cat*, Tartaglia treats us to a cat-and-mouse game with the Grim Reaper himself. On sliding strings, we hear the cat meowing in protest, and later even scratching on the box through a *ponticello* effect. There are frequent references to Chopin's death march. And in the end, we are caught suspended simultaneously between major and minor keys in imitation of the perplexing quantum combination of life and death.

The title of the fourth vignette, "*Surely, Mr. Feynman... (in memoriam)*", is taken from an autobiographical account of Richard Feynman, one of the illustrious twentieth century physicists who extended quantum mechanics to the complex realm of electromagnetic phenomena, for which he won the Nobel Prize in 1965. Feynman was an authentic iconoclast and eccentric, beloved by his colleagues and students alike for his brilliant physical insights, his down-to-earth style of teaching, and his simple and unassuming ways. In the final movement, Tartaglia has chosen to depart from the strange world of quantum mechanics, and instead to pay tribute in memoriam to one of its greatest proponents, practitioners and teachers. In this touching passage, we hear the solemn tones of the liturgical Hebrew prayer, *Kol Nidre*, traditionally associated with the memorial for the dead. Feynman had little use for religion, and rejected his own Judaism. And yet perhaps it is fitting to acknowledge the irony of a spiritual culture that helped to nurture such a secular view of the world. Or is it that humanity truly occupies a combined state of spirit and matter?

Program notes by Roger S. Jones,
University of Minnesota Morse Alumni Distinguished Teaching Professor of Physics
and author of *Physics as Metaphor* and *Physics for the Rest of Us*.

WAVE FUNCTIONS

(Four vignettes about the new [quantum] physics)

(for string trio)

John Tartaglia

I. The Dancing Wu-Li

Assai moderato
♩ = 60

Violin *misterioso* *pp*

Viola *p* *misterioso* *ponticello* *ord. solo* *mp*

Cello *pp* *p* *ord.*

A subito, poco più mosso

11

vn *cresc. molto* *f* *p*

va *cresc. molto* *f* *sfp* *pizz.* *3* *p* *arco* *p* *ponticello*

vc *cresc. molto* *f* *p* *mp*

WAVE FUNCTIONS - 2

vn 18
va
vc

mf sf mp
ord. mf sf mp
mf sf p

Detailed description: This system contains measures 18 through 23. The violin part (vn) features a melodic line with various dynamics including *mf*, *fsf*, and *mp*. The viola part (va) includes an *ord.* (ordine) marking and dynamics of *mf*, *sf*, and *mp*. The cello part (vc) has dynamics of *mf*, *sf*, and *p*. The music is written in a key with one flat and a 3/4 time signature.

vn 24
va
vc

veloce **B** a Tempo

f fp f

Detailed description: This system contains measures 24 through 28. Measure 24 is marked *veloce* and *f*. Measure 25 is marked *fp*. Measure 26 is marked *f* and **B** a Tempo. The time signature changes from 3/4 to 2/4 at measure 26. The violin part (vn) has dynamics of *f*, *fp*, and *f*. The viola part (va) has a dynamic of *f*. The cello part (vc) has a dynamic of *f*.

vn 29
va
vc

f f f
secco meno f
secco meno f

Detailed description: This system contains measures 29 through 33. The violin part (vn) has dynamics of *f*, *f*, and *f*. The viola part (va) has dynamics of *f*, *f*, and *f*, with a *secco* marking at measure 31 and a *meno f* dynamic at measure 32. The cello part (vc) has dynamics of *f*, *f*, and *f*, with *secco* markings at measures 31 and 32, and a *meno f* dynamic at measure 32. The time signature changes from 2/4 to 3/4 at measure 31.

WAVE FUNCTIONS - 3

35

vn

va

vc

calmando

Rall.

fp

mf

sf

mf

p

pizz.

poco sf

42

C *Meno mosso*

vn

va

vc

Allegretto ♩ = 84
assai ritmico

p

ponticello

mp

arco

mp

tr. C#

ppp

pp

ord. V

mp

molto

fsf

p

assai ritmico

ponticello

pp

ord.

mp

mp

mp

ppp

molto

fsf

p

assai ritmico

mp

50

vn

va

vc

mf

ord.

mf

fp

f

ff

ponticello V

mf

fp

f

ff

mf

fp

f

ff

WAVE FUNCTIONS - 4

57

vn *ponticello* *mf* *dim.* *p* *p* *mp* *f* *ord.*

va *mf* *p* *sf* *cresc.* *f*

vc *mf* *p* *sf* *cresc.* *f*

64

vn *dim.* *mp* *dim.* *p* *f* *fsf*

va *mf* *dim.* *mp* *p* *f* *fsf*

vc *mf* *p* *p* *f* *fsf*

D **E** *Meno mosso* ♩ = 63

gliss. *gliss.* *f sul do*

72 *ponticello* *ord.* *vla cad. - senza misura*

vn *fsf* *sf* *sf* *gliss.*

va *fsf* *sf* *sf* *mp* *cresc.* *f*

vc *f* *fsf* *f* *(pont.)*

* strike upper part of finger board with wood of bow - or try 'slapping' with hand- for best effect!

WAVE FUNCTIONS - 5

F a Tempo primo

77 (a Tempo)

vn *p* *f* *ff sostenuto* *fp*

va *p* *f* *ff sostenuto* *mp* *f*

vc *ord.* *p* *f* *ff sostenuto* *fp* *ponticello* *f*

85

vn *f* *mf* *f*

va *mf* *f*

vc *ord.* *mf* *f*

93 G Waltz (alla Bulesca) ♩ = 132-144

vn *mf* *cresc.* *ff* *pp* *p* *cresc.* *mf*

va *fp* *ff* *pp* *p* *mf*

vc *ff* *pp* *poco* *più f* *mf*

WAVE FUNCTIONS - 6

103

vn *sfp* *cresc.* *f*

va *mp* *pizz.* *arco* *mf* *f*

vc *pizz.* *p* *arco* *mf* *sf* *cresc.* *f*

3 3

113

vn *ponticello* *sfp* *ord.* *f*

va *ponticello* *sfp* *ord.* *p* *cresc.* *f* *mf* *f*

vc *ponticello* *sfp* *ord.* *p* *f*

ord.

122

vn *f* *fp* *cresc.* *f*

va *f* *fp* *cresc.* *f*

vc *f* *fp* *cresc.* *f*

WAVE FUNCTIONS - 7

131

vn *mf* *f* *dim.* *p* *mf*

va *mf* *f* *dim.* *p* *mf*

vc *mf* *f* *dim.* *p* *mf* *f*

H

142

vn *p*

va *mp* *cresc.* *p* *sf poco* *pp*

vc *p sub.* *mp* *p* *pp*

Più Lento ♩ = 80

152

vn *mf* *cresc.* *f* *mp*

va *mf* *cresc.* *f* *p*

vc *mf* *cresc.* *f* *p* *mf*

affrett. poco a poco...

Tempo del principio

ponti. ad lib.

No meter; play the patterns indicated - any order
- repeat as needed - short bursts, space between

WAVE FUNCTIONS - 8

158

vn

va

vc

mf

p

p

mf

mf

fsf

fsf

ponticello

ord.

164

vn

va

vc

mp

mp

p

dim.

p

agitato

agitato

p

p

(senza rit.)

J Poco più mosso

172

vn

va

vc

f

f

f

p

mf

mf

fp

mf

cresc.

cresc.

cresc.

fp

mf

cresc.

Più calmo

WAVE FUNCTIONS - 9

179

vn *ff*

va *ff*

vc *ff*

G.P.

G.P.

G.P.

sf

sf

sf

** Left hand pizz. the open string (non-ponti.)
while simultaneously drawing bow

Adagio ♩ = 72 II. Bell's Theorem

1

vn *p* *mf sf* *pp* *mf* *p* *non ponti.*

va *p* *mf sf* *mf* *p* *ponticello* *** senza vib.* *n. f sf* *n. f sf* *n. f sf*

vc *p* *mf sf* *pp* *f sf* *senza vib.* *n. f sf* *n. f sf* *n. f sf*

9

vn *mf* *f*

va *n.* *ord.* *mf* *f* *** senza vib.* *n. f sf* *n. f sf* *n.*

vc *n.* *ord.* *mf* *f* *senza vib.* *n. f sf* *n. f sf* *n.*

WAVE FUNCTIONS - 10

15

vn *fsf* *p sub.* *dim.* *n.*

va *f* *ord.* *p* *dim.* *n.*

vc *f* *ord.* *p* *dim.* *n.*

21 **A** **Con Brio** ♩ = 126-132 *leggiero*

vn *mp* *mf* *f* *mf*

va *mp* *mf* *f* *mf*

vc *mp* *mf* *f* *mf*

27

vn *f* *p*

va *f* *p*

vc *f* *p*

WAVE FUNCTIONS - 11

33

vn *f* *p* *ff* *mf*

va *f* *p* *ff* *mf*

vc *f* *fp* *ff* *mf*

39

vn *p* *mf* *f* *mf*

va *p* *mp* *f* *mf* *ord.* *mf*

vc *p* *p* *pp* *f* *mf*

ponticello *ord.*

45

vn *f* *mf* *mp* *f* *pp* *f feroce*

va *f* *f* *pp* *f feroce*

vc *f* *ponticello* *ord.* *pp* *f feroce*

sf poco *dim.*

B

WAVE FUNCTIONS - 12

50

vn *mf* *cresc.* *f* *mf* *f* *dim.*

va *cresc.* *mf* *f* *dim.*

vc *cresc.* *f* *dim.*

55

vn *p* *cresc.* *dim.* *gliss.*

va *p* *cresc.* *dim.* *gliss.*

vc *p* *cresc.* *sf* *col legno* *p sub.* *sf*

60

vn *n.* *f* *f* *p*

va *n.* *f* *f* *p* *ponticello* *V*

vc *pp* *ord.* *f* *f* *p* *ponticello* *V*

WAVE FUNCTIONS - 13

66

vn *f* *mf* *cresc.* *f*

va *ord.* *f* *f*

vc *f* *ord.* *mf* *f* *ponticello* *ord.*

71

vn *mp* *fp* *dim.*

va *fp* *dim.*

vc *ponticello* *ord.* *meno f* *fp* *dim.*

77

vn *pp* *cresc. molto* *gliss.* *f* *mf* *p* *dim.* *pp* *f*

va *pp* *cresc. molto* *gliss.* *f* *mf* *p* *dim.* *pp* *f*

vc *col legno* *cresc. molto* *ord.* *dim.* *p* *dim.* *pp* *f*

WAVE FUNCTIONS - 14

C

83

vn *f* *mf* *f*

va *mf* *mf* *f* *mf*

vc *f* *mf* *mf* *f* *mf*

89

vn *f* *p sub.* *cresc.* *f*

va *mf* *dim.* *ponticello* *ord.* *f* *p sub.* *cresc.* *f*

vc *f* *p sub.* *cresc.* *f*

D Il Doppio Più Lento

95

vn *sf*

va *sf*

vc *sf* *cominciare non trem.* *freely* *affrett.* *f*

cello cad. - senza misura

E a Tempo

WAVE FUNCTIONS - 15

99

vn *mf* *dim.* *p* *f* *p* *cresc.* *f*

va *mf* *dim.* *p* *f* *p* *cresc.* *f*

vc *mf* *dim.* *p* *f* *p* *cresc.* *f*

105

vn *con forza* *mf*

va *con forza*

vc *con forza* *pizz.* *arco*

111

vn *sf* *mp* *mf*

va *sf* *p* *mf* *p*

vc *sf* *p* *mf*

WAVE FUNCTIONS - 16

F Adagio (come al principio)
♩ = 72

117

vn *p* *pp* *con sord.* *flowing* *sfp* *mf*

va *pp* *con sord.* *fsf* *p* *mf*

vc *p* *pp* *con sord.* *sfp*

124

vn *espressivo* *mf* *espressivo* *f* *espressivo* *f*

va *** senza vib.* *fsf* *n.* *fsf* *n.* *fsf* *n.* *fsf* *n.* *fsf* *espressivo* *f* *senza vib.* *fsf* *senza vib.*

vc *senza vib.* *fsf* *n.* *fsf* *n.* *fsf* *n.* *fsf* *n.* *fsf* *espressivo* *mf* *f* *senza vib.* *fsf*

130

vn *fsf* *ord.* *f* *p sub.* *p*

va **** *n.* *fsf* *n.* *fsf* *n.* *fsf* *n.* *fsf* *ord.* *f* *p*

vc *n.* *fsf* *n.* *fsf* *n.* *fsf* *n.* *fsf* *ord.* *f*

WAVE FUNCTIONS - 17

Presto ♩ = 138

136

vn *dim.* *pp mf* *poco sf* *p*

va *dim.* *pp* *mp* *p* *dim.*

vc *p* *dim.* *pp* *p*

Meno mosso, subito

145

vn *pp* *sfp* *pp* *pizz.* *poco sf* *pp* *dim.* *n.*

va *pp* *sfp* *mp* *poco sf* *senza vib.* *pp* *dim.* *n.*

vc *pp* *sfp* *pp* *poco sf* *pp* *dim.* *n.*

III. Schrödinger's Cat

Adagietto
con tristezza

Rit. a Tempo

Violin *con sord.*
Viola *con sord.*
Cello *con sord.*

Measures 1-6 of the score for Violin, Viola, and Cello. The Violin part starts with a *con sord.* marking and a *p* dynamic. The Viola part starts with a *p* dynamic and a *pp* dynamic. The Cello part starts with a *con sord.* marking and a *pp* dynamic. Dynamics include *p*, *pp*, *mf*, *cresc.*, and *mp*. There are also markings for *con sord.* and *bend*.

vn
va
vc

Measures 7-13 of the score for Violin, Viola, and Cello. The Violin part starts with a *mp* dynamic. The Viola part starts with a *f* dynamic. The Cello part starts with a *cresc.* dynamic. Dynamics include *mp*, *f*, *sf*, *dim.*, and *pp*. There are also markings for *Rit.*, *a Tempo*, and *bend*.

vn
va
vc

Measures 14-18 of the score for Violin, Viola, and Cello. The Violin part starts with a *pizz.* marking and a *mf* dynamic. The Viola part starts with a *pizz.* marking and a *mf* dynamic. The Cello part starts with a *pizz.* marking and a *mf* dynamic. Dynamics include *mf*, *dim.*, *poco cresc.*, and *mp*. There are also markings for *arco* and a triplet.

WAVE FUNCTIONS - 19

20 *poco rit.* *accelerando* *Tempo primo* **A**

vn *poco sf* *pp* *harm.* *p* *mf* *f* *p con vigore* *ord.* *mf* *meno f* *dim.*

va *poco sf* *pp* *col legno* *p* *mf* *f* *ord.* *mf* *meno f* *dim.*

vc *poco sf* *pp* *p* *mf* *f* *ord.* *mf* *meno f* *dim.*

25 *dim.* *p* *f* *agitato* *agitato* *agitato* *mf*

31 *gliss.* *ponticello* *ord.* *ponticello* *ord.* *mf* *p* *fp* *fp* *cresc.* *f* *sfp*

vc *p sub.* *p sub.* *fp* *fp* *cresc.* *f* *sfp*

WAVE FUNCTIONS - 20

36 B

vn *harm.*
mp *ponticello* *f* *p* *f* *sfp* *(p) cresc.* *f*

va *ord.*
mp *ponticello* *f* *p* *f* *sfp* *f*

vc *ord.*
mp *f* *p* *f* *sfp* *f*

42

vn *p* *cresc.* *molto dim.* *p* *mf* *Largamente via sord.*

va *p* *cresc.* *p* *mf* *via sord.*

vc *p* *cresc.* *mp* *mf* *p*

tranquillo

47

vn *senza vib.* *mp* *con vib. espressivo* *p* *senza vib.* *mp* *mf* *un po' rit.* *pp* *mp*

va *mf* *mp* *mp*

vc *p* *dim.*

C Allegro non troppo
♩ = 116

52

vn *ppp* *p* *scherzoso* *cresc.* *f*

va *ppp* *p scherzoso* *mf* *pizz.*

vc *ppp* *via sord.* *p* *mf*

59

vn *mf* *p* *mf* *p*

va *arco* *f* *mf* *p* *f en de hors* *dim.*

vc *f* *mf* *p* *mf* *dim.*

66

vn *p* *f* *sf* *ponticello* *ord.* *p*

va *p* *f* *sf* *ponticello* *p sub.* *ord.*

vc *pp* *p* *f* *ponticello* *ord.* *p*

WAVE FUNCTIONS - 22

73 **D** *Meno mosso*

vn *cresc.* *sf* *f* *fp*

va *ponticello* *sf* *f* *fp*

vc *cresc.* *f* *sf* *mp*

82 *accelerando* *Tempo (Allegro non troppo)* **E**

vn *mf* *f* *mf* *p*

va *mf* *f* *mf* *p* *ponticello* *ord.*

vc *cresc.* *f* *dim.* *p*

90

vn *fp* *ff* *sf* *meno f*

va *fp* *f*

vc *fp* *f*

WAVE FUNCTIONS - 23

98

vn *mp* *lagnoso* *non espress.* *(senza cresc.)*

va *ponticello* *ord.* *mf* *gliss.* *mf* *ponticello* *p*

vc *meno f* *mf* *mf* *ponticello* *p*

107

vn *meno mosso* *mf espressivo* *sf*

va *ord.* *mf*

vc *ord.* *mf* *mp*

115

vn *p* *mp* *poco f* *espressivo*

va *p* *pp* *gliss.* *mp* *gliss.* *mp* *p*

vc *p* *espressivo* *p*

F

WAVE FUNCTIONS - 24

123

vn *p* *pp* *più f* *mf*

va *pp* *mf*

vc *p* *mf*

G *plaintive espressivo*

129 *ten.* *quietly* *ritenuto*

vn *pp* *mf* *mf*

va *mf* *mf*

vc *mf* *mf*

130 *a Tempo, ma ancora meno mosso*

vn *p* *f* *f* *freely (cello cad.)*

va *pp* *f* *f* *freely (cello cad.)*

vc *pp* *f* *f* *espressivo* *freely*

WAVE FUNCTIONS - 25

H a Tempo

accelerando

136

vn *harm.* *mf* *p*

va *col legno* *mf* *ord.* *p*

vc *col legno* *mf* *ord.* *p*

mf *molto dim.* *n.* *mf* *p*

da qui alla fine, sempre più lento

144

vn *mp* *mf* *sf* *p* *ord.*

va *mp* *mf* *sf* *ord.* *sf* *p one-finger gliss.*

vc *mf* *p*

ponticello *ord.*

152

vn *Rit.* *dim.* *n.*

va *dim.* *n.*

vc *pizz.* *p* *dim.* *pp*

IV. "Surely, Mr. Feynman..." (in memoriam)

Violin

1 Quietly $\text{♩} = 58$ IV III

Viola

Cello

pizz. *pp* *pp* *pp* *pp* *pp*

più f *p*

p poco espress. *ponticello*

vn

7 *p* *ord.* *mp* *mf* *pizz.* *(ten.)* *arco* *p* *cresc.*

va

più f *arco* *mf* *p* *dim.* *ten.* *p* *cresc.*

vc

mp *poco sf* *p* *pp* *cresc.*

A

WAVE FUNCTIONS - 27

tranquillo

14

vn

va

vc

pp

p

p senza vib.

suono espress.

cresc.

19

vn

va

vc

mf

f

pizz.

arco

sfp

cresc.

p cresc.

p cresc.

24

vn

va

vc

f

dim. molto

pizz.

f

dim. molto

senza vib.

arco

p

più tranquillo

tema

mf

più espress.

più espress.

WAVE FUNCTIONS - 28

29 *Broadly*

vn *f* *p* *mf*

va *f* *mf sub.* *p* *mf*

vc *f*

34 *Broadly*

vn *mf* *poco espress.*

va *poco f* *più f*

vc *mf* *poco espress.*

38 *ponticello* *ord.*

vn *meno f* *cresc.* *f*

va *tema con sentimento* *f* *cresc.* *f*

vc *meno f* *cresc.* *f*

WAVE FUNCTIONS - 29

42

vn

va

vc

p *sub.* *cresc.* *f* *mf* *f* *fp* *fp*

L.H. pizz. *arco*

47

vn

va

vc

cresc. *f* *dim. molto* *pizz.* *f* *BONGOS ** *mf*

***BONGOS** - the rhythmic notation on top of the staff indicates a higher pitch by tapping on the side (rib) of the cello. The notation below the staff indicates a low pitch by tapping on the top(belly) of the cello with other hand.
 (Experiment to find most contrasted pitches.
 For fast patterns use two fingers)

WAVE FUNCTIONS - 30

51 D *ponticello*

vn *p*

va *p*

vc *dim.* *mp* *cresc.* *mf* *p sub.* *cresc.*

57 *ord.*

vn *mf* *dim.* *n.*

va *mf*

vc *f* *dim. sempre* *mp*

63

vc *sf* *sub. mf* *p* *dim.* *fsf* *dim. molto* *n.*

ROLL - both hands, same area on cello