Quantum Enigma

Twin-state photons do not have a particular polarization until the polarization of one of them is observed. Twin-state photons are entangled in a state of identical polarization but have no particular polarization. It is the observation of the polarization of one of the photons as being, say, vertical that instantaneously collapses *both* photons to vertical polarization.

Quantum probability is *not* the probability of where the atom is. It is the objective probability of where you (or anyone) will find it. The atom wasn't in that box before you observed it to be there.

Heisenberg: But the atoms or elementary particles are not real; they form a world of potentialities or possibilities rather than one of things or facts.

1
00:00:04,309 --> 00:00:01,459
physics that's usually not appreciate

2
00:00:06,349 --> 00:00:04,319
even by people that you know get degrees

3
00:00:08,419 --> 00:00:06,359
in physics are not necessarily quantum

4
00:00:10,190 --> 00:00:08,429
experts you know but they have spent

5
00:00:12,560 --> 00:00:10,200
quite a bit of time studying quantum

6
00:00:14,089 --> 00:00:12,570
physics it's sometimes not really

7
00:00:16,129 --> 00:00:14,099
appreciated that the wave function is

8
00:00:17,269 --> 00:00:16,139
the same thing as the the particle that

9
00:00:19,609 --> 00:00:17,279
ultimately comes out of a measurement

10
00:00:21,500 --> 00:00:19,619
and we cause the atom and it's wave

11
00:00:23,120 --> 00:00:21,510
function of the same thing and Adam can

12
00:00:24,470 --> 00:00:23,130
be in two places at once or three or

13
00:00:26,900 --> 00:00:24,480

four or actually an infinite number of

14
00:00:28,250 --> 00:00:26,910
places at once the observation

15
00:00:33,260 --> 00:00:28,260
collapsing the wave function is what

16
00:00:36,139 --> 00:00:33,270
creates literally creates the atom now

17
00:00:38,900 --> 00:00:36,149
let's give an example of the weirdness

18
00:00:41,060 --> 00:00:38,910
of a quantum measurement let's take this

19
00:00:43,490 --> 00:00:41,070
is a penny and you can slice this penny

20
00:00:47,119 --> 00:00:43,500
two ways you can slice the penny down

21
00:00:48,650 --> 00:00:47,129
the right down the middle and you can

22
00:00:50,660 --> 00:00:48,660
get the Lincoln on the front and the

23
00:00:53,479 --> 00:00:50,670
memorial on the back or you could call

24
00:00:54,979 --> 00:00:53,489
this thing chopping the penny in half

25
00:00:56,000 --> 00:00:54,989
where you have the top half the penny in

26
00:00:58,430 --> 00:00:56,010
the bottom half of the pennies all

27
00:01:00,740 --> 00:00:58,440
called as a slice I'll call this a chop

28
00:01:03,290 --> 00:01:00,750
for the experiment the thought

29
00:01:05,810 --> 00:01:03,300
experiment assume we have a mutual

30
00:01:09,560 --> 00:01:05,820
friend called Niels miss for fun column

31
00:01:11,750 --> 00:01:09,570
Niels you might know why maybe he has

32
00:01:13,969 --> 00:01:11,760
two machines that sliced chop and mail

33
00:01:15,560 --> 00:01:13,979
out pennies one machine is labeled

34
00:01:17,960 --> 00:01:15,570
classical in the others label quantum

35
00:01:20,120 --> 00:01:17,970
now when he sets the classical machine

36
00:01:22,070 --> 00:01:20,130
to slice the cut is parallel through the

37
00:01:23,630 --> 00:01:22,080
penny so that you wind up with two thin

38
00:01:25,249 --> 00:01:23,640

coins one is Lincoln on one side the

39
00:01:27,440 --> 00:01:25,259
other has linked in the memorial on on

40
00:01:29,690 --> 00:01:27,450
the other side when he sets the

41
00:01:31,280 --> 00:01:29,700
classical machine to chop the chop is

42
00:01:33,649 --> 00:01:31,290
perpendicular to the penny resulting in

43
00:01:34,730 --> 00:01:33,659
to half moon shape at penneys wonderful

44
00:01:37,340 --> 00:01:34,740
Lincoln's head the other blinking

45
00:01:40,190 --> 00:01:37,350
shoulders so now he takes the two sliced

46
00:01:43,999 --> 00:01:40,200
penny so the two the two sliced pennies

47
00:01:45,800 --> 00:01:44,009
on the top it takes those and puts one

48
00:01:47,630 --> 00:01:45,810
an envelope label sliced pennies and

49
00:01:50,690 --> 00:01:47,640
emails one envelope to you and one to me

50
00:01:53,179 --> 00:01:50,700
I opened my envelope and I find a thin

51
00:01:55,039 --> 00:01:53,189
penny with Lincoln on it so i can safely

52
00:01:56,780 --> 00:01:55,049
infer that your envelope contains a thin

53
00:01:58,490 --> 00:01:56,790
cutting with a lincoln lincoln memorial

54
00:02:00,649 --> 00:01:58,500
on one side and sure enough when you

55
00:02:03,050 --> 00:02:00,659
open your envelope you're going to see

56
00:02:05,719 --> 00:02:03,060
if I have this and my envelope you'll

57
00:02:07,639 --> 00:02:05,729
have that one all right well now my

58
00:02:08,900 --> 00:02:07,649
friend Niels takes the 2 chopped pennies

59
00:02:11,059 --> 00:02:08,910
it puts one in each envelope labeled

60
00:02:13,850 --> 00:02:11,069
chopped pennies again emails one to you

61
00:02:16,160 --> 00:02:13,860
and one to me now I open my own flow

62
00:02:17,780 --> 00:02:16,170
when I find a penny with Lincoln's head

63
00:02:19,820 --> 00:02:17,790

in it so this is what's in my honey and

64
00:02:22,340 --> 00:02:19,830
sure enough I guess that you're going to

65
00:02:23,840 --> 00:02:22,350
find the bottom half of the coin in

66
00:02:25,640 --> 00:02:23,850
yours and that's indeed what you find

67
00:02:28,250 --> 00:02:25,650
all right no big mystery here kind of

68
00:02:30,770 --> 00:02:28,260
boring now one day I get an envelope

69
00:02:32,120 --> 00:02:30,780
with the word quantum written on it and

70
00:02:34,760 --> 00:02:32,130
I figured this might be important so I

71
00:02:36,620 --> 00:02:34,770
call Neil's and I ask Niels what do I

72
00:02:39,230 --> 00:02:36,630
have do I have a sliced penny or a

73
00:02:41,210 --> 00:02:39,240
chopped penny and he says well this time

74
00:02:42,920 --> 00:02:41,220
I use the quantum machine on this one

75
00:02:46,910 --> 00:02:42,930
not the classical machine so it's your

76
00:02:48,770 --> 00:02:46,920
choice I say oh well what do you mean

77
00:02:50,780 --> 00:02:48,780
you've already sliced or chopped opinion

78
00:02:53,090 --> 00:02:50,790
mail it to me I've got it in my hands

79
00:02:55,370 --> 00:02:53,100
how can i change that now he says well

80
00:02:58,160 --> 00:02:55,380
the quantum machine is special it

81
00:03:00,350 --> 00:02:58,170
processes penny it males out the pairs

82
00:03:02,750 --> 00:03:00,360
and unlabeled envelopes without anybody

83
00:03:04,430 --> 00:03:02,760
looking at the pennies the process does

84
00:03:08,030 --> 00:03:04,440
not get turned into a slice or a chop

85
00:03:09,890 --> 00:03:08,040
until somebody looks at the coin do you

86
00:03:11,990 --> 00:03:09,900
mean to say I asked that I can decide

87
00:03:13,850 --> 00:03:12,000
whether I've got a sliced penny or a

88
00:03:16,600 --> 00:03:13,860

chopped penny and out that envelope and

89
00:03:19,280 --> 00:03:16,610
magically I will get one or the other

90
00:03:21,530 --> 00:03:19,290
that's correct saz Neil's and danish and

91
00:03:22,880 --> 00:03:21,540
as soon as you open the envelope and

92
00:03:24,350 --> 00:03:22,890
look at whether you've got a sliced

93
00:03:26,810 --> 00:03:24,360
penny or a chopped can you guess what

94
00:03:29,060 --> 00:03:26,820
the other half the correct other half

95
00:03:32,150 --> 00:03:29,070
will be what your buddy over there is

96
00:03:33,860 --> 00:03:32,160
going to have in his envelope but I say

97
00:03:35,690 --> 00:03:33,870
it's already been sliced or chopped he

98
00:03:37,130 --> 00:03:35,700
says no the quantum machine only does

99
00:03:40,190 --> 00:03:37,140
that part of the joint as part of the

100
00:03:41,720 --> 00:03:40,200
job it correlates the two halves but it

101
00:03:43,910 --> 00:03:41,730
takes your consciousness to complete the

102
00:03:45,320 --> 00:03:43,920
process you get to decide which way the

103
00:03:48,860 --> 00:03:45,330
penny has been have when you open the

104
00:03:51,320 --> 00:03:48,870
envelope now this very same thing can be

105
00:03:54,259 --> 00:03:51,330
done of course not with real pennies but

106
00:03:56,180 --> 00:03:54,269
it can be done with with quantum objects

107
00:03:57,530 --> 00:03:56,190
such as photons yes I'm going to talk

108
00:04:00,050 --> 00:03:57,540
about next I'm going to talk about the

109
00:04:01,759 --> 00:04:00,060
bell in equality and more importantly a

110
00:04:03,289 --> 00:04:01,769
new inequality that you might never have

111
00:04:05,509 --> 00:04:03,299
heard of called the Leggett inequality

112
00:04:07,880 --> 00:04:05,519
that was recently measured it was

113
00:04:10,880 --> 00:04:07,890

actually formulated almost 30 years ago

114
00:04:13,130 --> 00:04:10,890
by a by a professor Leggett who was a

115
00:04:14,870 --> 00:04:13,140
Nobel Prize winner but it wasn't tested

116
00:04:16,819 --> 00:04:14,880
until about a year and a half ago when

117
00:04:18,349 --> 00:04:16,829
an article appeared in nature that a

118
00:04:19,940 --> 00:04:18,359
measurement was made by this prominent

119
00:04:22,070 --> 00:04:19,950
quantum optics group in at the

120
00:04:23,900 --> 00:04:22,080
University of Vienna read by led by

121
00:04:25,490 --> 00:04:23,910
Anton Zeilinger in which they measured

122
00:04:27,590 --> 00:04:25,500
the legged inequality which actually

123
00:04:29,360 --> 00:04:27,600
goes a step deeper than the bell one

124
00:04:31,280 --> 00:04:29,370
rules out any possible interpretation

125
00:04:35,630 --> 00:04:31,290
other than that consciousness creates

126
00:04:38,510 --> 00:04:35,640
reality when the measurement is made now

127
00:04:40,040 --> 00:04:38,520
in the quantum enigma of course you

128
00:04:41,780 --> 00:04:40,050
don't have coins but you have twin state

129
00:04:44,060 --> 00:04:41,790
photons that don't have any particular

130
00:04:46,100 --> 00:04:44,070
polarization until their polarization

131
00:04:47,780 --> 00:04:46,110
one of them is measured so twin state

132
00:04:49,670 --> 00:04:47,790
photons can be entangled in a state of

133
00:04:51,410 --> 00:04:49,680
identical polarization but really have

134
00:04:53,240 --> 00:04:51,420
no particular polarization until you

135
00:04:54,830 --> 00:04:53,250
measure it it's the observation of the

136
00:04:58,580 --> 00:04:54,840
polarization of one of the photons as

137
00:05:00,500 --> 00:04:58,590
being say vertical or horizontal that

138
00:05:02,810 --> 00:05:00,510

instantaneously collapses both photons

139
00:05:04,250 --> 00:05:02,820
to vertical visit polarizations and

140
00:05:06,140 --> 00:05:04,260
that's true when they fly apart you

141
00:05:07,640 --> 00:05:06,150
create a pair of photons one flies this

142
00:05:09,440 --> 00:05:07,650
way one flies that way I make a

143
00:05:11,810 --> 00:05:09,450
measurement over here that measurement

144
00:05:13,460 --> 00:05:11,820
and the kind of measurement I make is

145
00:05:15,290 --> 00:05:13,470
determined by what I decide over here

146
00:05:17,030 --> 00:05:15,300
that measurement will then be reflected

147
00:05:18,740 --> 00:05:17,040
in what this coin over here is going to

148
00:05:20,090 --> 00:05:18,750
do even though they're flying a part of

149
00:05:23,270 --> 00:05:20,100
the speed of light can't communicate

150
00:05:25,040 --> 00:05:23,280
with each other quantum probability is

151
00:05:27,080 --> 00:05:25,050
not the probability of where the atom is

152
00:05:29,180 --> 00:05:27,090
or where a photon is it is the objective

153
00:05:32,030 --> 00:05:29,190
probability of where you will find it

154
00:05:34,130 --> 00:05:32,040
the atom was not in the box if the box

155
00:05:35,570 --> 00:05:34,140
is where the atom is the item was not in

156
00:05:38,150 --> 00:05:35,580
the box before you observed it to be

157
00:05:40,400 --> 00:05:38,160
there and Heisenberg had this to say is

158
00:05:42,050 --> 00:05:40,410
the runner Heisenberg's words but the

159
00:05:44,600 --> 00:05:42,060
atom or elementary particles are not

160
00:05:46,880 --> 00:05:44,610
real they form a world of potentialities

161
00:05:51,500 --> 00:05:46,890
or possibilities rather than one effects

162
00:05:55,640 --> 00:05:51,510
or things or facts let's look at the

163
00:05:58,880 --> 00:05:55,650

bell inequality if you have a quantum

164
00:06:00,650 --> 00:05:58,890
object that has a spin then you can

165
00:06:02,630 --> 00:06:00,660
choose to measure the spin in any given

166
00:06:04,130 --> 00:06:02,640
direction and what you'll find is that

167
00:06:06,410 --> 00:06:04,140
whatever direction you choose as spin is

168
00:06:07,850 --> 00:06:06,420
going to be either up or down by up I

169
00:06:09,230 --> 00:06:07,860
mean if it's spinning like this the

170
00:06:11,540 --> 00:06:09,240
access points up it is spinning like

171
00:06:13,610 --> 00:06:11,550
that the access points down so you have

172
00:06:15,410 --> 00:06:13,620
actually have two particles that are

173
00:06:16,760 --> 00:06:15,420
entangled with each other and I'll tell

174
00:06:18,650 --> 00:06:16,770
you in a second why we have two instead

175
00:06:20,840 --> 00:06:18,660
of one so one of them flies off in one

176
00:06:22,910 --> 00:06:20,850
direction i choose to measure its spin

177
00:06:25,520 --> 00:06:22,920
say in this direction and call that

178
00:06:27,230 --> 00:06:25,530
direction a so i measure that now there

179
00:06:29,780 --> 00:06:27,240
are also two other directions I could

180
00:06:31,310 --> 00:06:29,790
measure B and C they're arbitrary I can

181
00:06:32,330 --> 00:06:31,320
choose them in a anyway I want to but

182
00:06:34,130 --> 00:06:32,340
there are two other possible directions

183
00:06:36,050 --> 00:06:34,140
I could measure but having measured this

184
00:06:38,240 --> 00:06:36,060
one direction quantum theory says I

185
00:06:39,560 --> 00:06:38,250
can't measure the second one but I can

186
00:06:41,420 --> 00:06:39,570
measure the second one indirectly

187
00:06:43,970 --> 00:06:41,430
because if the two particles were in 10

188
00:06:46,370 --> 00:06:43,980

it's partner over here is guaranteed to

189
00:06:47,840 --> 00:06:46,380
have the opposite spin sometimes the

190
00:06:49,550 --> 00:06:47,850
same sometimes the opposite depending on

191
00:06:51,290 --> 00:06:49,560
which which which kind of particle you

192
00:06:52,790 --> 00:06:51,300
choose let's assume it's exactly the

193
00:06:54,350 --> 00:06:52,800
opposite spin now I can make a

194
00:06:55,880 --> 00:06:54,360
measurement on this one in some other

195
00:06:58,490 --> 00:06:55,890
directions I'm second direction call it

196
00:07:00,710 --> 00:06:58,500
be and I know then that if I measure

197
00:07:03,110 --> 00:07:00,720
this one to be in that direction then

198
00:07:04,460 --> 00:07:03,120
this one over here would be in this one

199
00:07:06,260 --> 00:07:04,470
the opposite direction so I've

200
00:07:08,150 --> 00:07:06,270
determined two directions for this

201
00:07:09,740 --> 00:07:08,160
particle over here by virtue of a direct

202
00:07:11,770 --> 00:07:09,750
measurement by virtue of a measurement

203
00:07:14,030 --> 00:07:11,780
of its partner in a different direction

204
00:07:19,490 --> 00:07:14,040
so i can write out these probabilities

205
00:07:21,800 --> 00:07:19,500
the probability of measuring probability

206
00:07:24,110 --> 00:07:21,810
of measuring say spin up in Direction a

207
00:07:25,730 --> 00:07:24,120
and spin down and direction b is the

208
00:07:28,370 --> 00:07:25,740
probability measuring spin up in

209
00:07:29,840 --> 00:07:28,380
direction a down in direction b+

210
00:07:32,030 --> 00:07:29,850
indirection see which i don't know which

211
00:07:34,580 --> 00:07:32,040
i never measured and again the plus the

212
00:07:37,700 --> 00:07:34,590
probability of spin up being positive in

213
00:07:39,800 --> 00:07:37,710

a down in B and in the other direction

214
00:07:41,960 --> 00:07:39,810
and see and as you with a little bit of

215
00:07:48,470 --> 00:07:41,970
mathematical manipulation you can show

216
00:07:50,420 --> 00:07:48,480
that this plus that equals that one plus

217
00:07:52,190 --> 00:07:50,430
something and the fact of the matter is

218
00:07:53,390 --> 00:07:52,200
that something is positive it's always

219
00:07:55,460 --> 00:07:53,400
got to be positive you can't have

220
00:07:58,250 --> 00:07:55,470
negative probabilities therefore this

221
00:08:01,430 --> 00:07:58,260
equation leads to an inequality that the

222
00:08:05,300 --> 00:08:01,440
spin in this direction a and direction B

223
00:08:06,680 --> 00:08:05,310
plus the spin in direction B and C it

224
00:08:09,080 --> 00:08:06,690
has to be greater than or equal to the

225
00:08:11,630 --> 00:08:09,090
spin and direction AC so this is the

226
00:08:13,970 --> 00:08:11,640
bell inequality this is what's predicted

227
00:08:17,300 --> 00:08:13,980
if particles have an intrinsic spin

228
00:08:21,950 --> 00:08:17,310
before you look at them now as it turns

229
00:08:24,410 --> 00:08:21,960
out quantum physics has a rule that says

230
00:08:26,810 --> 00:08:24,420
that if you take the spins in two

231
00:08:28,850 --> 00:08:26,820
different directions now this is the

232
00:08:32,720 --> 00:08:28,860
this is the formula that tells you what

233
00:08:33,890 --> 00:08:32,730
the probability is a finding the if you

234
00:08:36,470 --> 00:08:33,900
have a whole distribution of particles

235
00:08:38,840 --> 00:08:36,480
finding some fraction of them separated

236
00:08:40,820 --> 00:08:38,850
by some angle theta as it turns out if

237
00:08:43,220 --> 00:08:40,830
you put this formula into the bell

238
00:08:46,010 --> 00:08:43,230

inequality the beltline equality is

239
00:08:47,900 --> 00:08:46,020
violated Bell inequality is not true and

240
00:08:50,420 --> 00:08:47,910
the bell inequality is based upon the

241
00:08:52,400 --> 00:08:50,430
idea that spin is something that's

242
00:08:53,900 --> 00:08:52,410
intrinsic that's that's not dependent

243
00:08:55,190 --> 00:08:53,910
upon your measuring it but it's there

244
00:08:57,260 --> 00:08:55,200
all along and you

245
00:08:59,030 --> 00:08:57,270
choose to measure it so it's there when

246
00:09:01,100 --> 00:08:59,040
the particles were were joined together

247
00:09:03,080 --> 00:09:01,110
when they were made to fly apart there's

248
00:09:04,580 --> 00:09:03,090
the the spins in the different

249
00:09:06,230 --> 00:09:04,590
directions are inherent to the particles

250
00:09:08,710 --> 00:09:06,240
and when you choose to measure over here

251
00:09:11,780 --> 00:09:08,720
that's fine and this one's going to be

252
00:09:14,150 --> 00:09:11,790
an anti was going to be in the opposite

253
00:09:16,220 --> 00:09:14,160
direction for any given spin because

254
00:09:17,510 --> 00:09:16,230
they were they were entangled here but

255
00:09:19,490 --> 00:09:17,520
really those spins belong to the

256
00:09:21,140 --> 00:09:19,500
particles and your measurement is like a

257
00:09:23,450 --> 00:09:21,150
classical thing you look at something

258
00:09:25,010 --> 00:09:23,460
objectively you measure what it is but

259
00:09:26,720 --> 00:09:25,020
in fact the fact that the belly

260
00:09:29,840 --> 00:09:26,730
inequality is violated and the quantum

261
00:09:31,280 --> 00:09:29,850
rule is followed implies that that spin

262
00:09:34,160 --> 00:09:31,290
is not really there until you make it

263
00:09:36,410 --> 00:09:34,170

happen the spin in a given direction is

264
00:09:38,840 --> 00:09:36,420
created by your deciding to measure that

265
00:09:42,860 --> 00:09:38,850
direction and then that requires that

266
00:09:45,050 --> 00:09:42,870
its partner will be the in the opposite

267
00:09:46,940 --> 00:09:45,060
direction for that spin measurement and

268
00:09:48,500 --> 00:09:46,950
have its own angle of spin in a

269
00:09:51,110 --> 00:09:48,510
different direction which then this one

270
00:09:52,610 --> 00:09:51,120
would have so the bell inequality is

271
00:09:54,500 --> 00:09:52,620
telling us or the violation of the bell

272
00:09:58,270 --> 00:09:54,510
inequality is telling us that it's the