

A close-up portrait of Norman Wildberger, a man with short, light-colored hair, looking slightly to the right with a neutral expression. He is wearing a dark blue, textured shirt. The background is a dark, chalkboard-like surface filled with faint, white mathematical diagrams and equations, including circles, lines, and various mathematical symbols.

**NORMAN  
WILDBERGER**

**REAL NUMBERS  
AREN'T REAL**

1  
00:00:03,669 --> 00:00:01,910  
it's rare that i feel such an

2  
00:00:05,030 --> 00:00:03,679  
instantaneous warmth with a guest

3  
00:00:06,550 --> 00:00:05,040  
especially when we're meeting for the

4  
00:00:08,790 --> 00:00:06,560  
first time hopefully you sense the

5  
00:00:10,790 --> 00:00:08,800  
comfort and mutual adoration as well as

6  
00:00:12,709 --> 00:00:10,800  
many viewers often joke it's not a live

7  
00:00:14,470 --> 00:00:12,719  
stream it's a love stream

8  
00:00:15,829 --> 00:00:14,480  
norman will be back for a part two so

9  
00:00:17,990 --> 00:00:15,839  
make sure to write your questions down

10  
00:00:19,830 --> 00:00:18,000  
in the comments norman wildberger is a

11  
00:00:22,150 --> 00:00:19,840  
professor of pure mathematics at the

12  
00:00:24,230 --> 00:00:22,160  
university of new south wales and is the

13  
00:00:26,390 --> 00:00:24,240

founder of the youtube channel insights

14

00:00:28,950 --> 00:00:26,400

into mathematics which just passed its

15

00:00:31,349 --> 00:00:28,960

100 000 subscriber mark norman

16

00:00:33,350 --> 00:00:31,359

wildberger is one of the rare examples

17

00:00:35,430 --> 00:00:33,360

of a mathematician examining the

18

00:00:37,270 --> 00:00:35,440

foundations of mathematics in order to

19

00:00:39,190 --> 00:00:37,280

reformulate it ridding it of the

20

00:00:41,190 --> 00:00:39,200

qualities considered abhorrent by the

21

00:00:43,030 --> 00:00:41,200

intuitionists if these phrases or

22

00:00:44,549 --> 00:00:43,040

concepts are unfamiliar to you don't

23

00:00:46,790 --> 00:00:44,559

worry keep watching and it will be

24

00:00:48,950 --> 00:00:46,800

explained in detail within the podcast

25

00:00:51,510 --> 00:00:48,960

today we discuss whether the concept of

26

00:00:54,310 --> 00:00:51,520

infinity is well-founded as well as the

27

00:00:55,430 --> 00:00:54,320

reality or unreality to the real numbers

28

00:00:57,029 --> 00:00:55,440

click on the timestamp in the

29

00:00:59,510 --> 00:00:57,039

description if you'd like to skip this

30

00:01:01,750 --> 00:00:59,520

intro my name is kirchey mungle i'm a

31

00:01:04,229 --> 00:01:01,760

torontonian filmmaker with a background

32

00:01:06,710 --> 00:01:04,239

in mathematical physics dedicated to the

33

00:01:08,469 --> 00:01:06,720

explication of the variegated terrain of

34

00:01:10,469 --> 00:01:08,479

theories of everything from a

35

00:01:12,390 --> 00:01:10,479

theoretical physics perspective but as

36

00:01:14,149 --> 00:01:12,400

well as analyzing consciousness and

37

00:01:16,310 --> 00:01:14,159

seeing its potential connection to

38

00:01:18,230 --> 00:01:16,320

fundamental reality whatever that is

39

00:01:20,789 --> 00:01:18,240

essentially this channel is dedicated to

40

00:01:22,870 --> 00:01:20,799

exploring the under nature of reality

41

00:01:24,469 --> 00:01:22,880

the constitutional laws that govern it

42

00:01:26,870 --> 00:01:24,479

provided those laws exist at all and are

43

00:01:28,789 --> 00:01:26,880

even noble to us if you enjoy witnessing

44

00:01:31,510 --> 00:01:28,799

and engaging with others on the topics

45

00:01:33,749 --> 00:01:31,520

of psychology consciousness physics etc

46

00:01:35,429 --> 00:01:33,759

the channel's themes then do consider

47

00:01:37,270 --> 00:01:35,439

going to the discord and the subreddit

48

00:01:39,109 --> 00:01:37,280

which are linked in the description

49

00:01:40,789 --> 00:01:39,119

there's also a link to the patreon that

50

00:01:42,550 --> 00:01:40,799

is [patreon.com](https://www.patreon.com)

51  
00:01:44,630 --> 00:01:42,560  
kirchimongo if you'd like to support

52  
00:01:46,469 --> 00:01:44,640  
this podcast as the patrons and the

53  
00:01:48,950 --> 00:01:46,479  
sponsors are the only reasons that i'm

54  
00:01:50,870 --> 00:01:48,960  
able to have podcasts of this quality

55  
00:01:53,109 --> 00:01:50,880  
and this depth given that i can do this

56  
00:01:54,870 --> 00:01:53,119  
now full time thanks to both the patrons

57  
00:01:57,190 --> 00:01:54,880  
and the sponsors support speaking of

58  
00:01:59,190 --> 00:01:57,200  
sponsors there are two the first sponsor

59  
00:02:00,550 --> 00:01:59,200  
is brilliant during the winter break i

60  
00:02:02,389 --> 00:02:00,560  
decided to brush up on some of the

61  
00:02:04,550 --> 00:02:02,399  
fundamentals of physics particularly

62  
00:02:06,469 --> 00:02:04,560  
with regard to information theory as i'd

63  
00:02:08,150 --> 00:02:06,479

like to interview chiara marletto on

64

00:02:09,749 --> 00:02:08,160

constructor theory which is heavily

65

00:02:11,430 --> 00:02:09,759

based in information theory now

66

00:02:12,790 --> 00:02:11,440

information theory is predicated on

67

00:02:15,190 --> 00:02:12,800

entropy at least there's a fundamental

68

00:02:16,949 --> 00:02:15,200

formula for entropy so i ended up taking

69

00:02:19,030 --> 00:02:16,959

the brilliant course i challenged myself

70

00:02:21,030 --> 00:02:19,040

to do one lesson per day and i took the

71

00:02:23,270 --> 00:02:21,040

course's random variable distributions

72

00:02:24,949 --> 00:02:23,280

and knowledge slash uncertainty what i

73

00:02:26,710 --> 00:02:24,959

loved is that despite knowing the

74

00:02:28,869 --> 00:02:26,720

formula for entropy which is essentially

75

00:02:30,790 --> 00:02:28,879

hammered into you as an undergraduate it

76

00:02:32,630 --> 00:02:30,800

seems like it comes down from the sky

77

00:02:34,390 --> 00:02:32,640

arbitrarily and with brilliant for the

78

00:02:35,990 --> 00:02:34,400

first time i was able to see how the

79

00:02:38,309 --> 00:02:36,000

formula for entropy which you're seeing

80

00:02:39,990 --> 00:02:38,319

right now is actually extremely natural

81

00:02:41,990 --> 00:02:40,000

and it'd be strange to define it in any

82

00:02:43,589 --> 00:02:42,000

other manner there are plenty of courses

83

00:02:44,949 --> 00:02:43,599

and you can even learn group theory

84

00:02:46,309 --> 00:02:44,959

which is what's being referenced when

85

00:02:49,190 --> 00:02:46,319

you hear that the standard model is

86

00:02:50,869 --> 00:02:49,200

predicated on  $u_1$  cross  $su_2$  cross  $su_3$

87

00:02:52,949 --> 00:02:50,879

those are league groups continuous lead

88

00:02:55,589 --> 00:02:52,959

groups visit [brilliant.org](http://brilliant.org)

89

00:02:57,270 --> 00:02:55,599

tow t-o-e to get 20 off an annual

90

00:02:59,430 --> 00:02:57,280

subscription and i recommend that you

91

00:03:01,270 --> 00:02:59,440

don't stop before four lessons i think

92

00:03:03,030 --> 00:03:01,280

you'll be greatly surprised at the ease

93

00:03:04,869 --> 00:03:03,040

at which you can now comprehend subjects

94

00:03:07,589 --> 00:03:04,879

you previously had a difficult time

95

00:03:09,670 --> 00:03:07,599

grokking the second sponsor is algo now

96

00:03:11,750 --> 00:03:09,680

algo is an end-to-end supply chain

97

00:03:13,750 --> 00:03:11,760

optimization software company with

98

00:03:15,750 --> 00:03:13,760

software that helps business users

99

00:03:17,990 --> 00:03:15,760

optimize sales and operations planning

100

00:03:19,910 --> 00:03:18,000

to avoid stockouts reduce return and

101  
00:03:22,229 --> 00:03:19,920  
inventory write-downs while reducing

102  
00:03:25,430 --> 00:03:22,239  
inventory investment it's a supply chain

103  
00:03:27,509 --> 00:03:25,440  
ai that drives smart roi headed by amjad

104  
00:03:29,910 --> 00:03:27,519  
hussein who's been a huge supporter of

105  
00:03:32,949 --> 00:03:29,920  
this podcast since near its inception in

106  
00:03:34,789 --> 00:03:32,959  
fact amjad has his own podcast on ai and

107  
00:03:36,710 --> 00:03:34,799  
consciousness and business growth and if

108  
00:03:38,630 --> 00:03:36,720  
you'd like to support the tow podcast

109  
00:03:40,390 --> 00:03:38,640  
then visit the link in the description

110  
00:03:42,390 --> 00:03:40,400  
to see amjad's podcast because

111  
00:03:44,789 --> 00:03:42,400  
subscribing to him or at least visiting

112  
00:03:47,270 --> 00:03:44,799  
supports the toe podcast indirectly

113  
00:03:48,630 --> 00:03:47,280

thank you and enjoy first man it's an

114

00:03:50,869 --> 00:03:48,640

honor to speak with you i've been

115

00:03:52,470 --> 00:03:50,879

watching some of your videos for

116

00:03:54,470 --> 00:03:52,480

about two years

117

00:03:56,229 --> 00:03:54,480

well thanks so much um you know like i i

118

00:03:58,390 --> 00:03:56,239

think what you're doing is so fabulous

119

00:04:00,390 --> 00:03:58,400

you've got so many interesting guests

120

00:04:02,550 --> 00:04:00,400

and so on so in fact i'm honored to join

121

00:04:05,190 --> 00:04:02,560

the pantheon of uh

122

00:04:07,509 --> 00:04:05,200

of uh impressive people that you've been

123

00:04:09,509 --> 00:04:07,519

talking to uh so it's really great the

124

00:04:12,710 --> 00:04:09,519

pantheon is elevated by your true

125

00:04:14,630 --> 00:04:12,720

monotheism by you being the one true one

126

00:04:16,949 --> 00:04:14,640

well you're very uh

127

00:04:19,909 --> 00:04:16,959

yes uh thank you

128

00:04:22,550 --> 00:04:19,919

i've made quite a few notes and they're

129

00:04:25,189 --> 00:04:22,560

somewhat scrambled so if this interview

130

00:04:26,390 --> 00:04:25,199

is half hazard i will edit it to make it

131

00:04:28,629 --> 00:04:26,400

consistent

132

00:04:31,030 --> 00:04:28,639

and your answers will of course be ella

133

00:04:34,469 --> 00:04:31,040

quint i'm fairly certain of that

134

00:04:37,110 --> 00:04:34,479

so just please just forgive my adhd my

135

00:04:39,909 --> 00:04:37,120

scrambled notes and so on

136

00:04:42,310 --> 00:04:39,919

well likewise i'm likely to um

137

00:04:44,390 --> 00:04:42,320

stumble or uh you know repeat myself or

138

00:04:45,909 --> 00:04:44,400

uh or say the wrong thing and then have

139

00:04:47,749 --> 00:04:45,919

to correct myself because as you get

140

00:04:49,270 --> 00:04:47,759

older and you get more senile these

141

00:04:50,629 --> 00:04:49,280

things happen so

142

00:04:52,950 --> 00:04:50,639

that's one of the nice things about the

143

00:04:54,710 --> 00:04:52,960

youtube format is it's a little bit less

144

00:04:56,469 --> 00:04:54,720

pressure than actually having to write

145

00:04:57,430 --> 00:04:56,479

something formal you know that's going

146

00:04:59,909 --> 00:04:57,440

to be

147

00:05:01,510 --> 00:04:59,919

analyzed you know line by line

148

00:05:02,469 --> 00:05:01,520

i think there's a bit of slack involved

149

00:05:06,230 --> 00:05:02,479

and people

150

00:05:08,070 --> 00:05:06,240

can appreciate that so yes i'm happy

151

00:05:09,990 --> 00:05:08,080

just as a side note man i saw some

152

00:05:12,310 --> 00:05:10,000

earlier pictures of you you were bluff

153

00:05:14,790 --> 00:05:12,320

at one point you look like you put on

154

00:05:17,189 --> 00:05:14,800

quite a significant amount of muscle

155

00:05:18,550 --> 00:05:17,199

yeah i don't know i i i go swimming and

156

00:05:20,629 --> 00:05:18,560

i you know i work out a little bit

157

00:05:23,029 --> 00:05:20,639

sometimes i go bicycling yeah i try to

158

00:05:25,029 --> 00:05:23,039

now that i'm retired i have to um

159

00:05:26,950 --> 00:05:25,039

you know use some time to be more active

160

00:05:29,110 --> 00:05:26,960

uh how about you do you get you get uh

161

00:05:31,749 --> 00:05:29,120

some exercise or you i try to exercise

162

00:05:34,870 --> 00:05:31,759

every day oh that's great it's mainly

163

00:05:37,990 --> 00:05:34,880

because i'm i'm a glut and i like to eat

164

00:05:41,270 --> 00:05:38,000

and gorge myself voraciously and so i

165

00:05:45,110 --> 00:05:41,280

have to offset those calories

166

00:05:46,870 --> 00:05:45,120

kurt has anybody uh interviewed you

167

00:05:48,629 --> 00:05:46,880

a couple times i'm not terribly

168

00:05:50,550 --> 00:05:48,639

comfortable with it because i don't have

169

00:05:52,710 --> 00:05:50,560

much of a well-defined world view a much

170

00:05:54,390 --> 00:05:52,720

more comfortable asking questions and so

171

00:05:55,830 --> 00:05:54,400

when someone asks me a question most of

172

00:05:57,110 --> 00:05:55,840

the time my answer is i don't know i'm

173

00:05:58,870 --> 00:05:57,120

thinking about that and my answer

174

00:06:01,029 --> 00:05:58,880

changes with the seasons my answer

175

00:06:01,990 --> 00:06:01,039

changes yeah

176

00:06:03,510 --> 00:06:02,000

well that's

177

00:06:04,629 --> 00:06:03,520

not necessarily a weakness you know

178

00:06:06,710 --> 00:06:04,639

that's

179

00:06:08,710 --> 00:06:06,720

that can be a good point of view in fact

180

00:06:11,590 --> 00:06:08,720

it's somehow uh representative of a

181

00:06:14,950 --> 00:06:11,600

general scientific orientation a certain

182

00:06:18,309 --> 00:06:14,960

uh willingness to to uh adapt to the to

183

00:06:19,189 --> 00:06:18,319

the facts or to the compelling arguments

184

00:06:21,189 --> 00:06:19,199

um

185

00:06:22,950 --> 00:06:21,199

but yeah just uh just uh

186

00:06:24,710 --> 00:06:22,960

anyway maybe at some future point i

187

00:06:26,950 --> 00:06:24,720

wouldn't mind um you know

188

00:06:29,189 --> 00:06:26,960

asking you some questions and uh

189

00:06:31,510 --> 00:06:29,199

you know about your not not not today or

190

00:06:32,390 --> 00:06:31,520

anything but you know at some

191

00:06:34,390 --> 00:06:32,400

point

192

00:06:36,550 --> 00:06:34,400

about what specifically

193

00:06:37,749 --> 00:06:36,560

well about about your um you know your

194

00:06:39,830 --> 00:06:37,759

trajectory i think it's pretty

195

00:06:42,150 --> 00:06:39,840

interesting you've been a filmmaker and

196

00:06:43,830 --> 00:06:42,160

uh and and and with a mathematics and

197

00:06:46,870 --> 00:06:43,840

physics background and now you're you

198

00:06:50,309 --> 00:06:46,880

know engaged in this very broad

199

00:06:52,550 --> 00:06:50,319

um sort of uh campaign uh

200

00:06:53,510 --> 00:06:52,560

dealing with really big issues

201  
00:06:55,510 --> 00:06:53,520  
um

202  
00:06:56,230 --> 00:06:55,520  
that that involves you know huge amounts

203  
00:06:59,510 --> 00:06:56,240  
of

204  
00:07:01,510 --> 00:06:59,520  
different

205  
00:07:05,830 --> 00:07:01,520  
positions you know so that's that's

206  
00:07:07,909 --> 00:07:05,840  
rather um a unique kind of let's say um

207  
00:07:09,110 --> 00:07:07,919  
niche that you've got and i think

208  
00:07:10,230 --> 00:07:09,120  
probably people would be interested in

209  
00:07:12,230 --> 00:07:10,240  
what's it like

210  
00:07:14,830 --> 00:07:12,240  
you know to do what you what you do and

211  
00:07:17,589 --> 00:07:14,840  
how do you do it um it's

212  
00:07:19,350 --> 00:07:17,599  
torturous that's what it's like well i

213  
00:07:21,830 --> 00:07:19,360

like i absolutely love it much like

214

00:07:25,110 --> 00:07:21,840

yourself i'm sure you're like my gosh i

215

00:07:27,510 --> 00:07:25,120

am lucky holy moly i get to do what i

216

00:07:28,710 --> 00:07:27,520

love to do and sure there are tedious

217

00:07:31,430 --> 00:07:28,720

aspects like

218

00:07:33,430 --> 00:07:31,440

maybe formatting a latex document or the

219

00:07:36,230 --> 00:07:33,440

submission process or responding to

220

00:07:37,990 --> 00:07:36,240

certain administrative details

221

00:07:39,830 --> 00:07:38,000

i have that with regard to editing i

222

00:07:43,110 --> 00:07:39,840

hate editing everything else i like to

223

00:07:44,869 --> 00:07:43,120

do i think what we could explore is

224

00:07:46,869 --> 00:07:44,879

first and foremost the unreality of

225

00:07:48,790 --> 00:07:46,879

infinity people would be extremely

226

00:07:51,909 --> 00:07:48,800

interested in that especially because as

227

00:07:53,510 --> 00:07:51,919

you know i interview many people who

228

00:07:55,670 --> 00:07:53,520

are

229

00:07:57,830 --> 00:07:55,680

okay they run the gamut from math profs

230

00:07:59,430 --> 00:07:57,840

and physics profs to people who are

231

00:08:00,710 --> 00:07:59,440

trying to explain what consciousness is

232

00:08:02,629 --> 00:08:00,720

and people who've had insights into

233

00:08:05,510 --> 00:08:02,639

consciousness via certain experiences

234

00:08:07,990 --> 00:08:05,520

and those the latter category tend to

235

00:08:09,670 --> 00:08:08,000

equate consciousness with infinity

236

00:08:11,749 --> 00:08:09,680

whatever that means and they'll say well

237

00:08:14,309 --> 00:08:11,759

the ground of reality is both zero and

238

00:08:16,150 --> 00:08:14,319

infinity you and i will both say i'm

239

00:08:17,990 --> 00:08:16,160

unsure what that means and they'll be

240

00:08:21,270 --> 00:08:18,000

like yes well you haven't reached

241

00:08:22,869 --> 00:08:21,280

enlightenment yet okay well

242

00:08:24,070 --> 00:08:22,879

i still i'm not dismissing them like it

243

00:08:25,189 --> 00:08:24,080

could be the case just because i don't

244

00:08:27,189 --> 00:08:25,199

know what it means doesn't mean it's

245

00:08:29,189 --> 00:08:27,199

false how about we explore what you mean

246

00:08:30,550 --> 00:08:29,199

when you say that infinity is not real

247

00:08:32,550 --> 00:08:30,560

or that you don't like the concept of

248

00:08:34,149 --> 00:08:32,560

infinity why psychologically and perhaps

249

00:08:35,670 --> 00:08:34,159

practically

250

00:08:37,029 --> 00:08:35,680

and then also i'm super interested to

251

00:08:39,589 --> 00:08:37,039

hear about your new ideas for

252

00:08:41,029 --> 00:08:39,599

mathematics and unifying it yeah so well

253

00:08:42,949 --> 00:08:41,039

i think there's there's i have lots of

254

00:08:45,350 --> 00:08:42,959

different interests and so i'm pushing

255

00:08:47,430 --> 00:08:45,360

barrels in different directions um

256

00:08:49,030 --> 00:08:47,440

so uh

257

00:08:51,509 --> 00:08:49,040

there's i wouldn't say that i have you

258

00:08:52,790 --> 00:08:51,519

know a grandiose revision of mathematics

259

00:08:55,670 --> 00:08:52,800

um i i

260

00:08:58,710 --> 00:08:55,680

i have a way of thinking about

261

00:09:01,670 --> 00:08:58,720

mathematics that's more concrete and

262

00:09:03,509 --> 00:09:01,680

explicit than say most practitioners and

263

00:09:06,070 --> 00:09:03,519

i think that there's actually a lot to

264

00:09:08,710 --> 00:09:06,080

be gained by adopting that more more

265

00:09:10,949 --> 00:09:08,720

restrictive and more careful and more

266

00:09:12,790 --> 00:09:10,959

sort of computationally based approach

267

00:09:14,310 --> 00:09:12,800

and i can see how to how to push

268

00:09:15,990 --> 00:09:14,320

mathematics forward in various

269

00:09:17,829 --> 00:09:16,000

directions

270

00:09:18,949 --> 00:09:17,839

with that kind of orientation so we

271

00:09:21,590 --> 00:09:18,959

could explore that i mean you know i

272

00:09:22,550 --> 00:09:21,600

have my algebraic calculus project i

273

00:09:25,190 --> 00:09:22,560

have

274

00:09:27,350 --> 00:09:25,200

a project on rational trigonometry and

275

00:09:29,030 --> 00:09:27,360

hyperbolic geometry that's sort of built

276

00:09:31,670 --> 00:09:29,040

up from that point of view and recently

277

00:09:33,990 --> 00:09:31,680

i've been talking about um

278

00:09:36,470 --> 00:09:34,000

solving polynomial equations on one of

279

00:09:38,949 --> 00:09:36,480

my channels and sort of outlining um you

280

00:09:39,910 --> 00:09:38,959

know a broad new approach to that that

281

00:09:41,509 --> 00:09:39,920

problem

282

00:09:42,630 --> 00:09:41,519

but there's other things as well so you

283

00:09:45,030 --> 00:09:42,640

know um

284

00:09:46,870 --> 00:09:45,040

you know i i guess i i i'm more

285

00:09:48,870 --> 00:09:46,880

comfortable in dealing with specifics

286

00:09:51,030 --> 00:09:48,880

and and and uh illustrating things

287

00:09:53,190 --> 00:09:51,040

through specific examples and maybe i'll

288

00:09:55,430 --> 00:09:53,200

try to do that in our conversation let's

289

00:09:57,269 --> 00:09:55,440

talk about why what your gripe is what

290

00:09:59,430 --> 00:09:57,279

is your gripe with infinity and it's not

291

00:10:01,110 --> 00:09:59,440

just the real number it's not just card

292

00:10:03,829 --> 00:10:01,120

it's all infinities

293

00:10:05,509 --> 00:10:03,839

even the countable infinities yeah so i

294

00:10:07,590 --> 00:10:05,519

would say that um

295

00:10:10,069 --> 00:10:07,600

my my main reservation

296

00:10:12,710 --> 00:10:10,079

probably is in the direction of

297

00:10:14,790 --> 00:10:12,720

uh assuming that what can do an infinite

298

00:10:17,110 --> 00:10:14,800

number of things

299

00:10:20,230 --> 00:10:17,120

so um i think it's worthwhile to point

300

00:10:23,750 --> 00:10:20,240

out you know this classical uh

301  
00:10:25,829 --> 00:10:23,760  
dichotomy between an ongoing infinity

302  
00:10:28,310 --> 00:10:25,839  
and a completed infinity

303  
00:10:30,230 --> 00:10:28,320  
that was already the subject of thought

304  
00:10:32,790 --> 00:10:30,240  
in aristotle's day

305  
00:10:35,190 --> 00:10:32,800  
and the ancient greeks had uh had a view

306  
00:10:36,870 --> 00:10:35,200  
that uh you know an unbounded infinity

307  
00:10:39,590 --> 00:10:36,880  
was like a like in euclid you know

308  
00:10:41,590 --> 00:10:39,600  
there's a euclid draws lines but the

309  
00:10:43,430 --> 00:10:41,600  
hymn lines can be extended that's one of

310  
00:10:45,430 --> 00:10:43,440  
his sort of axioms or assumptions you

311  
00:10:47,910 --> 00:10:45,440  
can always extend a line

312  
00:10:50,150 --> 00:10:47,920  
but it's not an infinite object to begin

313  
00:10:52,389 --> 00:10:50,160

with in fact at any particular point

314

00:10:55,350 --> 00:10:52,399

it's always a finite object but it's a

315

00:10:56,710 --> 00:10:55,360

finite object that can be extended

316

00:10:58,069 --> 00:10:56,720

in a similar way you know we can talk

317

00:10:59,990 --> 00:10:58,079

about the natural numbers and we can

318

00:11:02,069 --> 00:11:00,000

count you know from one up to a certain

319

00:11:04,310 --> 00:11:02,079

amount and recognize that we could at

320

00:11:06,710 --> 00:11:04,320

least potentially carry on that counting

321

00:11:08,790 --> 00:11:06,720

but at any given time we are always sort

322

00:11:12,310 --> 00:11:08,800

of only in a possession with only a

323

00:11:13,269 --> 00:11:12,320

range of possible um you know actual

324

00:11:16,310 --> 00:11:13,279

numbers

325

00:11:18,550 --> 00:11:16,320

perhaps constrained by by our computers

326

00:11:20,710 --> 00:11:18,560

our memories or perhaps even more

327

00:11:22,069 --> 00:11:20,720

strongly constrained by the the size of

328

00:11:24,389 --> 00:11:22,079

the universe and

329

00:11:26,069 --> 00:11:24,399

and and perhaps limits that the compute

330

00:11:28,550 --> 00:11:26,079

that the you know the computational

331

00:11:31,110 --> 00:11:28,560

power of the universe imposes on

332

00:11:32,550 --> 00:11:31,120

on on numbers and possibilities for

333

00:11:34,790 --> 00:11:32,560

numbers

334

00:11:37,430 --> 00:11:34,800

so so if we have this distinction then

335

00:11:39,509 --> 00:11:37,440

um i think what what characterizes

336

00:11:41,990 --> 00:11:39,519

modern say 20th century approaches to

337

00:11:43,509 --> 00:11:42,000

infinity is is this idea that we can

338

00:11:45,829 --> 00:11:43,519

capture

339

00:11:47,670 --> 00:11:45,839

the the completed infinity

340

00:11:50,550 --> 00:11:47,680

and that we can

341

00:11:53,910 --> 00:11:50,560

give that a name and we can treat it as

342

00:11:56,230 --> 00:11:53,920

an object ah which which is then a a

343

00:11:58,470 --> 00:11:56,240

prior a prior object that we can then

344

00:12:00,870 --> 00:11:58,480

use for further for further

345

00:12:03,430 --> 00:12:00,880

constructions and such

346

00:12:05,509 --> 00:12:03,440

there's this long standing respect for

347

00:12:07,750 --> 00:12:05,519

the for the you know ongoing aspect

348

00:12:09,509 --> 00:12:07,760

infinity the fact that you know it goes

349

00:12:11,670 --> 00:12:09,519

beyond our view and at some point we

350

00:12:13,269 --> 00:12:11,680

were no longer able to deal with it that

351  
00:12:15,350 --> 00:12:13,279  
has been lost and we've replaced that

352  
00:12:18,230 --> 00:12:15,360  
with a a kind of

353  
00:12:20,230 --> 00:12:18,240  
an arrogance in my view um that that we

354  
00:12:21,590 --> 00:12:20,240  
can do something which in fact we can't

355  
00:12:23,430 --> 00:12:21,600  
do

356  
00:12:24,470 --> 00:12:23,440  
so at the heart of my objection i guess

357  
00:12:26,550 --> 00:12:24,480  
is is this

358  
00:12:28,389 --> 00:12:26,560  
implicit belief that

359  
00:12:30,389 --> 00:12:28,399  
people have that they can

360  
00:12:33,910 --> 00:12:30,399  
they can do something that they actually

361  
00:12:33,920 --> 00:12:38,389  
and you know and whether it be um

362  
00:12:43,670 --> 00:12:40,949  
working with uh infinite decimals

363  
00:12:46,389 --> 00:12:43,680

working with dedicated cuts working with

364

00:12:48,629 --> 00:12:46,399

cochise sequences of

365

00:12:50,790 --> 00:12:48,639

rational numbers or whatever framework for the

366

00:12:52,629 --> 00:12:50,800

real numbers would be or whether it's

367

00:12:55,509 --> 00:12:52,639

involving infinite sets which are the

368

00:12:58,470 --> 00:12:55,519

basis of manifolds or perhaps varieties

369

00:13:00,310 --> 00:12:58,480

or topological vector spaces right in in

370

00:13:02,230 --> 00:13:00,320

all these cases we're kind of assuming

371

00:13:04,150 --> 00:13:02,240

that we have this this collection of

372

00:13:06,150 --> 00:13:04,160

objects that we actually have it's right

373

00:13:09,430 --> 00:13:06,160

in front of us

374

00:13:13,430 --> 00:13:09,440

and that we can uh we can then use it to

375

00:13:16,230 --> 00:13:13,440

manipulate it in in other ways so

376

00:13:17,269 --> 00:13:16,240

i think what we need to do is uh adopt a

377

00:13:19,509 --> 00:13:17,279

more

378

00:13:20,550 --> 00:13:19,519

modest and and sober

379

00:13:22,710 --> 00:13:20,560

position

380

00:13:24,629 --> 00:13:22,720

and and recognize

381

00:13:26,550 --> 00:13:24,639

what it is that we can and we can't do

382

00:13:29,430 --> 00:13:26,560

we should try to restrict ourselves in

383

00:13:32,470 --> 00:13:29,440

my view to things that that we can do

384

00:13:34,550 --> 00:13:32,480

and a good litmus test for that is can

385

00:13:35,430 --> 00:13:34,560

we get our computer

386

00:13:43,269 --> 00:13:35,440

to

387

00:13:45,509 --> 00:13:43,279

you know so it's not a philosophical

388

00:13:48,470 --> 00:13:45,519

discussion uh particularly where you

389

00:13:49,750 --> 00:13:48,480

know i i create uh you know pleasant

390

00:13:51,910 --> 00:13:49,760

arguments and you create pleasant

391

00:13:53,430 --> 00:13:51,920

arguments you know it's rather

392

00:13:56,069 --> 00:13:53,440

can the computer

393

00:13:57,990 --> 00:13:56,079

support the objects that you're that

394

00:14:01,110 --> 00:13:58,000

you're talking about or that you're

395

00:14:05,030 --> 00:14:03,750

i've heard you say before in a few

396

00:14:06,949 --> 00:14:05,040

different interviews

397

00:14:08,470 --> 00:14:06,959

that it's not real unless you can write

398

00:14:09,829 --> 00:14:08,480

it down now i think you're amending that

399

00:14:11,509 --> 00:14:09,839

and what you mean is it's not real

400

00:14:13,590 --> 00:14:11,519

unless you can program a computer to do

401  
00:14:16,389 --> 00:14:13,600  
it because we can write down real

402  
00:14:17,750 --> 00:14:16,399  
analysis with infinities so i'm assuming

403  
00:14:20,310 --> 00:14:17,760  
when you say write it down you have a

404  
00:14:22,389 --> 00:14:20,320  
specific meaning of write it down well

405  
00:14:24,550 --> 00:14:22,399  
actually i don't know if we can i mean

406  
00:14:27,829 --> 00:14:24,560  
what we can do is and what we often do

407  
00:14:30,310 --> 00:14:27,839  
is we write down symbols for things

408  
00:14:32,870 --> 00:14:30,320  
you know and and we identify in our mind

409  
00:14:35,910 --> 00:14:32,880  
like we write down this this uh

410  
00:14:38,150 --> 00:14:35,920  
this r this r you know this uh

411  
00:14:40,389 --> 00:14:38,160  
double barred r and say okay there's the

412  
00:14:41,750 --> 00:14:40,399  
real numbers um but of course that's not

413  
00:14:44,150 --> 00:14:41,760

really the real numbers that's just a

414

00:14:46,870 --> 00:14:44,160

symbol for it and in fact we have the

415

00:14:49,829 --> 00:14:46,880

symbols for a whole variety of things

416

00:14:51,670 --> 00:14:49,839

including constants including function

417

00:14:55,670 --> 00:14:51,680

values and such which

418

00:14:57,350 --> 00:14:55,680

actually we have a hard time actually

419

00:15:00,230 --> 00:14:57,360

really writing down in any meaningful

420

00:15:02,069 --> 00:15:00,240

way and and in a completely parallel way

421

00:15:05,110 --> 00:15:02,079

we have a hard time encoding on our

422

00:15:09,750 --> 00:15:07,829

are you of the mind that

423

00:15:12,629 --> 00:15:09,760

underlying reality is something like an

424

00:15:14,550 --> 00:15:12,639

algorithmic process to at its core

425

00:15:16,949 --> 00:15:14,560

nature is computational much like i'm

426

00:15:18,150 --> 00:15:16,959

sure you've heard wolfram talk about

427

00:15:20,230 --> 00:15:18,160

uh

428

00:15:21,910 --> 00:15:20,240

yeah no i don't have that opinion i'm

429

00:15:25,030 --> 00:15:21,920

not saying that's not not a good opinion

430

00:15:27,030 --> 00:15:25,040

and it very well may end up being

431

00:15:28,389 --> 00:15:27,040

jury uh very close to what's what's

432

00:15:30,790 --> 00:15:28,399

happening so i think we have to

433

00:15:33,910 --> 00:15:30,800

certainly uh embrace that as a

434

00:15:35,749 --> 00:15:33,920

possibility you know um but i i feel as

435

00:15:37,990 --> 00:15:35,759

if we're not close enough to the bottom

436

00:15:40,550 --> 00:15:38,000

yet to to really have a good sense of

437

00:15:42,550 --> 00:15:40,560

what's going on um you know i we we

438

00:15:44,629 --> 00:15:42,560

still have to get these submersibles

439

00:15:46,710 --> 00:15:44,639

down further and deeper and and in a

440

00:15:47,749 --> 00:15:46,720

more thorough way before we can really

441

00:15:50,870 --> 00:15:47,759

start

442

00:15:53,829 --> 00:15:50,880

making um i think confident assessments

443

00:15:55,269 --> 00:15:53,839

about what's really going on

444

00:15:56,550 --> 00:15:55,279

but i i do

445

00:15:59,189 --> 00:15:56,560

believe that

446

00:16:01,590 --> 00:15:59,199

the algorithmic or computational

447

00:16:05,430 --> 00:16:01,600

approach to mathematics is a solid one

448

00:16:09,189 --> 00:16:07,430

that it gives us

449

00:16:10,069 --> 00:16:09,199

a surety

450

00:16:11,509 --> 00:16:10,079

that

451  
00:16:14,069 --> 00:16:11,519  
transcends

452  
00:16:16,790 --> 00:16:14,079  
arguments just with phrases and words

453  
00:16:19,350 --> 00:16:16,800  
and an english language

454  
00:16:23,749 --> 00:16:19,360  
it's a kind of a litmus test for whether

455  
00:16:26,230 --> 00:16:23,759  
we're we're on the right track or not

456  
00:16:28,870 --> 00:16:26,240  
when a physics student first encounters

457  
00:16:31,350 --> 00:16:28,880  
infinity as an object well let's forget

458  
00:16:33,829 --> 00:16:31,360  
about the real numbers it is usually

459  
00:16:35,509 --> 00:16:33,839  
from an investigation into spinners and

460  
00:16:37,269 --> 00:16:35,519  
then penrose has

461  
00:16:38,710 --> 00:16:37,279  
the riemann sphere and says well okay

462  
00:16:40,470 --> 00:16:38,720  
the top point of the riemann sphere

463  
00:16:42,150 --> 00:16:40,480

let's call that infinity and then we

464

00:16:44,790 --> 00:16:42,160

give it some algebraic properties that

465

00:16:46,629 --> 00:16:44,800

we imagine infinity may have so if you

466

00:16:48,550 --> 00:16:46,639

plus infinity with another constant

467

00:16:50,389 --> 00:16:48,560

would equal infinity so i assume you

468

00:16:51,670 --> 00:16:50,399

have an objection to that or maybe you

469

00:16:53,430 --> 00:16:51,680

have an objection far before because

470

00:16:55,670 --> 00:16:53,440

it's a sphere which is a continuous

471

00:16:57,990 --> 00:16:55,680

entity so you're like well i object even

472

00:17:01,990 --> 00:16:58,000

far before that level

473

00:17:03,350 --> 00:17:02,000

um well you know i don't uh object to um

474

00:17:04,870 --> 00:17:03,360

you know the the

475

00:17:07,510 --> 00:17:04,880

the riemann sphere utilizes

476  
00:17:09,429 --> 00:17:07,520  
stereographic projection to uh you know

477  
00:17:10,789 --> 00:17:09,439  
you think of the equatorial plane as

478  
00:17:13,029 --> 00:17:10,799  
being sort of a copy of the complex

479  
00:17:15,350 --> 00:17:13,039  
numbers and you can then stereograph

480  
00:17:17,990 --> 00:17:15,360  
uh plea project from the north north

481  
00:17:20,069 --> 00:17:18,000  
pole so you can sort of wrap the the the

482  
00:17:21,590 --> 00:17:20,079  
plane or the complex numbers onto the

483  
00:17:24,309 --> 00:17:21,600  
onto the sphere with the exception of

484  
00:17:26,069 --> 00:17:24,319  
this north pole and and then as you go

485  
00:17:27,750 --> 00:17:26,079  
far out on the complex number plane then

486  
00:17:29,430 --> 00:17:27,760  
you're approaching this north pole so it

487  
00:17:31,270 --> 00:17:29,440  
makes sense to say okay well we have a

488  
00:17:32,710 --> 00:17:31,280

new point here we should give it a name

489

00:17:35,510 --> 00:17:32,720

why don't we call it something so we

490

00:17:37,990 --> 00:17:35,520

could call it aleph or or zeta or

491

00:17:40,070 --> 00:17:38,000

infinity so i have no problem at all

492

00:17:41,830 --> 00:17:40,080

with someone saying well let's use this

493

00:17:44,070 --> 00:17:41,840

particular symbol the laminar scat

494

00:17:48,150 --> 00:17:44,080

symbol and call it infinity

495

00:17:49,909 --> 00:17:48,160

so that's that's not an example of um

496

00:17:51,750 --> 00:17:49,919

of assuming that you can do an infinite

497

00:17:53,029 --> 00:17:51,760

number of things

498

00:17:55,909 --> 00:17:53,039

which is which is

499

00:17:57,669 --> 00:17:55,919

ultimately my my serious objection that

500

00:17:59,190 --> 00:17:57,679

that that you you're believing that you

501  
00:18:00,950 --> 00:17:59,200  
can do something which you actually

502  
00:18:02,549 --> 00:18:00,960  
can't in the case of the sphere you can

503  
00:18:03,990 --> 00:18:02,559  
do this stereographic projection it's

504  
00:18:06,789 --> 00:18:04,000  
all algebraic you can make it all

505  
00:18:08,870 --> 00:18:06,799  
algebraic and so it's completely well

506  
00:18:10,950 --> 00:18:08,880  
defined and  $i$   $i$  have no problems with

507  
00:18:12,470 --> 00:18:10,960  
that so in classical geometry for

508  
00:18:15,110 --> 00:18:12,480  
example in projective geometry

509  
00:18:18,230 --> 00:18:15,120  
projective geometry uh uses points at

510  
00:18:20,710 --> 00:18:18,240  
infinity so-called you know in in a in a

511  
00:18:23,750 --> 00:18:20,720  
very important and integral way

512  
00:18:25,750 --> 00:18:23,760  
and in the uh 17th and 18th centuries

513  
00:18:28,390 --> 00:18:25,760

these points at infinity had something

514

00:18:29,990 --> 00:18:28,400

of a mystical aspect

515

00:18:31,990 --> 00:18:30,000

and and people didn't really know you

516

00:18:33,750 --> 00:18:32,000

know what what what does it mean to to

517

00:18:36,950 --> 00:18:33,760

have a point at infinity like it's like

518

00:18:39,110 --> 00:18:36,960

the horizon it's infinitely far away etc

519

00:18:41,190 --> 00:18:39,120

but in the 19th century people people

520

00:18:43,990 --> 00:18:41,200

realize that you could you could rethink

521

00:18:46,470 --> 00:18:44,000

this in in terms of uh affine geometry

522

00:18:48,150 --> 00:18:46,480

in one dimension up

523

00:18:49,430 --> 00:18:48,160

so you could understand the projective

524

00:18:51,110 --> 00:18:49,440

plane by

525

00:18:53,830 --> 00:18:51,120

embedding it in a certain way in

526

00:18:55,350 --> 00:18:53,840

three-dimensional affine space

527

00:18:58,070 --> 00:18:55,360

and so and then that

528

00:18:59,830 --> 00:18:58,080

completely demystified the the role of

529

00:19:02,789 --> 00:18:59,840

infinity so the infinity then just

530

00:19:05,190 --> 00:19:02,799

becomes uh those points whose whose

531

00:19:06,470 --> 00:19:05,200

third coordinate is zero as opposed to

532

00:19:09,350 --> 00:19:06,480

the other ones which are have third

533

00:19:10,549 --> 00:19:09,360

chord at one so it becomes completely uh

534

00:19:12,310 --> 00:19:10,559

uh

535

00:19:14,230 --> 00:19:12,320

reasonable and and all the mystery

536

00:19:16,070 --> 00:19:14,240

vanishes

537

00:19:18,470 --> 00:19:16,080

yeah so

538

00:19:21,830 --> 00:19:18,480

so that that's that that's i think a

539

00:19:24,310 --> 00:19:21,840

good thing to keep in mind it it's um

540

00:19:25,510 --> 00:19:24,320

whether the crucial the crucial thing is

541

00:19:26,950 --> 00:19:25,520

are you

542

00:19:28,870 --> 00:19:26,960

assuming that you're able to do an

543

00:19:31,510 --> 00:19:28,880

infinite number of things and and get a

544

00:19:34,070 --> 00:19:31,520

completed result which you're then

545

00:19:36,230 --> 00:19:34,080

then using for further uh constructions

546

00:19:38,470 --> 00:19:36,240

let's drill down into this notion of do

547

00:19:40,230 --> 00:19:38,480

like we can't do the infinity so

548

00:19:42,870 --> 00:19:40,240

specifically what's meant when you say

549

00:19:45,190 --> 00:19:42,880

we cannot do it

550

00:19:46,710 --> 00:19:45,200

well i think maybe it would be good at

551

00:19:48,390 --> 00:19:46,720

this point if i could sort of

552

00:19:50,630 --> 00:19:48,400

demonstrate some things in a little bit

553

00:19:52,870 --> 00:19:50,640

of a hands-on way because i sort of like

554

00:19:55,430 --> 00:19:52,880

to be explicit and maybe you know that

555

00:19:57,990 --> 00:19:55,440

would be a benefit to your um

556

00:19:58,950 --> 00:19:58,000

to your viewers and listeners can you

557

00:20:00,070 --> 00:19:58,960

see this

558

00:20:03,029 --> 00:20:00,080

yes

559

00:20:03,990 --> 00:20:03,039

i've spoke your name correctly i hope

560

00:20:06,149 --> 00:20:04,000

good good

561

00:20:07,909 --> 00:20:06,159

okay so this is a little program it's

562

00:20:09,830 --> 00:20:07,919

called scientific workplace uh it's it's

563

00:20:12,230 --> 00:20:09,840

quite convenient it's what i use to

564

00:20:14,549 --> 00:20:12,240

write papers with but it's also has some

565

00:20:16,710 --> 00:20:14,559

mathematical computational power so that

566

00:20:19,430 --> 00:20:16,720

i'm quite familiar with so i can use it

567

00:20:21,430 --> 00:20:19,440

to illustrate things great so let me

568

00:20:23,029 --> 00:20:21,440

just start by just uh

569

00:20:24,789 --> 00:20:23,039

showing you a few things first of all

570

00:20:26,630 --> 00:20:24,799

just to impress you with the power of

571

00:20:28,950 --> 00:20:26,640

this um sure

572

00:20:31,350 --> 00:20:28,960

this uh this program okay so here here's

573

00:20:34,470 --> 00:20:31,360

a number okay which i'm just randomly

574

00:20:35,909 --> 00:20:34,480

making and i'm going to ask it to um to

575

00:20:37,750 --> 00:20:35,919

factor this

576

00:20:39,990 --> 00:20:37,760

okay so what you see here is the prime

577

00:20:42,310 --> 00:20:40,000

factorization of this number

578

00:20:43,909 --> 00:20:42,320

okay so that that's good um if i want to

579

00:20:45,029 --> 00:20:43,919

do arithmetic like let's say i want to

580

00:20:47,270 --> 00:20:45,039

do um

581

00:20:48,549 --> 00:20:47,280

eight no i have to go into math mode

582

00:20:49,909 --> 00:20:48,559

okay 8

583

00:20:50,710 --> 00:20:49,919

to the 8

584

00:20:51,669 --> 00:20:50,720

plus

585

00:20:55,990 --> 00:20:51,679

7

586

00:20:58,149 --> 00:20:56,000

potential arithmetic if i evaluate that

587

00:21:01,110 --> 00:20:58,159

i get some number like this

588

00:21:03,669 --> 00:21:01,120

if i if i make this 8 into 18 let's say

589

00:21:05,430 --> 00:21:03,679

in this into 17 i can evaluate again i'm

590

00:21:07,270 --> 00:21:05,440

going to get some some bigger number so

591

00:21:09,029 --> 00:21:07,280

we we have the potential of doing

592

00:21:10,789 --> 00:21:09,039

arithmetic here but

593

00:21:12,870 --> 00:21:10,799

one of the things that i think people

594

00:21:16,470 --> 00:21:12,880

perhaps don't appreciate is that

595

00:21:18,710 --> 00:21:16,480

our ability to do arithmetic smoothly

596

00:21:21,990 --> 00:21:18,720

diminishes it diminishes

597

00:21:22,710 --> 00:21:22,000

quite steadily as the numbers get big

598

00:21:24,789 --> 00:21:22,720

and

599

00:21:27,190 --> 00:21:24,799

you know a lot of talk about infinity

600

00:21:29,430 --> 00:21:27,200

and the problems of infinity are a

601  
00:21:31,909 --> 00:21:29,440  
little bit of a red herring because

602  
00:21:35,430 --> 00:21:33,350  
the essential

603  
00:21:37,510 --> 00:21:35,440  
problems actually manifest themselves

604  
00:21:39,270 --> 00:21:37,520  
long before you get to infinity

605  
00:21:41,029 --> 00:21:39,280  
they manifest themselves already when

606  
00:21:42,789 --> 00:21:41,039  
you start dealing with bigger and bigger

607  
00:21:45,510 --> 00:21:42,799  
numbers

608  
00:21:48,310 --> 00:21:45,520  
so for example if let's say i i replace

609  
00:21:51,350 --> 00:21:48,320  
this eight um with an eight to the eight

610  
00:21:52,470 --> 00:21:51,360  
and this um so now i'm talking about

611  
00:21:54,310 --> 00:21:52,480  
um

612  
00:21:57,029 --> 00:21:54,320  
you know this thing here

613  
00:21:58,950 --> 00:21:57,039

so if i was do to do this i i'm not sure

614

00:22:00,950 --> 00:21:58,960

if i really want to do this um but okay

615

00:22:03,029 --> 00:22:00,960

let me just try okay so that this is

616

00:22:05,430 --> 00:22:03,039

what's going to happen um my computer is

617

00:22:07,110 --> 00:22:05,440

going to uh sit here for um and i don't

618

00:22:09,270 --> 00:22:07,120

know how long you know

619

00:22:10,630 --> 00:22:09,280

maybe some some years okay

620

00:22:12,789 --> 00:22:10,640

yeah

621

00:22:13,830 --> 00:22:12,799

now it it has realized that this is his

622

00:22:14,630 --> 00:22:13,840

way

623

00:22:17,270 --> 00:22:14,640

okay

624

00:22:19,510 --> 00:22:17,280

so um

625

00:22:22,070 --> 00:22:19,520

okay and edit has told me okay this is

626

00:22:23,990 --> 00:22:22,080

this is silly you're not able to do this

627

00:22:27,990 --> 00:22:24,000

now

628

00:22:31,430 --> 00:22:28,000

so when we when we do a lot of um

629

00:22:33,110 --> 00:22:31,440

calculations in in in mathematics

630

00:22:36,950 --> 00:22:33,120

we're

631

00:22:39,669 --> 00:22:36,960

crucial aspect of reality of

632

00:22:41,909 --> 00:22:39,679

computational reality uh sufficiently

633

00:22:44,950 --> 00:22:41,919

you know uh seriously

634

00:22:47,750 --> 00:22:44,960

so let's say for example that um

635

00:22:50,470 --> 00:22:47,760

i want to calculate exponential function

636

00:22:52,230 --> 00:22:50,480

of 7. so i want e to the 7. so what what

637

00:22:54,549 --> 00:22:52,240

is that

638

00:22:56,870 --> 00:22:54,559

so i could evaluate it numerically i'm

639

00:22:59,990 --> 00:22:56,880

getting this this number here so what is

640

00:23:01,270 --> 00:23:00,000

actually e to this to the seven well um

641

00:23:03,750 --> 00:23:01,280

you will know of course that this thing

642

00:23:05,590 --> 00:23:03,760

has a power series expansion and i can

643

00:23:06,830 --> 00:23:05,600

just remind people what that is by going

644

00:23:09,270 --> 00:23:06,840

to power

645

00:23:11,110 --> 00:23:09,280

series okay

646

00:23:13,029 --> 00:23:11,120

so here here is the power series

647

00:23:14,870 --> 00:23:13,039

expansion for e to the x and most

648

00:23:17,029 --> 00:23:14,880

functions that physicists deal with in

649

00:23:17,830 --> 00:23:17,039

fact that mathematicians deal with are

650

00:23:19,750 --> 00:23:17,840

all

651  
00:23:22,630 --> 00:23:19,760  
sort of something similar like this that

652  
00:23:25,830 --> 00:23:22,640  
they can ultimately be reduced to to

653  
00:23:29,110 --> 00:23:25,840  
series which which carry on okay they're

654  
00:23:31,430 --> 00:23:29,120  
they're ongoing and the the arithmetic

655  
00:23:33,990 --> 00:23:31,440  
with such things is very parallel to

656  
00:23:35,990 --> 00:23:34,000  
arithmetic with polynomials polynomials

657  
00:23:38,149 --> 00:23:36,000  
are just sort of the finite versions of

658  
00:23:40,149 --> 00:23:38,159  
this where you truncate and and do the

659  
00:23:41,669 --> 00:23:40,159  
arithmetic and then you get a finite

660  
00:23:44,630 --> 00:23:41,679  
polynomial

661  
00:23:46,470 --> 00:23:44,640  
so uh what we're really doing when we

662  
00:23:48,470 --> 00:23:46,480  
calculate e to the seven is we're

663  
00:23:50,789 --> 00:23:48,480

supposing that we're going to replace

664

00:23:53,110 --> 00:23:50,799

this x here with with seven and we're

665

00:23:56,789 --> 00:23:53,120

going to calculate all these terms and

666

00:23:58,710 --> 00:23:56,799

we're going to um you know see see what

667

00:24:01,590 --> 00:23:58,720

what we get

668

00:24:04,470 --> 00:24:01,600

but so this is this is a key example of

669

00:24:06,950 --> 00:24:04,480

a calculation that actually we cannot do

670

00:24:09,190 --> 00:24:06,960

in its entirety

671

00:24:10,230 --> 00:24:09,200

so you you cannot

672

00:24:11,269 --> 00:24:10,240

you cannot

673

00:24:13,990 --> 00:24:11,279

uh

674

00:24:16,070 --> 00:24:14,000

look at this this sum

675

00:24:21,029 --> 00:24:16,080

uh going to infinity

676

00:24:25,430 --> 00:24:23,029

what what you can do is you can truncate

677

00:24:27,190 --> 00:24:25,440

it like like what right the program is

678

00:24:28,870 --> 00:24:27,200

doing right here okay so like this is

679

00:24:30,789 --> 00:24:28,880

what what your calculator you will do

680

00:24:32,630 --> 00:24:30,799

your calculator will dispense with all

681

00:24:34,630 --> 00:24:32,640

the terms past some point

682

00:24:36,630 --> 00:24:34,640

and just use this finite polynomial to

683

00:24:38,230 --> 00:24:36,640

calculate e to the seven

684

00:24:40,630 --> 00:24:38,240

but with with this understanding that

685

00:24:43,110 --> 00:24:40,640

there's there's some uh some some

686

00:24:46,549 --> 00:24:43,120

inaccuracy or some some error because

687

00:24:48,630 --> 00:24:46,559

we've truncated things and just as a

688

00:24:51,430 --> 00:24:48,640

note to the audience that term you

689

00:24:53,590 --> 00:24:51,440

erased is a stand-in for an infinite

690

00:24:55,190 --> 00:24:53,600

sequence of additions

691

00:24:58,310 --> 00:24:55,200

that's right that's right yes so this

692

00:24:59,190 --> 00:24:58,320

series ostensibly carries on to infinity

693

00:25:01,110 --> 00:24:59,200

okay

694

00:25:03,269 --> 00:25:01,120

with the coefficients that that are in

695

00:25:04,630 --> 00:25:03,279

front here getting uh increasingly big

696

00:25:07,190 --> 00:25:04,640

in the denominators and then these

697

00:25:09,110 --> 00:25:07,200

powers are getting increasingly large

698

00:25:11,110 --> 00:25:09,120

um and and when we calculate e to the

699

00:25:13,350 --> 00:25:11,120

seven we're thinking about you know

700

00:25:14,789 --> 00:25:13,360

adding up all of these things so we

701  
00:25:16,870 --> 00:25:14,799  
could we could talk about you know the

702  
00:25:18,470 --> 00:25:16,880  
difficulty in in in doing this to

703  
00:25:20,950 --> 00:25:18,480  
infinity but before we get to that

704  
00:25:23,029 --> 00:25:20,960  
difficulty we we get to the difficulty

705  
00:25:25,909 --> 00:25:23,039  
of of getting to the range where we're

706  
00:25:28,390 --> 00:25:25,919  
talking about numbers even of this size

707  
00:25:31,190 --> 00:25:28,400  
so in other words if i take this sum

708  
00:25:34,070 --> 00:25:31,200  
okay um for let me write it out as a sum

709  
00:25:36,149 --> 00:25:34,080  
so if i take the sum from k equals oops

710  
00:25:39,110 --> 00:25:36,159  
k equals zero

711  
00:25:41,669 --> 00:25:39,120  
two okay let me uh put in here uh

712  
00:25:48,789 --> 00:25:43,830  
to the 10

713  
00:25:50,470 --> 00:25:48,799

summing we're summing 1 over

714

00:25:52,870 --> 00:25:50,480

k factorial

715

00:25:57,110 --> 00:25:52,880

and times x to the

716

00:26:01,830 --> 00:26:00,310

okay so that's that's not e to the x but

717

00:26:02,710 --> 00:26:01,840

that's

718

00:26:05,350 --> 00:26:02,720

uh

719

00:26:06,549 --> 00:26:05,360

like the first 10 to the 10 terms of e

720

00:26:07,510 --> 00:26:06,559

to the x

721

00:26:09,430 --> 00:26:07,520

okay

722

00:26:11,430 --> 00:26:09,440

so we have not gone to infinity but we

723

00:26:13,830 --> 00:26:11,440

have gone a long long ways

724

00:26:15,430 --> 00:26:13,840

and already at this stage we are talking

725

00:26:18,070 --> 00:26:15,440

about something that doesn't make sense

726

00:26:19,909 --> 00:26:18,080

computationally on our computers

727

00:26:21,669 --> 00:26:19,919

and and more crucially we're talking

728

00:26:24,710 --> 00:26:21,679

about something which does not make

729

00:26:26,549 --> 00:26:24,720

sense in the universe as as we as we are

730

00:26:30,470 --> 00:26:26,559

in

731

00:26:33,350 --> 00:26:30,480

even though it's relatively modest by

732

00:26:35,350 --> 00:26:33,360

big number standards is already

733

00:26:37,669 --> 00:26:35,360

ensuring that that this

734

00:26:39,669 --> 00:26:37,679

this computation will overwhelm the

735

00:26:42,870 --> 00:26:39,679

computational aspects of the entire

736

00:26:46,470 --> 00:26:44,630

in fact i took to be completely

737

00:26:47,190 --> 00:26:46,480

confident about that statement if i go

738

00:26:49,430 --> 00:26:47,200

to

739

00:26:50,710 --> 00:26:49,440

one more okay now i can be completely

740

00:26:52,149 --> 00:26:50,720

confident i've got a

741

00:26:54,149 --> 00:26:52,159

10 to the 10 to the 10 to the 10. so

742

00:26:56,149 --> 00:26:54,159

that that's that sum is going to be

743

00:26:57,510 --> 00:26:56,159

completely overwhelming the the

744

00:26:59,830 --> 00:26:57,520

computational

745

00:27:02,310 --> 00:26:59,840

capacity of the universe even if we use

746

00:27:04,230 --> 00:27:02,320

the entire universe and even if we write

747

00:27:05,190 --> 00:27:04,240

at the planck scale

748

00:27:06,470 --> 00:27:05,200

sure

749

00:27:12,470 --> 00:27:06,480

so

750

00:27:15,510 --> 00:27:12,480

problem that we we cannot calculate this

751  
00:27:18,470 --> 00:27:15,520  
initial sum so in

752  
00:27:19,269 --> 00:27:18,480  
to be honest we have no right to assert

753  
00:27:23,830 --> 00:27:19,279  
the

754  
00:27:27,110 --> 00:27:23,840  
much about uh

755  
00:27:28,630 --> 00:27:27,120  
some which is vastly superior vastly

756  
00:27:31,029 --> 00:27:28,640  
bigger than this one namely going to

757  
00:27:34,070 --> 00:27:31,039  
infinity so this is very disconcerting

758  
00:27:35,909 --> 00:27:34,080  
to uh to a modern analyst they don't

759  
00:27:37,750 --> 00:27:35,919  
want to think this way because

760  
00:27:40,310 --> 00:27:37,760  
this means that

761  
00:27:41,669 --> 00:27:40,320  
the the exactness that they currently

762  
00:27:44,549 --> 00:27:41,679  
ascribe to something like the

763  
00:27:46,870 --> 00:27:44,559

exponential function or or the cosine or

764

00:27:48,710 --> 00:27:46,880

the sign or the tan or the arctan or

765

00:27:49,590 --> 00:27:48,720

one of hundreds of other such similar

766

00:27:51,990 --> 00:27:49,600

things

767

00:27:54,789 --> 00:27:52,000

that exactness is is illusory and that

768

00:27:58,230 --> 00:27:54,799

it's uh more a game that we're playing

769

00:28:00,830 --> 00:27:58,240

that's not really computationally

770

00:28:03,190 --> 00:28:00,840

valid so we would we would like the

771

00:28:05,110 --> 00:28:03,200

exponential function to be a function in

772

00:28:07,110 --> 00:28:05,120

the sense that it inputs a real number

773

00:28:09,269 --> 00:28:07,120

and outputs a real number

774

00:28:10,230 --> 00:28:09,279

but the reality is that's not what

775

00:28:11,990 --> 00:28:10,240

happens

776

00:28:13,830 --> 00:28:12,000

i know you mentioned that this is not a

777

00:28:16,230 --> 00:28:13,840

philosophical statement but to me it

778

00:28:18,389 --> 00:28:16,240

sounds philosophical and underneath it

779

00:28:20,230 --> 00:28:18,399

has a practical nature to it that we

780

00:28:22,310 --> 00:28:20,240

practically cannot calculate this and

781

00:28:25,190 --> 00:28:22,320

then it also has the term

782

00:28:27,269 --> 00:28:25,200

existence or real this is not real now

783

00:28:29,190 --> 00:28:27,279

just for those who are listening i know

784

00:28:30,470 --> 00:28:29,200

we use the terms real number we

785

00:28:32,389 --> 00:28:30,480

shouldn't use the word real number

786

00:28:33,990 --> 00:28:32,399

because it muddies the waters so you're

787

00:28:37,110 --> 00:28:34,000

saying that this

788

00:28:40,070 --> 00:28:37,120

is not real because you can't input

789

00:28:41,830 --> 00:28:40,080

and get an output in the universe

790

00:28:44,389 --> 00:28:41,840

so is it a practical claim i'm trying to

791

00:28:46,310 --> 00:28:44,399

understand what the objection is it's a

792

00:28:49,269 --> 00:28:46,320

practical objection or it's an

793

00:28:51,909 --> 00:28:49,279

in-principle objection so it it's really

794

00:28:54,710 --> 00:28:51,919

ultimately a question not of existence

795

00:28:56,389 --> 00:28:54,720

but of definition i mean i know often we

796

00:28:58,310 --> 00:28:56,399

phrase these questions in terms of

797

00:29:01,190 --> 00:28:58,320

existence like does infinity exist or

798

00:29:04,149 --> 00:29:01,200

does e to the seven exist etcetera but a

799

00:29:05,190 --> 00:29:04,159

prior and and usually more uh profound

800

00:29:08,549 --> 00:29:05,200

question is you know what is the

801  
00:29:10,149 --> 00:29:08,559  
definition of infinity or e to the seven

802  
00:29:11,190 --> 00:29:10,159  
that's what you want to think about

803  
00:29:14,470 --> 00:29:11,200  
first

804  
00:29:18,070 --> 00:29:15,990  
what i'm saying is that the definition

805  
00:29:19,990 --> 00:29:18,080  
of e to the seven is not it's not a

806  
00:29:21,269 --> 00:29:20,000  
valid definition let me see if i'm

807  
00:29:23,510 --> 00:29:21,279  
understanding it correctly so you're

808  
00:29:25,750 --> 00:29:23,520  
saying it's not valid because inside e

809  
00:29:28,630 --> 00:29:25,760  
to the any number is an infinite amount

810  
00:29:30,630 --> 00:29:28,640  
of steps we cannot do an infinite amount

811  
00:29:33,269 --> 00:29:30,640  
of steps therefore the definition it

812  
00:29:35,190 --> 00:29:33,279  
fails at the definitional level

813  
00:29:37,350 --> 00:29:35,200

that's right that's right we cannot get

814

00:29:39,750 --> 00:29:37,360

to the end of the rainbow so for us to

815

00:29:42,389 --> 00:29:39,760

say let let g be the pot of gold at the

816

00:29:45,190 --> 00:29:42,399

end of the rainbow is is is is not a

817

00:29:47,029 --> 00:29:45,200

proper definition

818

00:29:49,269 --> 00:29:47,039

now what if someone says like a child

819

00:29:51,110 --> 00:29:49,279

says or a first-year student which at

820

00:29:52,789 --> 00:29:51,120

least i was a child when i was like

821

00:29:54,389 --> 00:29:52,799

childlike and naive like what if they

822

00:29:56,710 --> 00:29:54,399

say okay forget about

823

00:29:59,830 --> 00:29:56,720

whether or not e to the 10 to the 10 to

824

00:30:01,510 --> 00:29:59,840

the 10 exists and think of it as well if

825

00:30:04,710 --> 00:30:01,520

we treat this

826

00:30:07,430 --> 00:30:04,720

as if it exists then it allows us some

827

00:30:09,669 --> 00:30:07,440

simplicity in other calculations so for

828

00:30:11,430 --> 00:30:09,679

example i have a circle here

829

00:30:13,590 --> 00:30:11,440

this diffuser right here and i have a

830

00:30:16,070 --> 00:30:13,600

circle if i treat it mathematically like

831

00:30:18,789 --> 00:30:16,080

an actual circle it simplifies

832

00:30:20,870 --> 00:30:18,799

calculations for me whether or not it is

833

00:30:22,870 --> 00:30:20,880

a circle or whether or not a circle

834

00:30:25,110 --> 00:30:22,880

exists

835

00:30:27,190 --> 00:30:25,120

that's another question so what if i use

836

00:30:29,430 --> 00:30:27,200

it almost like an architect uses design

837

00:30:31,430 --> 00:30:29,440

so i use this i know the final building

838

00:30:33,909 --> 00:30:31,440

won't look like this but hey for my

839

00:30:36,870 --> 00:30:33,919

purposes it's fine so what are your

840

00:30:38,870 --> 00:30:36,880

objections to that first of all your

841

00:30:41,110 --> 00:30:38,880

your choice of the circle is a very very

842

00:30:42,870 --> 00:30:41,120

good one because the the circle actually

843

00:30:45,430 --> 00:30:42,880

is at the heart of a lot of these

844

00:30:47,269 --> 00:30:45,440

difficult issues even historically uh

845

00:30:50,470 --> 00:30:47,279

going back to the origins of

846

00:30:52,310 --> 00:30:50,480

trigonometry with the uh the astronomers

847

00:30:53,909 --> 00:30:52,320

uh the greek astronomers and hindu

848

00:30:54,870 --> 00:30:53,919

astronomers and so on

849

00:30:57,509 --> 00:30:54,880

um

850

00:31:01,430 --> 00:30:57,519

the the need for uh for essentially trig

851  
00:31:03,909 --> 00:31:01,440  
tables that that related uh angles to x

852  
00:31:05,590 --> 00:31:03,919  
and y-coordinates essentially

853  
00:31:07,029 --> 00:31:05,600  
i mean these these

854  
00:31:09,590 --> 00:31:07,039  
the people who created these tables

855  
00:31:11,350 --> 00:31:09,600  
realized that you could not

856  
00:31:13,909 --> 00:31:11,360  
create exact values that this was

857  
00:31:16,470 --> 00:31:13,919  
necessarily an approximate story

858  
00:31:17,669 --> 00:31:16,480  
and that that approximate aspect has

859  
00:31:19,909 --> 00:31:17,679  
permitted

860  
00:31:23,269 --> 00:31:19,919  
almost not all but almost all

861  
00:31:25,830 --> 00:31:23,279  
trigonometric tables since ancient times

862  
00:31:27,029 --> 00:31:25,840  
and so there's a distinction i think a

863  
00:31:28,870 --> 00:31:27,039

really important distinction here

864

00:31:30,870 --> 00:31:28,880

between things which are intrinsically

865

00:31:33,029 --> 00:31:30,880

approximate and things which are

866

00:31:35,430 --> 00:31:33,039

intrinsically exact

867

00:31:36,870 --> 00:31:35,440

and i suppose one way of

868

00:31:39,269 --> 00:31:36,880

thinking about my objection is that i

869

00:31:40,950 --> 00:31:39,279

want to make very clear the distinction

870

00:31:43,029 --> 00:31:40,960

in our minds between

871

00:31:45,110 --> 00:31:43,039

uh being on the exact side of the fence

872

00:31:46,470 --> 00:31:45,120

and being on the approximate side of the

873

00:31:49,350 --> 00:31:46,480

fence

874

00:31:51,669 --> 00:31:49,360

okay um and i think

875

00:31:54,230 --> 00:31:51,679

yes it that does complicate things in in

876

00:31:57,590 --> 00:31:54,240

the sense that whenever you

877

00:32:00,149 --> 00:31:57,600

uh add distinctions on into a theory it

878

00:32:02,470 --> 00:32:00,159

will typically complicate the theory but

879

00:32:05,350 --> 00:32:02,480

it also makes it more

880

00:32:07,269 --> 00:32:05,360

accurate and representative of reality

881

00:32:09,430 --> 00:32:07,279

in mathematics most

882

00:32:11,430 --> 00:32:09,440

most applied mathematicians first of all

883

00:32:13,430 --> 00:32:11,440

mathematics has been largely applied

884

00:32:15,190 --> 00:32:13,440

mathematics for for most of its history

885

00:32:16,470 --> 00:32:15,200

i think perhaps we should we should say

886

00:32:17,909 --> 00:32:16,480

that

887

00:32:20,470 --> 00:32:17,919

um i mean a lot of the great

888

00:32:22,549 --> 00:32:20,480

mathematicians you know uh were

889

00:32:24,310 --> 00:32:22,559

essentially applied mathematicians they

890

00:32:26,789 --> 00:32:24,320

were interested in concrete problems and

891

00:32:29,430 --> 00:32:26,799

solving solving real life problems and

892

00:32:31,029 --> 00:32:29,440

they they recognize that a lot of the

893

00:32:33,430 --> 00:32:31,039

techniques that they had

894

00:32:35,669 --> 00:32:33,440

were sort of operating in this

895

00:32:37,190 --> 00:32:35,679

approximate space

896

00:32:39,269 --> 00:32:37,200

you know where

897

00:32:40,789 --> 00:32:39,279

like like sine and cosine you don't you

898

00:32:42,950 --> 00:32:40,799

don't know exactly what the sine or

899

00:32:44,710 --> 00:32:42,960

cosine of some particular angle is but

900

00:32:46,549 --> 00:32:44,720

you you know it's two three or four

901  
00:32:48,310 --> 00:32:46,559  
decimal places because you have tables

902  
00:32:50,149 --> 00:32:48,320  
and that's good enough to solve whatever

903  
00:32:52,549 --> 00:32:50,159  
problem that you're working on

904  
00:32:55,269 --> 00:32:52,559  
this this is i think a really important

905  
00:32:58,070 --> 00:32:55,279  
distinction and you could characterize

906  
00:33:00,149 --> 00:32:58,080  
mathematics pure mathematicians desire

907  
00:33:01,990 --> 00:33:00,159  
for real numbers

908  
00:33:04,230 --> 00:33:02,000  
okay and and we said we were going to

909  
00:33:06,310 --> 00:33:04,240  
maybe stick to infinity but but to be to

910  
00:33:08,789 --> 00:33:06,320  
be honest it's really the real number

911  
00:33:11,669 --> 00:33:08,799  
question which is really at the heart of

912  
00:33:14,230 --> 00:33:11,679  
this this discussion okay the the real

913  
00:33:15,190 --> 00:33:14,240

critical um issue is

914

00:33:19,029 --> 00:33:15,200

what's

915

00:33:21,110 --> 00:33:19,039

of of the continuum

916

00:33:23,350 --> 00:33:21,120

because that's the basis for for for

917

00:33:24,950 --> 00:33:23,360

modern geometry that's the basis for for

918

00:33:26,870 --> 00:33:24,960

analysis

919

00:33:29,750 --> 00:33:26,880

see historically the the role of

920

00:33:30,630 --> 00:33:29,760

infinity has been a supporting role

921

00:33:33,990 --> 00:33:30,640

um

922

00:33:37,110 --> 00:33:34,000

infinity arose with cantor and promoted

923

00:33:39,830 --> 00:33:37,120

by dedicant as a supportive structure to

924

00:33:42,230 --> 00:33:39,840

frame a theory of real numbers

925

00:33:43,909 --> 00:33:42,240

this is sort of how the story goes and

926

00:33:45,990 --> 00:33:43,919

this is essentially why it's so

927

00:33:48,549 --> 00:33:46,000

important for analysts to

928

00:33:50,789 --> 00:33:48,559

to you know play along with with modern

929

00:33:53,350 --> 00:33:50,799

set theory because they they see that as

930

00:33:55,110 --> 00:33:53,360

a buttress for the the theory of real

931

00:33:55,990 --> 00:33:55,120

numbers

932

00:33:56,870 --> 00:33:56,000

but

933

00:34:00,630 --> 00:33:56,880

the

934

00:34:03,669 --> 00:34:00,640

arithmetic which i point out uh in a lot

935

00:34:05,430 --> 00:34:03,679

of places is that this this lack of

936

00:34:07,430 --> 00:34:05,440

being able to actually perform

937

00:34:09,829 --> 00:34:07,440

calculations

938

00:34:13,270 --> 00:34:09,839

is is right in your face if you really

939

00:34:15,349 --> 00:34:13,280

uh work with the computer

940

00:34:16,389 --> 00:34:15,359

so i i have to illustrate what i'm

941

00:34:18,310 --> 00:34:16,399

saying here

942

00:34:20,310 --> 00:34:18,320

in in a couple of important examples

943

00:34:22,790 --> 00:34:20,320

okay so let's have a look at this

944

00:34:25,030 --> 00:34:22,800

elementary problem which every primary

945

00:34:27,109 --> 00:34:25,040

school student who has done uh

946

00:34:28,950 --> 00:34:27,119

some some fractions will know so if one

947

00:34:31,510 --> 00:34:28,960

half plus one third plus one fifth if i

948

00:34:32,389 --> 00:34:31,520

evaluate that i get 31 over 30.

949

00:34:34,629 --> 00:34:32,399

and

950

00:34:35,510 --> 00:34:34,639

we can accept that

951  
00:34:37,430 --> 00:34:35,520  
you know

952  
00:34:39,109 --> 00:34:37,440  
a primary school student who's learning

953  
00:34:40,550 --> 00:34:39,119  
fractions ought to be able to make this

954  
00:34:42,069 --> 00:34:40,560  
calculation

955  
00:34:44,629 --> 00:34:42,079  
now suppose that i

956  
00:34:47,190 --> 00:34:44,639  
i want to demonstrate you know real

957  
00:34:49,030 --> 00:34:47,200  
number arithmetic

958  
00:34:52,230 --> 00:34:49,040  
which involves

959  
00:34:55,349 --> 00:34:52,240  
things like  $x e x$  plus seven or cosine

960  
00:34:57,510 --> 00:34:55,359  
of five or or the square root of of

961  
00:34:59,270 --> 00:34:57,520  
eleven or something like that if i try

962  
00:35:00,870 --> 00:34:59,280  
to uh well my favorite example which i'm

963  
00:35:02,950 --> 00:35:00,880

always

964

00:35:03,750 --> 00:35:02,960

telling people is is this one here so i

965

00:35:05,990 --> 00:35:03,760

should

966

00:35:08,470 --> 00:35:06,000

for consistency write it down what is pi

967

00:35:10,470 --> 00:35:08,480

plus e plus square root of two

968

00:35:13,910 --> 00:35:10,480

okay so my computer is pretty smart and

969

00:35:15,910 --> 00:35:13,920

if i ask it to to calculate this

970

00:35:17,829 --> 00:35:15,920

just to evaluate it you see what it

971

00:35:19,430 --> 00:35:17,839

gives me it gives me the same thing back

972

00:35:20,790 --> 00:35:19,440

again

973

00:35:22,630 --> 00:35:20,800

and this is not just because of this

974

00:35:24,390 --> 00:35:22,640

program if you ask mathematica or pretty

975

00:35:26,069 --> 00:35:24,400

well any other program you know to

976

00:35:27,990 --> 00:35:26,079

calculate to do this arithmetic you're

977

00:35:29,829 --> 00:35:28,000

going to get something similar

978

00:35:31,270 --> 00:35:29,839

but it's not just this it like i could

979

00:35:31,990 --> 00:35:31,280

do this in a

980

00:35:45,430 --> 00:35:32,000

a

981

00:35:46,310 --> 00:35:45,440

is um cosine of

982

00:35:48,550 --> 00:35:46,320

three

983

00:35:50,870 --> 00:35:48,560

um times uh

984

00:35:52,630 --> 00:35:50,880

you know sine of

985

00:35:55,270 --> 00:35:52,640

seven

986

00:35:57,589 --> 00:35:55,280

oh it doesn't know maybe

987

00:35:59,109 --> 00:35:57,599

you have a problem with this because

988

00:36:01,589 --> 00:35:59,119

i'm sure there's a way that you can get

989

00:36:03,829 --> 00:36:01,599

it to do a decimal expansion oh yes i

990

00:36:06,230 --> 00:36:03,839

can do that yes absolutely so i can i

991

00:36:07,829 --> 00:36:06,240

evaluate these things numerically uh

992

00:36:09,910 --> 00:36:07,839

very easily so i can evaluate this

993

00:36:11,430 --> 00:36:09,920

numerically i can evaluate all of these

994

00:36:14,550 --> 00:36:11,440

numerically

995

00:36:18,870 --> 00:36:14,560

and it's the numerical evaluation that

996

00:36:20,870 --> 00:36:19,910

so

997

00:36:24,069 --> 00:36:20,880

the

998

00:36:26,710 --> 00:36:24,079

work to four or five decimal places

999

00:36:28,630 --> 00:36:26,720

maybe if you're a theoretical physics

1000

00:36:30,390 --> 00:36:28,640

student maybe to 10 decimal places in

1001

00:36:32,470 --> 00:36:30,400

some strange

1002

00:36:35,589 --> 00:36:32,480

situations but typically to just a few

1003

00:36:37,829 --> 00:36:35,599

decimal places so

1004

00:36:39,829 --> 00:36:37,839

that's that's not a problem but

1005

00:36:42,470 --> 00:36:39,839

from a pure mathematics point of view

1006

00:36:44,790 --> 00:36:42,480

this idea that we have a valid

1007

00:36:46,390 --> 00:36:44,800

arithmetic of real numbers

1008

00:36:48,550 --> 00:36:46,400

is

1009

00:36:50,630 --> 00:36:48,560

it would seem contradicted here right

1010

00:36:52,230 --> 00:36:50,640

here i i'm i'm taking

1011

00:36:54,310 --> 00:36:52,240

very simple real numbers and i'm

1012

00:36:56,550 --> 00:36:54,320

performing very simple arithmetical

1013

00:36:58,310 --> 00:36:56,560

operations on them

1014

00:37:01,750 --> 00:36:58,320

and i'm not getting

1015

00:37:03,750 --> 00:37:01,760

any kind of of calculations

1016

00:37:04,630 --> 00:37:03,760

the reality is my computer and almost

1017

00:37:09,109 --> 00:37:04,640

all

1018

00:37:11,109 --> 00:37:09,119

incapable of doing real number

1019

00:37:12,950 --> 00:37:11,119

arithmetic

1020

00:37:14,550 --> 00:37:12,960

and you can frame that you know we have

1021

00:37:16,630 --> 00:37:14,560

various framings of real number

1022

00:37:19,430 --> 00:37:16,640

arithmetic in pure mathematics we talk

1023

00:37:22,150 --> 00:37:19,440

about dedicated cuts and we talk about

1024

00:37:23,589 --> 00:37:22,160

equivalence classes of koshi sequences

1025

00:37:25,589 --> 00:37:23,599

there's continued fractions there's

1026  
00:37:26,630 --> 00:37:25,599  
other ways it doesn't matter how you

1027  
00:37:28,550 --> 00:37:26,640  
frame it

1028  
00:37:31,270 --> 00:37:28,560  
their computational reality is always

1029  
00:37:32,470 --> 00:37:31,280  
the same that you can't actually compute

1030  
00:37:35,270 --> 00:37:32,480  
exactly

1031  
00:37:37,829 --> 00:37:35,280  
these operations on on on

1032  
00:37:40,230 --> 00:37:37,839  
relatively simple real numbers

1033  
00:37:42,230 --> 00:37:40,240  
what do people who are analysts

1034  
00:37:44,150 --> 00:37:42,240  
say to you in their response or their

1035  
00:37:44,870 --> 00:37:44,160  
objections

1036  
00:37:46,150 --> 00:37:44,880  
so

1037  
00:37:48,630 --> 00:37:46,160  
an analyst is going to be very

1038  
00:37:51,349 --> 00:37:48,640

uncomfortable with this conversation

1039

00:37:53,750 --> 00:37:51,359

you see um before before jedican came

1040

00:37:54,710 --> 00:37:53,760

along with uh his theory of dedication

1041

00:37:57,109 --> 00:37:54,720

cuts

1042

00:37:59,430 --> 00:37:57,119

people knew about these problems uh a

1043

00:38:01,750 --> 00:37:59,440

lot because for centuries earlier people

1044

00:38:03,670 --> 00:38:01,760

had been making computations

1045

00:38:05,270 --> 00:38:03,680

with uh maybe i'll stop

1046

00:38:08,069 --> 00:38:05,280

sharing the screen it's getting boring

1047

00:38:10,069 --> 00:38:08,079

what is it exactly that the analyst may

1048

00:38:11,589 --> 00:38:10,079

put to you as a rebuttal

1049

00:38:13,109 --> 00:38:11,599

yeah so most analysts are going to be

1050

00:38:14,230 --> 00:38:13,119

uncomfortable with this this train of

1051  
00:38:15,270 --> 00:38:14,240  
thought

1052  
00:38:17,910 --> 00:38:15,280  
because

1053  
00:38:22,069 --> 00:38:17,920  
historically long before dedicant the

1054  
00:38:25,270 --> 00:38:22,079  
cop theory came about in about the 1870s

1055  
00:38:27,109 --> 00:38:25,280  
the the working the working prototype of

1056  
00:38:29,829 --> 00:38:27,119  
a real number was an infinite decimal a

1057  
00:38:31,349 --> 00:38:29,839  
so-called infinite decimal

1058  
00:38:34,310 --> 00:38:31,359  
and

1059  
00:38:36,950 --> 00:38:34,320  
it's not too hard to to see that if you

1060  
00:38:38,710 --> 00:38:36,960  
want to have a theory of arithmetic with

1061  
00:38:42,950 --> 00:38:38,720  
infinite decimals

1062  
00:38:45,750 --> 00:38:42,960  
that's going to be problematic because

1063  
00:38:48,390 --> 00:38:45,760

because the infinite nature of of the

1064

00:38:50,470 --> 00:38:48,400

decimals means that it's going to be

1065

00:38:52,150 --> 00:38:50,480

difficult or actually impossible to

1066

00:38:55,349 --> 00:38:52,160

prescribe

1067

00:38:58,069 --> 00:38:55,359

what the operations are

1068

00:39:00,069 --> 00:38:58,079

so for to be

1069

00:39:02,790 --> 00:39:00,079

so to be specific suppose that you're

1070

00:39:06,069 --> 00:39:02,800

given two computer programs that will

1071

00:39:07,190 --> 00:39:06,079

output the nth digit of two

1072

00:39:09,349 --> 00:39:07,200

decimals

1073

00:39:11,670 --> 00:39:09,359

and you're asked to write another

1074

00:39:13,990 --> 00:39:11,680

computer program that will output the

1075

00:39:15,670 --> 00:39:14,000

nth digit of the sum of those two real

1076

00:39:17,109 --> 00:39:15,680

numbers

1077

00:39:18,710 --> 00:39:17,119

you just said the nth digit of two

1078

00:39:20,230 --> 00:39:18,720

decimals you mean the nth digit of the

1079

00:39:21,750 --> 00:39:20,240

sum of two numbers or

1080

00:39:24,150 --> 00:39:21,760

yeah so let's say you you want to sort

1081

00:39:26,310 --> 00:39:24,160

of incorporate real number addition

1082

00:39:28,950 --> 00:39:26,320

on a computer in in a computational

1083

00:39:31,109 --> 00:39:28,960

fashion the inputs are two infinite

1084

00:39:32,150 --> 00:39:31,119

decimals given as programs

1085

00:39:33,430 --> 00:39:32,160

and digits

1086

00:39:35,109 --> 00:39:33,440

and your output is supposed to be

1087

00:39:38,230 --> 00:39:35,119

another program of the same kind which

1088

00:39:39,430 --> 00:39:38,240

represents the sum of those two things

1089

00:39:40,630 --> 00:39:39,440

so if you think about this for a little

1090

00:39:44,069 --> 00:39:40,640

while the way

1091

00:39:45,990 --> 00:39:44,079

kids are taught um

1092

00:39:48,150 --> 00:39:46,000

decimal number arithmetic in schools you

1093

00:39:50,950 --> 00:39:48,160

have two decimals to add them you start

1094

00:39:55,430 --> 00:39:50,960

on the right hand side

1095

00:39:58,230 --> 00:39:55,440

and then the carries go to to the to the

1096

00:40:01,030 --> 00:39:58,240

left and so then you pick up the carries

1097

00:40:02,710 --> 00:40:01,040

as you proceed from right to left

1098

00:40:05,030 --> 00:40:02,720

the problem is with if you have a two

1099

00:40:07,750 --> 00:40:05,040

infinite decimals if you have in some

1100

00:40:10,309 --> 00:40:07,760

sense there's no right point to start

1101  
00:40:12,390 --> 00:40:10,319  
with right so what you have to do is you

1102  
00:40:14,710 --> 00:40:12,400  
have to typically sort of truncate and

1103  
00:40:16,790 --> 00:40:14,720  
then do some partial calculation

1104  
00:40:18,790 --> 00:40:16,800  
then go further trunk it again do uh the

1105  
00:40:20,550 --> 00:40:18,800  
calculation again and then modify what

1106  
00:40:24,309 --> 00:40:20,560  
you've got um

1107  
00:40:27,910 --> 00:40:25,750  
but the problem with that is there's the

1108  
00:40:29,670 --> 00:40:27,920  
problem of carry of nines so at some

1109  
00:40:31,910 --> 00:40:29,680  
point you have you have the the

1110  
00:40:35,109 --> 00:40:31,920  
potential of getting a lot of nines so

1111  
00:40:37,030 --> 00:40:35,119  
that you're never in in possession of a

1112  
00:40:39,270 --> 00:40:37,040  
program that will guarantee that you've

1113  
00:40:41,270 --> 00:40:39,280

got the nth decimal place

1114

00:40:44,069 --> 00:40:41,280

because

1115

00:40:46,710 --> 00:40:44,079

that nth decimal place could conceivably

1116

00:40:47,589 --> 00:40:46,720

depend on stuff that's happening very

1117

00:40:49,829 --> 00:40:47,599

very

1118

00:40:52,470 --> 00:40:49,839

far down down the track and you don't

1119

00:40:53,270 --> 00:40:52,480

know how far that's the critical thing

1120

00:40:54,230 --> 00:40:53,280

okay

1121

00:40:58,630 --> 00:40:54,240

so

1122

00:41:01,030 --> 00:40:58,640

been aware that that

1123

00:41:04,069 --> 00:41:01,040

in terms of a theoretical number system

1124

00:41:06,470 --> 00:41:04,079

the infinite decimals don't really work

1125

00:41:08,069 --> 00:41:06,480

this is why this is why you the the 17th

1126

00:41:08,950 --> 00:41:08,079

century people 18th century people

1127

00:41:10,790 --> 00:41:08,960

didn't

1128

00:41:12,870 --> 00:41:10,800

create such a theory they would work

1129

00:41:14,790 --> 00:41:12,880

with decimals all the time

1130

00:41:16,630 --> 00:41:14,800

but they didn't have a theoretical

1131

00:41:18,390 --> 00:41:16,640

understanding of those and then they

1132

00:41:21,270 --> 00:41:18,400

kind of avoided it because they knew of

1133

00:41:23,270 --> 00:41:21,280

these difficulties

1134

00:41:25,270 --> 00:41:23,280

so so the dedicant cut story the koshi

1135

00:41:26,550 --> 00:41:25,280

sequence uh equivalence class story

1136

00:41:29,349 --> 00:41:26,560

these are attempts by pure

1137

00:41:31,829 --> 00:41:29,359

mathematicians to kind of circumvent

1138

00:41:34,230 --> 00:41:31,839

um these difficulties would not face

1139

00:41:36,630 --> 00:41:34,240

them squarely on and surmount them but

1140

00:41:38,550 --> 00:41:36,640

to actually sort of circumvent them and

1141

00:41:40,230 --> 00:41:38,560

and and and and

1142

00:41:42,150 --> 00:41:40,240

you know and make it look like like we

1143

00:41:44,309 --> 00:41:42,160

have an arithmetic of real numbers when

1144

00:41:46,870 --> 00:41:44,319

we actually we don't

1145

00:41:48,760 --> 00:41:46,880

we don't have a valid arithmetic of real

1146

00:41:49,990 --> 00:41:48,770

numbers that's just the way the world is

1147

00:41:51,750 --> 00:41:50,000

[Music]

1148

00:41:53,750 --> 00:41:51,760

and it's not because we're not smart

1149

00:41:54,870 --> 00:41:53,760

enough it's it's because we're

1150

00:41:57,190 --> 00:41:54,880

attempting something that's

1151  
00:41:59,030 --> 00:41:57,200  
intrinsically impossible what we end up

1152  
00:42:01,510 --> 00:41:59,040  
having to do is we have to then uh

1153  
00:42:02,950 --> 00:42:01,520  
separate our mathematics from from

1154  
00:42:04,790 --> 00:42:02,960  
computational reality we have to kind of

1155  
00:42:07,510 --> 00:42:04,800  
go up you know

1156  
00:42:09,270 --> 00:42:07,520  
and and go up on stilts so that we never

1157  
00:42:11,349 --> 00:42:09,280  
touch the floor you know we're walking

1158  
00:42:13,829 --> 00:42:11,359  
around on these stilts and and not

1159  
00:42:15,829 --> 00:42:13,839  
looking down just always looking up

1160  
00:42:18,870 --> 00:42:15,839  
um so

1161  
00:42:21,349 --> 00:42:18,880  
this means a a lack of contact with with

1162  
00:42:23,109 --> 00:42:21,359  
mathematical reality ultimately

1163  
00:42:24,630 --> 00:42:23,119

and that manifests itself across i mean

1164

00:42:27,589 --> 00:42:24,640

i could talk for hours about these

1165

00:42:31,510 --> 00:42:27,599

manifolds varieties topological vector

1166

00:42:33,430 --> 00:42:31,520

spaces lead groups you know um

1167

00:42:35,190 --> 00:42:33,440

there's there's so many areas of

1168

00:42:36,790 --> 00:42:35,200

mathematics that um

1169

00:42:42,550 --> 00:42:36,800

get

1170

00:42:45,430 --> 00:42:42,560

underlying numerical system that's the

1171

00:42:47,430 --> 00:42:45,440

so-called real numbers or the associated

1172

00:42:49,670 --> 00:42:47,440

complex numbers i think it'd be a great

1173

00:42:52,150 --> 00:42:49,680

time to give an example of a problem

1174

00:42:54,230 --> 00:42:52,160

that arises when one

1175

00:42:57,190 --> 00:42:54,240

doesn't take this computational view for

1176

00:42:59,589 --> 00:42:57,200

example in physics we use e

1177

00:43:01,589 --> 00:42:59,599

all the time it's rare to find a formula

1178

00:43:03,270 --> 00:43:01,599

without e so what is the solution we

1179

00:43:05,270 --> 00:43:03,280

just replace this with something else is

1180

00:43:06,950 --> 00:43:05,280

is physics breaking down in some way now

1181

00:43:08,870 --> 00:43:06,960

i know with feynman path integrals you

1182

00:43:11,670 --> 00:43:08,880

can solve it by saying it's finite oh no

1183

00:43:13,510 --> 00:43:11,680

it's see i i i think you you've

1184

00:43:15,349 --> 00:43:13,520

yeah you i think you physicists are are

1185

00:43:17,670 --> 00:43:15,359

fine because you're not thinking of this

1186

00:43:19,750 --> 00:43:17,680

e as an infinite decimal you're thinking

1187

00:43:23,349 --> 00:43:19,760

of e as um

1188

00:43:25,190 --> 00:43:23,359

as a finite decimal of some variable uh

1189

00:43:27,510 --> 00:43:25,200

number of decimals which you can kind of

1190

00:43:29,270 --> 00:43:27,520

choose you can choose the amount of of a

1191

00:43:31,670 --> 00:43:29,280

resolution depending on the problem that

1192

00:43:33,589 --> 00:43:31,680

you have in mind

1193

00:43:35,510 --> 00:43:33,599

so you're playing along with with the

1194

00:43:37,190 --> 00:43:35,520

pure mathematician's notation because

1195

00:43:39,430 --> 00:43:37,200

you've gone to math class you've learned

1196

00:43:41,589 --> 00:43:39,440

about  $e$  and so on but effectively you're

1197

00:43:43,670 --> 00:43:41,599

adopting an applied mathematical point

1198

00:43:46,309 --> 00:43:43,680

of view which doesn't require the

1199

00:43:48,150 --> 00:43:46,319

infinite decimals

1200

00:43:50,550 --> 00:43:48,160

you know and and you're actually working

1201

00:43:53,109 --> 00:43:50,560

in a numerical system

1202

00:43:55,270 --> 00:43:53,119

which is a an approximate decimal system

1203

00:43:57,030 --> 00:43:55,280

which is not the real number system it's

1204

00:43:58,790 --> 00:43:57,040

it's what the computers actually do you

1205

00:44:00,309 --> 00:43:58,800

know you have

1206

00:44:01,430 --> 00:44:00,319

some finite number of decimals and you

1207

00:44:03,349 --> 00:44:01,440

have to work with that and you have to

1208

00:44:05,829 --> 00:44:03,359

deal with truncations and round off and

1209

00:44:07,430 --> 00:44:05,839

and so on so forth right right right

1210

00:44:08,790 --> 00:44:07,440

now there's this physicist i'm not sure

1211

00:44:11,510 --> 00:44:08,800

if you've heard of him his name is

1212

00:44:13,589 --> 00:44:11,520

nicholas jisson

1213

00:44:15,430 --> 00:44:13,599

have you heard of nicholas justin i have

1214

00:44:17,670 --> 00:44:15,440

his argument against the reality of the

1215

00:44:19,190 --> 00:44:17,680

real numbers goes as follows i think

1216

00:44:21,190 --> 00:44:19,200

it's an argument more about discrete

1217

00:44:23,829 --> 00:44:21,200

space-time though i don't know if that's

1218

00:44:25,349 --> 00:44:23,839

exactly the case if an electron carries

1219

00:44:27,270 --> 00:44:25,359

with its space-time point it would have

1220

00:44:28,790 --> 00:44:27,280

to carry an infinite amount of data to

1221

00:44:30,470 --> 00:44:28,800

specify a certain real number and thus

1222

00:44:31,910 --> 00:44:30,480

it would create a black hole now i don't

1223

00:44:33,109 --> 00:44:31,920

know if i buy that argument per se

1224

00:44:35,270 --> 00:44:33,119

because it means that the electron

1225

00:44:36,950 --> 00:44:35,280

carries with it at space-time point i'm

1226  
00:44:37,990 --> 00:44:36,960  
not sure what that means but for people

1227  
00:44:40,150 --> 00:44:38,000  
who feel like what you're saying is

1228  
00:44:42,950 --> 00:44:40,160  
radical in many ways some physicists

1229  
00:44:44,710 --> 00:44:42,960  
already are in line with this thinking i

1230  
00:44:46,950 --> 00:44:44,720  
think you're absolutely right and

1231  
00:44:50,790 --> 00:44:46,960  
you know the 20th century physics has

1232  
00:44:53,190 --> 00:44:50,800  
has um squarely acknowledge the the

1233  
00:44:56,870 --> 00:44:53,200  
the fact that our our our underlying

1234  
00:44:58,550 --> 00:44:56,880  
space time is not infinitely divisible

1235  
00:45:00,870 --> 00:44:58,560  
you see the the cont the model of the

1236  
00:45:03,190 --> 00:45:00,880  
continuum is the real number uh the real

1237  
00:45:06,069 --> 00:45:03,200  
number line it really assumes an

1238  
00:45:07,510 --> 00:45:06,079

essential infinite divisibility of of of

1239

00:45:09,829 --> 00:45:07,520

the line right that's the point and

1240

00:45:10,950 --> 00:45:09,839

you've got as many decimals as you want

1241

00:45:13,349 --> 00:45:10,960

so every time

1242

00:45:15,829 --> 00:45:13,359

you add a decimal you're dividing by ten

1243

00:45:17,589 --> 00:45:15,839

okay but physicists know that that's not

1244

00:45:19,829 --> 00:45:17,599

the way the world is you you get down to

1245

00:45:21,349 --> 00:45:19,839

10 to the minus 30 or whatever and you

1246

00:45:24,150 --> 00:45:21,359

add a planck scale and then and then

1247

00:45:26,069 --> 00:45:24,160

that divisibility just erodes

1248

00:45:28,230 --> 00:45:26,079

i have a physics question for you so in

1249

00:45:30,069 --> 00:45:28,240

quantum mechanics if you have the most

1250

00:45:31,589 --> 00:45:30,079

let's take the most basic wave function

1251

00:45:33,030 --> 00:45:31,599

and let's say that the wave function is

1252

00:45:35,030 --> 00:45:33,040

real some people say the wave function

1253

00:45:36,390 --> 00:45:35,040

is real whatever that means well people

1254

00:45:37,990 --> 00:45:36,400

who believe in the multiverse eight is

1255

00:45:38,950 --> 00:45:38,000

the most real there's only the wave

1256

00:45:40,230 --> 00:45:38,960

function

1257

00:45:42,470 --> 00:45:40,240

okay now let's say we have a simple

1258

00:45:44,390 --> 00:45:42,480

system where it's half half so half up

1259

00:45:47,750 --> 00:45:44,400

half down

1260

00:45:49,430 --> 00:45:47,760

okay then the wave function itself has 1

1261

00:45:51,349 --> 00:45:49,440

over square root of 2 because you have

1262

00:45:53,910 --> 00:45:51,359

to square the wave function to get half

1263

00:45:55,430 --> 00:45:53,920

are you saying that that's 1 over the

1264

00:45:58,309 --> 00:45:55,440

square root of 2

1265

00:45:59,829 --> 00:45:58,319

is not the wave function cannot be that

1266

00:46:02,230 --> 00:45:59,839

because the square root of two does not

1267

00:46:04,950 --> 00:46:02,240

exist

1268

00:46:07,910 --> 00:46:04,960

no no that's um that's that's just to

1269

00:46:10,150 --> 00:46:07,920

obtain a kind of a uniticity um

1270

00:46:15,349 --> 00:46:10,160

unitarity um

1271

00:46:20,390 --> 00:46:18,069

how should i say um

1272

00:46:21,670 --> 00:46:20,400

you you you can easily have equal you

1273

00:46:22,790 --> 00:46:21,680

know extent in this direction equal

1274

00:46:25,109 --> 00:46:22,800

extent in this direction like you can

1275

00:46:27,589 --> 00:46:25,119

have the point one one okay so the point

1276

00:46:30,710 --> 00:46:27,599

one one in the plane okay it's it's

1277

00:46:32,790 --> 00:46:30,720

distance from the origin is is is uh

1278

00:46:34,309 --> 00:46:32,800

square root of two but in rational

1279

00:46:35,990 --> 00:46:34,319

trigonometry which is you know my

1280

00:46:38,230 --> 00:46:36,000

preferred way of thinking about

1281

00:46:40,309 --> 00:46:38,240

metrical geometry it's not the distance

1282

00:46:41,990 --> 00:46:40,319

that matters it's the quadrants it's the

1283

00:46:44,309 --> 00:46:42,000

square of the distance it's the sum of

1284

00:46:46,470 --> 00:46:44,319

the squares okay so

1285

00:46:48,230 --> 00:46:46,480

if you adopt a rational trigonometry

1286

00:46:49,910 --> 00:46:48,240

point of view those kind of objections

1287

00:46:52,550 --> 00:46:49,920

having to do with distance

1288

00:46:53,829 --> 00:46:52,560

more or less disappear

1289

00:46:55,829 --> 00:46:53,839

so this is like

1290

00:46:57,589 --> 00:46:55,839

preferring preferring einstein's

1291

00:46:59,829 --> 00:46:57,599

interval to to the square root of the

1292

00:47:01,510 --> 00:46:59,839

interval you know to not insisting that

1293

00:47:03,430 --> 00:47:01,520

that we we take square roots of our

1294

00:47:05,270 --> 00:47:03,440

metrical quantities just to stick with

1295

00:47:07,349 --> 00:47:05,280

the metrical quantities themselves than

1296

00:47:08,950 --> 00:47:07,359

the natural quadratic ones let's say

1297

00:47:10,790 --> 00:47:08,960

you're speaking to a quantum physicist

1298

00:47:12,470 --> 00:47:10,800

who constantly has to take the square

1299

00:47:14,150 --> 00:47:12,480

root in a sense because the square is

1300

00:47:15,990 --> 00:47:14,160

what the wavefunction's probability is

1301

00:47:16,870 --> 00:47:16,000

the probability distribution is the

1302

00:47:18,710 --> 00:47:16,880

square

1303

00:47:19,990 --> 00:47:18,720

so you're saying that that is the

1304

00:47:21,670 --> 00:47:20,000

fundamental quantity not the

1305

00:47:23,430 --> 00:47:21,680

wavefunction itself

1306

00:47:24,870 --> 00:47:23,440

sorry that is the real quantity the

1307

00:47:26,630 --> 00:47:24,880

probability distribution is the real

1308

00:47:28,470 --> 00:47:26,640

quantity forget it no no i i wouldn't

1309

00:47:30,150 --> 00:47:28,480

say that i would have to be uh better

1310

00:47:31,910 --> 00:47:30,160

versed in in physics and and have an

1311

00:47:33,670 --> 00:47:31,920

opinion on on the nature of quantum

1312

00:47:36,829 --> 00:47:33,680

mechanics um

1313

00:47:39,349 --> 00:47:36,839

to to be able to you know to say that

1314

00:47:41,990 --> 00:47:39,359

um i think it's very interesting but i

1315

00:47:44,390 --> 00:47:42,000

don't have a strong opinion as to the

1316

00:47:46,870 --> 00:47:44,400

the true role of of the wave function

1317

00:47:48,790 --> 00:47:46,880

and how it should be interpreted

1318

00:47:51,270 --> 00:47:48,800

okay so let's talk about

1319

00:47:52,790 --> 00:47:51,280

not precisely about rational geometry i

1320

00:47:54,630 --> 00:47:52,800

believe that's what it's called rational

1321

00:47:55,750 --> 00:47:54,640

geometry rational trigonometry is what i

1322

00:47:57,030 --> 00:47:55,760

call it yeah

1323

00:47:58,470 --> 00:47:57,040

so let's talk about rational

1324

00:48:00,870 --> 00:47:58,480

trigonometry

1325

00:48:02,470 --> 00:48:00,880

not it itself but actually what led you

1326

00:48:03,990 --> 00:48:02,480

to that so you have this knack it's a

1327

00:48:06,390 --> 00:48:04,000

strange knack of saying strange in a

1328

00:48:07,829 --> 00:48:06,400

positive sense to look at what is so

1329

00:48:09,750 --> 00:48:07,839

elementary what's been looked at a

1330

00:48:11,270 --> 00:48:09,760

thousand times to the point now becomes

1331

00:48:13,190 --> 00:48:11,280

overlooked

1332

00:48:14,710 --> 00:48:13,200

and say well what is really going on

1333

00:48:16,630 --> 00:48:14,720

here that's a phrase that you've used

1334

00:48:18,069 --> 00:48:16,640

what is really going on here in fact you

1335

00:48:20,870 --> 00:48:18,079

say that that's a great

1336

00:48:23,990 --> 00:48:20,880

phrase to keep as a mantra as a phd

1337

00:48:26,549 --> 00:48:24,000

student to understand your phd what is

1338

00:48:28,150 --> 00:48:26,559

really going on here now

1339

00:48:30,790 --> 00:48:28,160

see for me if i was to look at something

1340

00:48:32,829 --> 00:48:30,800

as quote unquote simple as the circle i

1341

00:48:34,870 --> 00:48:32,839

would get so bored and i would move

1342

00:48:37,109 --> 00:48:34,880

on however

1343

00:48:39,270 --> 00:48:37,119

you don't have that you you're wondering

1344

00:48:41,430 --> 00:48:39,280

what the heck is going on here so please

1345

00:48:43,430 --> 00:48:41,440

describe to me psychologically where

1346

00:48:45,430 --> 00:48:43,440

does that come from and then what

1347

00:48:47,510 --> 00:48:45,440

insights have you gleaned

1348

00:48:48,390 --> 00:48:47,520

from investigating what ordinarily is

1349

00:48:50,230 --> 00:48:48,400

seen as

1350

00:48:52,870 --> 00:48:50,240

overtrodden ground

1351  
00:48:54,549 --> 00:48:52,880  
ground without any new territory to

1352  
00:48:57,589 --> 00:48:54,559  
explore

1353  
00:48:59,510 --> 00:48:57,599  
okay so let me answer that um in a sort

1354  
00:49:00,950 --> 00:48:59,520  
of a retrospective way i mean the actual

1355  
00:49:02,710 --> 00:49:00,960  
way that i stumbled upon rational

1356  
00:49:04,870 --> 00:49:02,720  
trigonometry was it was somehow a

1357  
00:49:07,750 --> 00:49:04,880  
sequence of accidents and maybe that's

1358  
00:49:08,950 --> 00:49:07,760  
not so interesting but in retrospect i

1359  
00:49:11,670 --> 00:49:08,960  
could say that

1360  
00:49:15,270 --> 00:49:11,680  
um one can be motivated by the desire

1361  
00:49:17,349 --> 00:49:15,280  
for for um generalization and generality

1362  
00:49:18,950 --> 00:49:17,359  
and and sort of universal

1363  
00:49:20,390 --> 00:49:18,960

applicability

1364

00:49:23,109 --> 00:49:20,400

so

1365

00:49:25,349 --> 00:49:23,119

after after um descartes

1366

00:49:28,829 --> 00:49:25,359

cartesian revolution in geometry we've

1367

00:49:31,349 --> 00:49:28,839

we've we've adopted this uh very

1368

00:49:33,750 --> 00:49:31,359

um cartesian point of view where where

1369

00:49:36,230 --> 00:49:33,760

numbers and and everything it depends on

1370

00:49:36,950 --> 00:49:36,240

on on a prior number system

1371

00:49:38,069 --> 00:49:36,960

and

1372

00:49:40,069 --> 00:49:38,079

so the

1373

00:49:41,510 --> 00:49:40,079

the usual uh

1374

00:49:43,109 --> 00:49:41,520

assumption is that okay it's the real

1375

00:49:45,190 --> 00:49:43,119

number system or perhaps from my point

1376  
00:49:47,349 --> 00:49:45,200  
of view the rational number system but

1377  
00:49:49,270 --> 00:49:47,359  
if you're a modern physicist you you

1378  
00:49:51,910 --> 00:49:49,280  
probably want to entertain possibility

1379  
00:49:54,470 --> 00:49:51,920  
of other number systems like like maybe

1380  
00:49:56,549 --> 00:49:54,480  
even finite finite number systems right

1381  
00:49:59,750 --> 00:49:56,559  
maybe the universe is some some finite

1382  
00:50:02,630 --> 00:49:59,760  
automata with some vast number of but

1383  
00:50:04,870 --> 00:50:02,640  
finite pieces in which case it might be

1384  
00:50:06,309 --> 00:50:04,880  
that a finite field is actually a more

1385  
00:50:11,030 --> 00:50:06,319  
appropriate

1386  
00:50:15,910 --> 00:50:14,069  
system in which to model things so so

1387  
00:50:18,549 --> 00:50:15,920  
what can

1388  
00:50:20,790 --> 00:50:18,559

uh aspire what we can aspire to then is

1389

00:50:23,349 --> 00:50:20,800

is to try to create a geometry which is

1390

00:50:25,190 --> 00:50:23,359

so flexible that it will work in

1391

00:50:28,309 --> 00:50:25,200

in different systems that it doesn't

1392

00:50:29,990 --> 00:50:28,319

depend on having a particular underlying

1393

00:50:31,990 --> 00:50:30,000

number system

1394

00:50:33,349 --> 00:50:32,000

and more generally that it works in such

1395

00:50:36,069 --> 00:50:33,359

a way that it doesn't depend on a

1396

00:50:37,750 --> 00:50:36,079

particular quadratic form

1397

00:50:39,750 --> 00:50:37,760

so you know the the properties of the

1398

00:50:42,549 --> 00:50:39,760

euclidean quadratic form where the unit

1399

00:50:44,870 --> 00:50:42,559

circle is is a circle versus say a

1400

00:50:45,589 --> 00:50:44,880

relativistic quadratic form like in like

1401

00:50:49,589 --> 00:50:45,599

th

1402

00:50:51,990 --> 00:50:49,599

you know a unit circle has a has a

1403

00:50:54,710 --> 00:50:52,000

hyperbolic aspect

1404

00:50:56,470 --> 00:50:54,720

that difference should not perhaps be so

1405

00:50:58,230 --> 00:50:56,480

important we should aspire to having a

1406

00:51:00,150 --> 00:50:58,240

theory of trigonometry that works just

1407

00:51:03,190 --> 00:51:00,160

in in the relativistic setting just as

1408

00:51:04,309 --> 00:51:03,200

well as as in the euclidean setting

1409

00:51:06,950 --> 00:51:04,319

now i think it's fair to say that

1410

00:51:09,750 --> 00:51:06,960

physicists have struggled with with this

1411

00:51:12,150 --> 00:51:09,760

because um the the current trigonometry

1412

00:51:13,910 --> 00:51:12,160

is not well suited for for relativistic

1413

00:51:15,910 --> 00:51:13,920

applications

1414

00:51:17,349 --> 00:51:15,920

um but one of the advantages in rational

1415

00:51:20,230 --> 00:51:17,359

trigonometry is that you know you you

1416

00:51:22,069 --> 00:51:20,240

kind of zoom out and and you see what's

1417

00:51:23,670 --> 00:51:22,079

going on in a bigger way and so you see

1418

00:51:25,670 --> 00:51:23,680

that these are all just aspects of the

1419

00:51:27,990 --> 00:51:25,680

same kind of thing and you can basically

1420

00:51:30,150 --> 00:51:28,000

deal with them um sort of all at the

1421

00:51:31,829 --> 00:51:30,160

same time if you set things up correctly

1422

00:51:34,150 --> 00:51:31,839

so you can work over a general field and

1423

00:51:35,829 --> 00:51:34,160

you can work with a general quadratic

1424

00:51:37,829 --> 00:51:35,839

form and you can do that right from the

1425

00:51:39,109 --> 00:51:37,839

beginning if if you set things up this

1426

00:51:41,430 --> 00:51:39,119

way and then and then you cover all

1427

00:51:43,589 --> 00:51:41,440

these things you know at one blow so

1428

00:51:45,990 --> 00:51:43,599

it's just hugely more powerful

1429

00:51:48,470 --> 00:51:46,000

even though you know particular aspects

1430

00:51:49,670 --> 00:51:48,480

of of of something or other

1431

00:51:52,549 --> 00:51:49,680

that

1432

00:51:53,990 --> 00:51:52,559

in the cleaning world might not appear

1433

00:51:55,829 --> 00:51:54,000

because because they're they're not

1434

00:51:57,030 --> 00:51:55,839

general enough

1435

00:51:58,549 --> 00:51:57,040

you know

1436

00:52:00,549 --> 00:51:58,559

so so that's that's that's a big

1437

00:52:03,510 --> 00:52:00,559

advantage i would say that's like a

1438

00:52:06,710 --> 00:52:03,520

a key selling point to the rational

1439

00:52:09,190 --> 00:52:06,720

trigonometry point of view

1440

00:52:11,349 --> 00:52:09,200

a somewhat more subtle

1441

00:52:13,109 --> 00:52:11,359

advantage is that it also makes it

1442

00:52:15,190 --> 00:52:13,119

easier to unite the affine and the

1443

00:52:17,670 --> 00:52:15,200

projective stories

1444

00:52:18,470 --> 00:52:17,680

so in geometry there's largely sort of

1445

00:52:19,910 --> 00:52:18,480

two

1446

00:52:22,309 --> 00:52:19,920

frames of thought there's sort of an

1447

00:52:23,670 --> 00:52:22,319

affine or vector space or linear algebra

1448

00:52:25,910 --> 00:52:23,680

sort of point of view and then there's a

1449

00:52:27,270 --> 00:52:25,920

projective point of view

1450

00:52:29,910 --> 00:52:27,280

and um

1451

00:52:32,549 --> 00:52:29,920

and with with rational trigonometry

1452

00:52:34,549 --> 00:52:32,559

orientation you can you can adapt the

1453

00:52:36,390 --> 00:52:34,559

affine story to the projective story

1454

00:52:38,230 --> 00:52:36,400

much much more easily

1455

00:52:40,390 --> 00:52:38,240

and then what's what's called hyperbolic

1456

00:52:42,390 --> 00:52:40,400

geometry emerges as a natural

1457

00:52:45,829 --> 00:52:42,400

consequence of of

1458

00:52:47,510 --> 00:52:45,839

of the projective side of things

1459

00:52:49,670 --> 00:52:47,520

and that turns out to actually to be uh

1460

00:52:52,390 --> 00:52:49,680

quite closely connected with the

1461

00:52:53,430 --> 00:52:52,400

einstein minkowski kind of geometry so

1462

00:52:57,990 --> 00:52:53,440

that's

1463

00:52:59,990 --> 00:52:58,000

what i was getting at firstly actually

1464

00:53:02,390 --> 00:53:00,000

what is the status of rational

1465

00:53:04,390 --> 00:53:02,400

trigonometry is it a field that that's

1466

00:53:05,910 --> 00:53:04,400

flourishing is it primarily you working

1467

00:53:07,910 --> 00:53:05,920

on it are you having a difficult time

1468

00:53:11,109 --> 00:53:07,920

convincing your colleagues

1469

00:53:13,190 --> 00:53:11,119

oh you look uh it's primarily me and and

1470

00:53:16,549 --> 00:53:13,200

my students um

1471

00:53:18,950 --> 00:53:16,559

it it will i i i'm sure it will uh take

1472

00:53:21,109 --> 00:53:18,960

some time for for people to slowly you

1473

00:53:22,870 --> 00:53:21,119

know come around um

1474

00:53:24,150 --> 00:53:22,880

partly also because i have other

1475

00:53:25,670 --> 00:53:24,160

projects that i'm involved with i'm

1476

00:53:27,030 --> 00:53:25,680

involved with this algebraic calculus

1477

00:53:27,829 --> 00:53:27,040

and these various other things so i'm

1478

00:53:29,829 --> 00:53:27,839

not

1479

00:53:32,230 --> 00:53:29,839

sort of solely concentrating on

1480

00:53:33,750 --> 00:53:32,240

promoting um rational trigonometry and

1481

00:53:36,549 --> 00:53:33,760

going around giving talks about how

1482

00:53:37,670 --> 00:53:36,559

great it is um i've got other things to

1483

00:53:38,470 --> 00:53:37,680

do so

1484

00:53:40,710 --> 00:53:38,480

um

1485

00:53:44,390 --> 00:53:40,720

yeah i mean eventually people will will

1486

00:53:46,150 --> 00:53:44,400

realize that it it's very powerful but

1487

00:53:48,470 --> 00:53:46,160

it will take some time

1488

00:53:51,430 --> 00:53:48,480

for the people who are watching the

1489

00:53:53,589 --> 00:53:51,440

series on norman wildberger's rational

1490

00:53:55,430 --> 00:53:53,599

trigonometry the links are all in the

1491

00:53:57,349 --> 00:53:55,440

descriptions the links to virtually

1492

00:53:59,670 --> 00:53:57,359

every one of whatever we've referenced

1493

00:54:02,390 --> 00:53:59,680

are in the description and you can watch

1494

00:54:04,390 --> 00:54:02,400

that and you can be a champion of it and

1495

00:54:07,270 --> 00:54:04,400

contribute to the field it's a new field

1496

00:54:08,630 --> 00:54:07,280

it's a burgeoning one okay now for my

1497

00:54:11,430 --> 00:54:08,640

second question

1498

00:54:13,190 --> 00:54:11,440

what i was getting at before was

1499

00:54:16,150 --> 00:54:13,200

psychologically what is it that makes

1500

00:54:18,790 --> 00:54:16,160

you go into looking at

1501  
00:54:19,990 --> 00:54:18,800  
babylonian texts and what archimedes

1502  
00:54:22,309 --> 00:54:20,000  
thought i don't know of any

1503  
00:54:24,870 --> 00:54:22,319  
mathematician or any physicist that goes

1504  
00:54:27,109 --> 00:54:24,880  
back that far in fact it's rare to find

1505  
00:54:29,349 --> 00:54:27,119  
even a physicist outside of a tenured

1506  
00:54:31,670 --> 00:54:29,359  
professor who's even looked at newton's

1507  
00:54:33,349 --> 00:54:31,680  
original works you're never assigned a

1508  
00:54:36,390 --> 00:54:33,359  
page of newton you're never assigned a

1509  
00:54:38,309 --> 00:54:36,400  
page of likeness so what is it that as

1510  
00:54:40,069 --> 00:54:38,319  
physicists and mathematicians we just

1511  
00:54:42,150 --> 00:54:40,079  
assume okay well

1512  
00:54:43,670 --> 00:54:42,160  
it's it's all been filtered and we're

1513  
00:54:45,270 --> 00:54:43,680

we're taught to the best of it so we

1514

00:54:48,470 --> 00:54:45,280

don't need to go back to the sources

1515

00:54:50,470 --> 00:54:48,480

what's making you go back to the sources

1516

00:54:53,109 --> 00:54:50,480

well first of all i i'd say i'm not

1517

00:54:53,990 --> 00:54:53,119

alone at all in this i think

1518

00:54:55,829 --> 00:54:54,000

maybe

1519

00:54:57,589 --> 00:54:55,839

as a mathematician mathematicians are

1520

00:54:59,030 --> 00:54:57,599

aware of a very broad history

1521

00:55:00,230 --> 00:54:59,040

mathematics has been around for a long

1522

00:55:02,390 --> 00:55:00,240

time

1523

00:55:05,270 --> 00:55:02,400

astronomy in its in its early days was

1524

00:55:07,430 --> 00:55:05,280

really sort of part of mathematics

1525

00:55:08,870 --> 00:55:07,440

the terms are almost synonymous so we

1526  
00:55:11,829 --> 00:55:08,880  
think of ourselves as having a you know

1527  
00:55:12,630 --> 00:55:11,839  
a 3000 year history

1528  
00:55:14,549 --> 00:55:12,640  
you know

1529  
00:55:17,750 --> 00:55:14,559  
and if you include the babylonians it's

1530  
00:55:19,430 --> 00:55:17,760  
more like four four thousand years

1531  
00:55:21,030 --> 00:55:19,440  
and so there's actually quite a lot of

1532  
00:55:22,950 --> 00:55:21,040  
mathematicians who are quite interested

1533  
00:55:24,710 --> 00:55:22,960  
in in aspects of the history of

1534  
00:55:27,030 --> 00:55:24,720  
mathematics so i don't think i'm unique

1535  
00:55:28,870 --> 00:55:27,040  
at all in that regard uh but with

1536  
00:55:30,950 --> 00:55:28,880  
respect to babylonian mathematics i'm

1537  
00:55:33,430 --> 00:55:30,960  
especially interested in in that well

1538  
00:55:35,510 --> 00:55:33,440

first of all because my initial interest

1539

00:55:37,510 --> 00:55:35,520

was with plympton322 and then the

1540

00:55:39,270 --> 00:55:37,520

realization that with daniel mansfield

1541

00:55:41,349 --> 00:55:39,280

that this was really essentially a

1542

00:55:43,670 --> 00:55:41,359

trigonometric table but sort of along

1543

00:55:45,990 --> 00:55:43,680

the lines something similar or akin to

1544

00:55:48,069 --> 00:55:46,000

to rational trigonometry in you know in

1545

00:55:48,789 --> 00:55:48,079

1800 bc

1546

00:55:50,470 --> 00:55:48,799

but

1547

00:55:52,950 --> 00:55:50,480

another really good reason to think

1548

00:55:55,589 --> 00:55:52,960

about the babylonians is because

1549

00:55:57,670 --> 00:55:55,599

they had this absolutely remarkable

1550

00:56:00,069 --> 00:55:57,680

numerical system i've been talking a lot

1551  
00:56:02,150 --> 00:56:00,079  
about numerical systems right so

1552  
00:56:04,230 --> 00:56:02,160  
we actually have a lot of numerical

1553  
00:56:05,510 --> 00:56:04,240  
systems floating around

1554  
00:56:07,270 --> 00:56:05,520  
currently you know we have we have

1555  
00:56:09,349 --> 00:56:07,280  
integers we have rational numbers we

1556  
00:56:11,589 --> 00:56:09,359  
have we have approximate decimal numbers

1557  
00:56:14,069 --> 00:56:11,599  
we have real numbers et cetera

1558  
00:56:17,109 --> 00:56:14,079  
and for a computer programmer you know

1559  
00:56:19,670 --> 00:56:17,119  
and then there's also binary uh you know

1560  
00:56:21,829 --> 00:56:19,680  
kind of system uh these these uh

1561  
00:56:24,870 --> 00:56:21,839  
different types of number systems are

1562  
00:56:26,630 --> 00:56:24,880  
all probably uh best kept apart and then

1563  
00:56:28,870 --> 00:56:26,640

separate and and and then you have to

1564

00:56:30,390 --> 00:56:28,880

build bridges between them so it's

1565

00:56:33,349 --> 00:56:30,400

really interesting to to find out that

1566

00:56:35,829 --> 00:56:33,359

the babylonians uh 4 000 years ago had

1567

00:56:38,789 --> 00:56:35,839

this other number system this base 60 or

1568

00:56:42,950 --> 00:56:38,799

sexism system which was in in in many

1569

00:56:45,990 --> 00:56:42,960

ways more powerful than than our systems

1570

00:56:49,430 --> 00:56:46,000

this is a a sort of a mind-blowing uh

1571

00:56:51,670 --> 00:56:49,440

fact you know that even today if if you

1572

00:56:53,589 --> 00:56:51,680

if you had to to start from scratch and

1573

00:56:55,670 --> 00:56:53,599

said okay we're going to do math from

1574

00:56:57,829 --> 00:56:55,680

scratch let's decide which number system

1575

00:56:59,910 --> 00:56:57,839

we're going to use should we use base 10

1576

00:57:01,990 --> 00:56:59,920

should we use base 2

1577

00:57:05,430 --> 00:57:02,000

there would be a good argument to be

1578

00:57:06,789 --> 00:57:05,440

made to use the babylonian base 60.

1579

00:57:08,069 --> 00:57:06,799

there would be a very good argument to

1580

00:57:10,230 --> 00:57:08,079

be made i'm not saying that that would

1581

00:57:12,549 --> 00:57:10,240

necessarily prevail but it would be a

1582

00:57:14,230 --> 00:57:12,559

very interesting discussion to have

1583

00:57:16,150 --> 00:57:14,240

and so it's completely fascinating to me

1584

00:57:18,470 --> 00:57:16,160

that these people you know

1585

00:57:20,870 --> 00:57:18,480

so long ago living under what we would

1586

00:57:23,030 --> 00:57:20,880

consider very primitive conditions had

1587

00:57:25,670 --> 00:57:23,040

such an evolved

1588

00:57:26,390 --> 00:57:25,680

mathematical numerical system

1589

00:57:29,910 --> 00:57:26,400

it's

1590

00:57:31,030 --> 00:57:29,920

think that's so intrinsically

1591

00:57:32,470 --> 00:57:31,040

interesting

1592

00:57:34,470 --> 00:57:32,480

besides the many other things that they

1593

00:57:36,549 --> 00:57:34,480

did i mean that's just one one aspect of

1594

00:57:37,910 --> 00:57:36,559

their remarkable culture

1595

00:57:39,990 --> 00:57:37,920

can you give an example of the

1596

00:57:42,309 --> 00:57:40,000

sexagesimal system being better than the

1597

00:57:44,309 --> 00:57:42,319

base 10. some non-interesting there's a

1598

00:57:45,589 --> 00:57:44,319

there's a really good example to keep in

1599

00:57:47,910 --> 00:57:45,599

mind

1600

00:57:49,270 --> 00:57:47,920

when you're learning fractions in school

1601  
00:57:51,109 --> 00:57:49,280  
you know and and actually the

1602  
00:57:52,390 --> 00:57:51,119  
relationship between fractions and

1603  
00:57:54,390 --> 00:57:52,400  
decimals

1604  
00:57:56,950 --> 00:57:54,400  
you learn that most fractions have

1605  
00:57:59,430 --> 00:57:56,960  
uh repeating decimals

1606  
00:58:02,390 --> 00:57:59,440  
that is they are not finite decimals but

1607  
00:58:05,349 --> 00:58:02,400  
some fractions uh have finite decimals

1608  
00:58:08,470 --> 00:58:05,359  
like one quarter that's 0.25 you know or

1609  
00:58:10,470 --> 00:58:08,480  
1 8. and in fact the the fractions with

1610  
00:58:13,510 --> 00:58:10,480  
finite decimals are the the ones with

1611  
00:58:16,470 --> 00:58:13,520  
denominators whose whose um whose

1612  
00:58:18,710 --> 00:58:16,480  
factors are all twos and fives

1613  
00:58:20,150 --> 00:58:18,720

oh i didn't know that yeah so two a if

1614

00:58:22,150 --> 00:58:20,160

you have a denominator and it's a

1615

00:58:24,230 --> 00:58:22,160

product of some power of two and some

1616

00:58:26,230 --> 00:58:24,240

power five then that's going to be what

1617

00:58:28,710 --> 00:58:26,240

we might say a regular number in our

1618

00:58:31,510 --> 00:58:28,720

system is gonna have a finite decimal

1619

00:58:33,829 --> 00:58:31,520

now the the babylonians basically did

1620

00:58:35,510 --> 00:58:33,839

like a decimal arithmetic they didn't

1621

00:58:37,750 --> 00:58:35,520

deal with fractions they did with deal

1622

00:58:40,470 --> 00:58:37,760

with decimals but they were finite

1623

00:58:41,829 --> 00:58:40,480

decimals they had no infinite decimals

1624

00:58:44,549 --> 00:58:41,839

but

1625

00:58:45,910 --> 00:58:44,559

in base 60 since 60 has

1626  
00:58:49,030 --> 00:58:45,920  
factors 2

1627  
00:58:50,950 --> 00:58:49,040  
3 and 5 there's crucially the the factor

1628  
00:58:53,670 --> 00:58:50,960  
three that gets added to the list for

1629  
00:58:56,069 --> 00:58:53,680  
regular numbers in in base 60.

1630  
00:58:58,710 --> 00:58:56,079  
so if you're a babylonian any number

1631  
00:59:00,390 --> 00:58:58,720  
that is made out of just twos threes and

1632  
00:59:01,510 --> 00:59:00,400  
fives if that's in the denominator of

1633  
00:59:05,510 --> 00:59:01,520  
your fraction then you're going to be

1634  
00:59:09,190 --> 00:59:05,520  
able to convert it to a a finite decimal

1635  
00:59:13,750 --> 00:59:11,510  
one over six one over twelve one over

1636  
00:59:16,150 --> 00:59:13,760  
eighteen one over twenty four you the

1637  
00:59:18,950 --> 00:59:16,160  
the number of numbers which are regular

1638  
00:59:21,109 --> 00:59:18,960

in your system is hugely

1639

00:59:22,390 --> 00:59:21,119

more and so you get a much more

1640

00:59:23,670 --> 00:59:22,400

tractable

1641

00:59:25,190 --> 00:59:23,680

arithmetic

1642

00:59:27,750 --> 00:59:25,200

so if you if you have to restrict

1643

00:59:29,670 --> 00:59:27,760

yourself to finite decimals that's very

1644

00:59:32,390 --> 00:59:29,680

restrictive for us because we can't

1645

00:59:34,230 --> 00:59:32,400

capture a lot of fractions that way

1646

00:59:36,230 --> 00:59:34,240

the babylonians could capture a lot of

1647

00:59:38,789 --> 00:59:36,240

fractions that way

1648

00:59:40,630 --> 00:59:38,799

so their their sexagesimal sort of

1649

00:59:43,109 --> 00:59:40,640

decimal arithmetic was

1650

00:59:45,510 --> 00:59:43,119

demonstrably more powerful than ours for

1651

00:59:47,829 --> 00:59:45,520

exactly that reason

1652

00:59:49,270 --> 00:59:47,839

and this this this uh they had tables

1653

00:59:51,430 --> 00:59:49,280

for everything so they had actually

1654

00:59:53,589 --> 00:59:51,440

tables of the reciprocals of like you

1655

00:59:55,910 --> 00:59:53,599

know one over six what what's that as as

1656

00:59:57,670 --> 00:59:55,920

a as a sex adjustment decimal so they

1657

00:59:59,829 --> 00:59:57,680

they had they had lists of all their

1658

01:00:00,950 --> 00:59:59,839

regular numbers and they had and these

1659

01:00:02,230 --> 01:00:00,960

are things that

1660

01:00:03,430 --> 01:00:02,240

all the scribes would have would have

1661

01:00:05,349 --> 01:00:03,440

memorized

1662

01:00:08,069 --> 01:00:05,359

so this this is a very concrete example

1663

01:00:11,589 --> 01:00:08,079

of a powerful

1664

01:00:14,950 --> 01:00:11,599

advantage to the base 60 system

1665

01:00:18,309 --> 01:00:14,960

is there a non-arithmetic example

1666

01:00:20,870 --> 01:00:18,319

like let's say we go all the way to

1667

01:00:23,190 --> 01:00:20,880

complex is complex analysis affected by

1668

01:00:32,309 --> 01:00:26,069

uh is complex analysis affected by this

1669

01:00:36,309 --> 01:00:34,069

i i might have to think about that but

1670

01:00:39,270 --> 01:00:36,319

but generally speaking a lot of like

1671

01:00:40,470 --> 01:00:39,280

once you once you adopt a sensitivity to

1672

01:00:42,630 --> 01:00:40,480

to

1673

01:00:44,789 --> 01:00:42,640

removing real numbers okay

1674

01:00:46,630 --> 01:00:44,799

then then um

1675

01:00:49,109 --> 01:00:46,640

questions like you know things like the

1676

01:00:50,870 --> 01:00:49,119

square root of 2 or the cubed root of 7

1677

01:00:53,109 --> 01:00:50,880

or something have to be constructed

1678

01:00:54,549 --> 01:00:53,119

algebraically if you want an exact

1679

01:00:55,910 --> 01:00:54,559

theory if you're an applied

1680

01:00:57,349 --> 01:00:55,920

mathematician you can still use square

1681

01:00:59,270 --> 01:00:57,359

root of two equals one point four one

1682

01:01:01,510 --> 01:00:59,280

four you know no problem but if you want

1683

01:01:04,069 --> 01:01:01,520

to sort of an exact algebraic system you

1684

01:01:06,150 --> 01:01:04,079

have to start constructing uh what we

1685

01:01:08,390 --> 01:01:06,160

call extension fields

1686

01:01:11,829 --> 01:01:08,400

to to um

1687

01:01:13,589 --> 01:01:11,839

for these these um radicals to to to

1688

01:01:16,390 --> 01:01:13,599

live in

1689

01:01:21,589 --> 01:01:16,400

um and and so a lot of problems in in

1690

01:01:26,470 --> 01:01:23,910

sort of meet meet this issue of whether

1691

01:01:28,549 --> 01:01:26,480

a given number is a square or not this

1692

01:01:30,950 --> 01:01:28,559

is like a critical question you say like

1693

01:01:32,549 --> 01:01:30,960

can you take the square root of seven

1694

01:01:34,470 --> 01:01:32,559

what does that mean it means is there a

1695

01:01:36,150 --> 01:01:34,480

number in your number system whose

1696

01:01:38,309 --> 01:01:36,160

square is seven

1697

01:01:39,270 --> 01:01:38,319

so that's that's a number theoretical um

1698

01:01:40,710 --> 01:01:39,280

issue

1699

01:01:43,910 --> 01:01:40,720

now that's not going to change if you

1700

01:01:46,230 --> 01:01:43,920

change your change your base okay

1701

01:01:48,950 --> 01:01:46,240

okay but it will change if you change

1702

01:01:50,870 --> 01:01:48,960

your number system but

1703

01:01:54,309 --> 01:01:50,880

so

1704

01:01:57,270 --> 01:01:54,319

with a babylonian system in which in

1705

01:01:59,190 --> 01:01:57,280

which the the 60 uh manifests itself in

1706

01:02:01,589 --> 01:01:59,200

terms of some some number theoretical

1707

01:02:03,510 --> 01:02:01,599

property i'm not sure but but my guess

1708

01:02:05,109 --> 01:02:03,520

would be yes because actually there's a

1709

01:02:06,390 --> 01:02:05,119

lot of number theoretical questions that

1710

01:02:09,109 --> 01:02:06,400

are somehow based

1711

01:02:11,910 --> 01:02:09,119

base 10 or oriented but

1712

01:02:13,430 --> 01:02:11,920

maybe they're not that interesting

1713

01:02:15,029 --> 01:02:13,440

this occurs to me right now this may be

1714

01:02:17,190 --> 01:02:15,039

a foolish question given that real

1715

01:02:19,910 --> 01:02:17,200

analysis needs to be revamped in your

1716

01:02:22,470 --> 01:02:19,920

eyes at least yes then see to me this

1717

01:02:24,630 --> 01:02:22,480

word beauty is misused in

1718

01:02:26,630 --> 01:02:24,640

in phsy not maybe it's an aesthetic word

1719

01:02:27,990 --> 01:02:26,640

it's a subjective word so for me to say

1720

01:02:29,990 --> 01:02:28,000

it's misused

1721

01:02:32,150 --> 01:02:30,000

who am i to say some people say string

1722

01:02:33,750 --> 01:02:32,160

theory is beautiful i think the word

1723

01:02:36,870 --> 01:02:33,760

natural is more appropriate when it

1724

01:02:39,190 --> 01:02:36,880

comes to string theory however beauty

1725

01:02:41,029 --> 01:02:39,200

i reserve for complex analysis there's

1726

01:02:42,390 --> 01:02:41,039

something about complex analysis that to

1727

01:02:43,829 --> 01:02:42,400

me is absolutely beautiful though

1728

01:02:45,270 --> 01:02:43,839

unnatural which is strange but we can

1729

01:02:46,470 --> 01:02:45,280

talk about that after let's assume that

1730

01:02:48,069 --> 01:02:46,480

you share that you know what i'm talking

1731

01:02:49,829 --> 01:02:48,079

about when you say compared to real

1732

01:02:51,910 --> 01:02:49,839

analysis complex analysis is beautiful

1733

01:02:53,750 --> 01:02:51,920

and simple now

1734

01:02:55,829 --> 01:02:53,760

does any of that beauty or simplicity

1735

01:02:58,870 --> 01:02:55,839

get removed when we make this change

1736

01:03:00,870 --> 01:02:58,880

from the real numbers to this more

1737

01:03:02,789 --> 01:03:00,880

finite computational approach does

1738

01:03:04,390 --> 01:03:02,799

anything i don't think it does i really

1739

01:03:06,230 --> 01:03:04,400

don't think it does but

1740

01:03:08,630 --> 01:03:06,240

that's a little bit of an optimistic

1741

01:03:10,710 --> 01:03:08,640

statement because it it does involve

1742

01:03:12,710 --> 01:03:10,720

people having to go over things and and

1743

01:03:14,630 --> 01:03:12,720

and go over all the traditional theories

1744

01:03:15,990 --> 01:03:14,640

and say well how are we going to

1745

01:03:17,270 --> 01:03:16,000

redo this how are we going to state

1746

01:03:18,549 --> 01:03:17,280

these things how are we going to capture

1747

01:03:20,630 --> 01:03:18,559

these ideas

1748

01:03:22,470 --> 01:03:20,640

without uh assuming that we can do an

1749

01:03:24,390 --> 01:03:22,480

infinite number of things

1750

01:03:26,789 --> 01:03:24,400

but i i do believe that that the

1751

01:03:28,549 --> 01:03:26,799

intrinsic beauty of complex numbers will

1752

01:03:30,630 --> 01:03:28,559

complex number analysis will shine

1753

01:03:31,990 --> 01:03:30,640

through in any case

1754

01:03:33,990 --> 01:03:32,000

maybe it becomes more beautiful who

1755

01:03:35,990 --> 01:03:34,000

knows it becomes yes i believe it'll

1756

01:03:38,470 --> 01:03:36,000

become more beautiful because the the

1757

01:03:39,670 --> 01:03:38,480

essential aspect of it will will become

1758

01:03:42,230 --> 01:03:39,680

clearer

1759

01:03:44,950 --> 01:03:42,240

see complex analysis in complex analysis

1760

01:03:46,309 --> 01:03:44,960

um so-called analytic functions play a

1761

01:03:47,670 --> 01:03:46,319

bigger role than they do in real

1762

01:03:49,910 --> 01:03:47,680

analysis

1763

01:03:51,349 --> 01:03:49,920

so an analytic function is like the

1764

01:03:53,349 --> 01:03:51,359

one i showed you i've been showing you

1765

01:03:56,309 --> 01:03:53,359

on my site workplace things that have

1766

01:03:58,549 --> 01:03:56,319

power series roughly okay and in complex

1767

01:04:00,390 --> 01:03:58,559

analysis you have a lot of reasons to to

1768

01:04:01,349 --> 01:04:00,400

restrict yourself to analytic functions

1769

01:04:04,870 --> 01:04:01,359

they have all these remarkable

1770

01:04:08,470 --> 01:04:04,880

properties in real analysis uh less so

1771

01:04:10,870 --> 01:04:08,480

and so in real analysis there's often

1772

01:04:12,230 --> 01:04:10,880

people use bump functions that that have

1773

01:04:14,069 --> 01:04:12,240

compact support that they're so

1774

01:04:16,390 --> 01:04:14,079

so-called  $C^\infty$  that means they're

1775

01:04:17,829 --> 01:04:16,400

smooth okay they're still smooth you

1776

01:04:19,990 --> 01:04:17,839

know they're very nice but they have

1777

01:04:22,230 --> 01:04:20,000

compact support and so these are sort of

1778

01:04:24,710 --> 01:04:22,240

technical tools that um that are used

1779

01:04:27,190 --> 01:04:24,720

but but they're not analytic

1780

01:04:29,190 --> 01:04:27,200

and so it it means that we're

1781

01:04:32,710 --> 01:04:29,200

we're kind of going beyond that that

1782

01:04:34,470 --> 01:04:32,720

that pleasant polynomial um

1783

01:04:38,789 --> 01:04:34,480

aspect that that was so attractive to

1784

01:04:41,829 --> 01:04:38,799

newton and and to euler and to lagrange

1785

01:04:43,510 --> 01:04:41,839

so that's that's that's a kind of a a

1786

01:04:45,510 --> 01:04:43,520

difference between the real analysis and

1787

01:04:47,190 --> 01:04:45,520

the complex analysis i think that we can

1788

01:04:49,670 --> 01:04:47,200

we can appreciate that the complex

1789

01:04:51,750 --> 01:04:49,680

analysis sort of has this more natural

1790

01:04:53,750 --> 01:04:51,760

analytic aspect

1791

01:04:56,150 --> 01:04:53,760

which is very like in my algebraic

1792

01:04:57,190 --> 01:04:56,160

calculus course which i'm trying to redo

1793

01:05:00,950 --> 01:04:57,200

calculus

1794

01:05:03,430 --> 01:05:00,960

this polynomial uh orientation is is is

1795

01:05:05,829 --> 01:05:03,440

is a key kind of thing we really want to

1796

01:05:07,670 --> 01:05:05,839

understand the polynomial story as a

1797

01:05:08,630 --> 01:05:07,680

stepping stone to the to the analytic

1798

01:05:10,789 --> 01:05:08,640

story

1799

01:05:13,029 --> 01:05:10,799

and and that's really where the main

1800

01:05:14,870 --> 01:05:13,039

interest lies

1801

01:05:16,549 --> 01:05:14,880

for the people watching again the link

1802

01:05:19,029 --> 01:05:16,559

to the algebraic calculus course will be

1803

01:05:20,150 --> 01:05:19,039

in the description and norman

1804

01:05:21,349 --> 01:05:20,160

sorry to call you normally i mean

1805

01:05:23,589 --> 01:05:21,359

professor

1806

01:05:25,270 --> 01:05:23,599

please let me know

1807

01:05:28,230 --> 01:05:25,280

norman has

1808

01:05:29,750 --> 01:05:28,240

an ability to make these abstruse topics

1809

01:05:32,230 --> 01:05:29,760

extremely

1810

01:05:33,750 --> 01:05:32,240

simple it's not an easy task so i

1811

01:05:35,510 --> 01:05:33,760

believe i was looking at your algebraic

1812

01:05:37,270 --> 01:05:35,520

topology course was it do you have a

1813

01:05:39,029 --> 01:05:37,280

course in algebraic to one where one of

1814

01:05:40,710 --> 01:05:39,039

the first lessons were on cycles and so

1815

01:05:43,670 --> 01:05:40,720

on and i was just thinking man that

1816

01:05:44,950 --> 01:05:43,680

that's abs remarkably simple and maybe

1817

01:05:47,349 --> 01:05:44,960

you don't i don't know if you see that

1818

01:05:50,710 --> 01:05:47,359

but i'm sure you get the feedback that

1819

01:05:53,270 --> 01:05:50,720

this is made clear it's lucid

1820

01:05:56,470 --> 01:05:53,280

oh well thank you kurt um yeah well i i

1821

01:05:58,230 --> 01:05:56,480

think perhaps i can ascribe that to my

1822

01:05:59,910 --> 01:05:58,240

relative simple-minded

1823

01:06:02,710 --> 01:05:59,920

nature and my

1824

01:06:04,630 --> 01:06:02,720

propensity to forget things

1825

01:06:06,870 --> 01:06:04,640

so in order for something to stick in my

1826

01:06:09,190 --> 01:06:06,880

mind i have to figure out uh kind of a

1827

01:06:10,789 --> 01:06:09,200

simple way of thinking about it

1828

01:06:13,109 --> 01:06:10,799

you know it's well there's benefits in

1829

01:06:15,109 --> 01:06:13,119

not being too smart actually i think you

1830

01:06:16,950 --> 01:06:15,119

know that you have to kind of organize

1831

01:06:18,069 --> 01:06:16,960

things uh so that you so that you know

1832

01:06:19,910 --> 01:06:18,079

where things are you can't remember

1833

01:06:21,670 --> 01:06:19,920

where things are so you organize them so

1834

01:06:23,990 --> 01:06:21,680

that they're in the right place and

1835

01:06:25,510 --> 01:06:24,000

somehow i think of of mathematics a

1836

01:06:28,630 --> 01:06:25,520

little bit like that our job is to

1837

01:06:31,109 --> 01:06:28,640

organize stuff in in in natural ways so

1838

01:06:32,950 --> 01:06:31,119

that so that things are easy to find and

1839

01:06:34,630 --> 01:06:32,960

so that everything is sort of natural so

1840

01:06:37,349 --> 01:06:34,640

you can sort of see what the next step

1841

01:06:40,309 --> 01:06:37,359

is before you actually get there

1842

01:06:42,230 --> 01:06:40,319

i'm not a big fan of brilliance actually

1843

01:06:43,910 --> 01:06:42,240

you know i don't think math should be

1844

01:06:44,870 --> 01:06:43,920

one sequence of brilliant things after

1845

01:06:47,190 --> 01:06:44,880

the other i think that's a

1846

01:06:49,029 --> 01:06:47,200

misrepresentation i think what we really

1847

01:06:51,109 --> 01:06:49,039

want to aspire to is something that's

1848

01:06:53,349 --> 01:06:51,119

that's so simple and everything's laid

1849

01:06:54,710 --> 01:06:53,359

out and it's completely obvious and you

1850

01:06:56,789 --> 01:06:54,720

know i know exactly what he's going to

1851

01:06:58,789 --> 01:06:56,799

say now you know

1852

01:07:01,109 --> 01:06:58,799

that kind of thing

1853

01:07:03,109 --> 01:07:01,119

that's what we can aspire to but of

1854

01:07:05,029 --> 01:07:03,119

course it's not so easy but well you're

1855

01:07:06,470 --> 01:07:05,039

gifted in that respect

1856

01:07:07,190 --> 01:07:06,480

i don't know of many

1857

01:07:11,270 --> 01:07:07,200

see

1858

01:07:12,950 --> 01:07:11,280

a minor point to you but it's a major

1859

01:07:15,270 --> 01:07:12,960

point to those who are watching lectures

1860

01:07:17,750 --> 01:07:15,280

online is that your videos have great

1861

01:07:19,910 --> 01:07:17,760

audio and great video and there are some

1862

01:07:22,069 --> 01:07:19,920

lectures that i would love to watch by

1863

01:07:24,150 --> 01:07:22,079

people like witton and their let's say

1864

01:07:25,750 --> 01:07:24,160

the titans of a certain field and you

1865

01:07:27,510 --> 01:07:25,760

can't watch it because the audio in the

1866

01:07:29,349 --> 01:07:27,520

video it's like from the 60s even was

1867

01:07:31,589 --> 01:07:29,359

filmed 10 years ago

1868

01:07:33,589 --> 01:07:31,599

yeah i commend you on the attention you

1869

01:07:35,349 --> 01:07:33,599

put it shows that you actually care

1870

01:07:37,349 --> 01:07:35,359

about the people who are watching your

1871

01:07:39,430 --> 01:07:37,359

students or your prospective students

1872

01:07:40,950 --> 01:07:39,440

the virtual students

1873

01:07:42,470 --> 01:07:40,960

you've invested some time and some

1874

01:07:45,990 --> 01:07:42,480

energy into how do i make this a

1875

01:07:49,990 --> 01:07:47,910

i think it's interesting going beyond

1876

01:07:52,150 --> 01:07:50,000

that i mean i think these days more and

1877

01:07:54,549 --> 01:07:52,160

more there's um channels which are which

1878

01:07:56,870 --> 01:07:54,559

are much you know better at that kind of

1879

01:07:59,270 --> 01:07:56,880

thing than i than mine where where

1880

01:08:01,750 --> 01:07:59,280

people utilize graphics in in really uh

1881

01:08:03,510 --> 01:08:01,760

remarkable ways those humanity and

1882

01:08:06,150 --> 01:08:03,520

illustrate things uh you know and i

1883

01:08:08,150 --> 01:08:06,160

think that's such a powerful um

1884

01:08:09,910 --> 01:08:08,160

tool in fact if i had unlimited amounts

1885

01:08:11,589 --> 01:08:09,920

of time i would probably do that too but

1886

01:08:13,270 --> 01:08:11,599

i just don't have time to do that so you

1887

01:08:14,390 --> 01:08:13,280

know i have to kind of have a bare bones

1888

01:08:16,229 --> 01:08:14,400

approach but

1889

01:08:18,229 --> 01:08:16,239

i do think you know educational

1890

01:08:20,550 --> 01:08:18,239

institutions should be watching what's

1891

01:08:22,229 --> 01:08:20,560

going on here on youtube very carefully

1892

01:08:23,430 --> 01:08:22,239

because

1893

01:08:26,870 --> 01:08:23,440

you know

1894

01:08:28,630 --> 01:08:26,880

a lot of learning is is now

1895

01:08:30,470 --> 01:08:28,640

potentially possible on youtube it's

1896

01:08:31,990 --> 01:08:30,480

like a golden age that we're living in

1897

01:08:33,990 --> 01:08:32,000

you know people can watch your channel

1898

01:08:36,550 --> 01:08:34,000

it can be exposed to all kinds of

1899

01:08:38,309 --> 01:08:36,560

remarkable ideas and thoughts and you

1900

01:08:41,110 --> 01:08:38,319

know and we can spend our time in

1901

01:08:43,910 --> 01:08:41,120

ultimately really productive ways

1902

01:08:46,789 --> 01:08:43,920

and increasingly especially with um

1903

01:08:48,550 --> 01:08:46,799

with good graphics and and other things

1904

01:08:50,309 --> 01:08:48,560

you know i think the potential for

1905

01:08:51,510 --> 01:08:50,319

learning is it's just going to keep on

1906

01:08:53,269 --> 01:08:51,520

increasing

1907

01:08:54,309 --> 01:08:53,279

it's really remarkable time that we live

1908

01:08:58,630 --> 01:08:54,319

in

1909

01:09:00,709 --> 01:08:58,640

analysis i would like to get back to

1910

01:09:02,550 --> 01:09:00,719

that quickly there's a field called

1911

01:09:04,829 --> 01:09:02,560

non-standard analysis do you have gripes

1912

01:09:08,229 --> 01:09:04,839

with that field and if so what are

1913

01:09:11,430 --> 01:09:08,239

they look i i have um a lot of sympathy

1914

01:09:13,110 --> 01:09:11,440

for that field but i also have have some

1915

01:09:15,269 --> 01:09:13,120

reservations also

1916

01:09:17,749 --> 01:09:15,279

um so non-standard analysis i we can

1917

01:09:20,070 --> 01:09:17,759

trace that back to to to leibniz and

1918

01:09:21,749 --> 01:09:20,080

newton you know with differentials and

1919

01:09:23,030 --> 01:09:21,759

infinitesimals

1920

01:09:24,149 --> 01:09:23,040

and in some sense people have been

1921

01:09:26,950 --> 01:09:24,159

trying to

1922

01:09:28,870 --> 01:09:26,960

to uh get past the 17th century

1923

01:09:30,709 --> 01:09:28,880

objections that people had to the

1924

01:09:32,789 --> 01:09:30,719

calculus for for a long time and and

1925

01:09:34,470 --> 01:09:32,799

that's that's one way of doing it and i

1926

01:09:36,789 --> 01:09:34,480

think that's actually quite an important

1927

01:09:39,510 --> 01:09:36,799

uh thing to do because physicists and

1928

01:09:41,910 --> 01:09:39,520

engineers love to use

1929

01:09:43,990 --> 01:09:41,920

differential kind of analysis

1930

01:09:46,390 --> 01:09:44,000

you know we have you know this is sigma

1931

01:09:48,070 --> 01:09:46,400

and we we change it by  $d\sigma$  so now we

1932

01:09:50,709 --> 01:09:48,080

have sigma plus  $d\sigma$  you know and

1933

01:09:52,870 --> 01:09:50,719

then you treat  $d\sigma$  as a small but

1934

01:09:54,149 --> 01:09:52,880

but non-zero infinitesimal object

1935

01:09:56,709 --> 01:09:54,159

effectively

1936

01:09:58,070 --> 01:09:56,719

so i have my own uh take on this i i've

1937

01:10:00,229 --> 01:09:58,080

talked a little bit about this i think

1938

01:10:03,430 --> 01:10:00,239

in one in my famous math problems uh

1939

01:10:05,669 --> 01:10:03,440

series uh constructing infinitesimals or

1940

01:10:07,350 --> 01:10:05,679

something there's algebraic ways of

1941

01:10:08,870 --> 01:10:07,360

doing that and it's basically using

1942

01:10:09,830 --> 01:10:08,880

matrix theory so

1943

01:10:15,669 --> 01:10:09,840

um

1944

01:10:17,510 --> 01:10:15,679

we have square roots of things well

1945

01:10:19,430 --> 01:10:17,520

similarly you can extend the number

1946

01:10:21,990 --> 01:10:19,440

systems so that you can create infinite

1947

01:10:23,030 --> 01:10:22,000

decimals and and from my view this is

1948

01:10:25,110 --> 01:10:23,040

the right way thinking about

1949

01:10:28,070 --> 01:10:25,120

infinitesimals there there are objects

1950

01:10:30,390 --> 01:10:28,080

that you create out of matrices

1951

01:10:32,149 --> 01:10:30,400

typically nil potent matrices that have

1952

01:10:34,390 --> 01:10:32,159

the property that their square is one or

1953

01:10:35,110 --> 01:10:34,400

their cube is one or some such thing

1954

01:10:36,390 --> 01:10:35,120

and

1955

01:10:38,310 --> 01:10:36,400

you know what if you do this in the

1956

01:10:41,270 --> 01:10:38,320

right way then it becomes

1957

01:10:42,709 --> 01:10:41,280

very understandable and and cut and dry

1958

01:10:44,550 --> 01:10:42,719

there's nothing mysterious about it

1959

01:10:46,470 --> 01:10:44,560

anymore

1960

01:10:48,310 --> 01:10:46,480

you know so so i have a lot of sympathy

1961

01:10:50,709 --> 01:10:48,320

with with the non-standard analysis

1962

01:10:52,470 --> 01:10:50,719

approach however the actual non-standard

1963

01:10:54,790 --> 01:10:52,480

analysis approach which is based on set

1964

01:10:57,270 --> 01:10:54,800

theory and uh and ultra filters and so

1965

01:10:59,669 --> 01:10:57,280

on and so forth uh those

1966

01:11:02,470 --> 01:10:59,679

those concepts are are

1967

01:11:04,630 --> 01:11:02,480

beyond what i would consider as as

1968

01:11:06,709 --> 01:11:04,640

something i'm comfortable with

1969

01:11:08,070 --> 01:11:06,719

you're not a fan of set theory now i

1970

01:11:10,630 --> 01:11:08,080

understand the axiom of choice but

1971

01:11:12,550 --> 01:11:10,640

you're not a fan of zf

1972

01:11:14,390 --> 01:11:12,560

no i'm not a fan of cf at all

1973

01:11:16,149 --> 01:11:14,400

okay i'll line to the audience wyatt

1974

01:11:18,709 --> 01:11:16,159

please

1975

01:11:20,070 --> 01:11:18,719

well you know like my view is that is

1976

01:11:24,630 --> 01:11:20,080

that

1977

01:11:26,870 --> 01:11:24,640

mathematics is based on axioms

1978

01:11:28,310 --> 01:11:26,880

so this is something i talk about a lot

1979

01:11:29,510 --> 01:11:28,320

but

1980

01:11:31,189 --> 01:11:29,520

i don't think mathematics should be

1981

01:11:33,270 --> 01:11:31,199

based on axioms what is an axiom an

1982

01:11:35,430 --> 01:11:33,280

axiom is an assumption okay you're

1983

01:11:37,510 --> 01:11:35,440

making some basic assumption about what

1984

01:11:39,030 --> 01:11:37,520

you're studying and i in my view that's

1985

01:11:40,390 --> 01:11:39,040

not necessary you don't need to make any

1986

01:11:41,830 --> 01:11:40,400

assumptions in fact you shouldn't make

1987

01:11:43,669 --> 01:11:41,840

any assumptions

1988

01:11:45,750 --> 01:11:43,679

just the way a scientist should not you

1989

01:11:47,830 --> 01:11:45,760

know go out in the field and have a

1990

01:11:49,910 --> 01:11:47,840

ready-made

1991

01:11:52,310 --> 01:11:49,920

okay bunch of assumptions you know one

1992

01:11:54,470 --> 01:11:52,320

should be assumption free and one should

1993

01:11:57,510 --> 01:11:54,480

one should observe carefully and one

1994

01:11:59,750 --> 01:11:57,520

should be very clear about definitions

1995

01:12:01,030 --> 01:11:59,760

okay that's really important but i don't

1996

01:12:02,310 --> 01:12:01,040

think there's any need to make

1997

01:12:03,750 --> 01:12:02,320

assumptions that that's just

1998

01:12:05,270 --> 01:12:03,760

representing some kind of fundamental

1999

01:12:07,110 --> 01:12:05,280

confusion

2000

01:12:08,870 --> 01:12:07,120

now admittedly

2001

01:12:10,470 --> 01:12:08,880

you have to start somewhere so you know

2002

01:12:14,070 --> 01:12:10,480

there has to be some initial discussion

2003

01:12:15,270 --> 01:12:14,080

as to how to to set things up initially

2004

01:12:16,790 --> 01:12:15,280

and i think

2005

01:12:19,110 --> 01:12:16,800

the sensible thing these days is to

2006

01:12:21,430 --> 01:12:19,120

start with the arithmetic of natural

2007

01:12:22,630 --> 01:12:21,440

numbers and that's i think more or less

2008

01:12:24,550 --> 01:12:22,640

the consensus you know that's a

2009

01:12:26,790 --> 01:12:24,560

reasonable place to start

2010

01:12:28,550 --> 01:12:26,800

um but we don't need we don't need set

2011

01:12:30,870 --> 01:12:28,560

theory for that set theory is a very

2012

01:12:32,310 --> 01:12:30,880

attractive branch of combinatorics as

2013

01:12:34,390 --> 01:12:32,320

far as i'm concerned you know there's

2014

01:12:36,470 --> 01:12:34,400

there's combinatorics and there's sort

2015

01:12:38,229 --> 01:12:36,480

of data structures and in data

2016

01:12:39,910 --> 01:12:38,239

structures there's there's set theory

2017

01:12:42,229 --> 01:12:39,920

there's multi-set theory there's list

2018

01:12:43,830 --> 01:12:42,239

theory uh there's there's ordered set

2019

01:12:45,990 --> 01:12:43,840

theory so there's there's these

2020

01:12:49,030 --> 01:12:46,000

different you know just another

2021

01:12:51,350 --> 01:12:49,040

kind of data collection that we that

2022

01:12:52,790 --> 01:12:51,360

we can manipulate and utilize for our

2023

01:12:54,310 --> 01:12:52,800

constructions

2024

01:12:56,390 --> 01:12:54,320

but this idea that it's somehow the

2025

01:12:58,470 --> 01:12:56,400

foundation of mathematics that we should

2026

01:12:59,430 --> 01:12:58,480

be you know framing everything in terms

2027

01:13:02,310 --> 01:12:59,440

of that

2028

01:13:03,990 --> 01:13:02,320

that's just not the way it happens

2029

01:13:05,750 --> 01:13:04,000

if you look at modern papers you'll see

2030

01:13:08,149 --> 01:13:05,760

that they don't actually they don't

2031

01:13:10,870 --> 01:13:08,159

actually reference zf you know

2032

01:13:12,630 --> 01:13:10,880

almost nobody does that um

2033

01:13:14,310 --> 01:13:12,640

it's more uh

2034

01:13:16,550 --> 01:13:14,320

a kind of you know when philosophers

2035

01:13:19,030 --> 01:13:16,560

press us we say okay look we believe in

2036

01:13:21,030 --> 01:13:19,040

zf now leave us leave us alone there's

2037

01:13:22,950 --> 01:13:21,040

one example in physics that i know of

2038

01:13:24,630 --> 01:13:22,960

where the axiom of choice is used there

2039

01:13:26,390 --> 01:13:24,640

might be multiple but i think it's to

2040

01:13:27,990 --> 01:13:26,400

say that a module has a basis and i

2041

01:13:28,870 --> 01:13:28,000

forget exactly what yeah the axiom of

2042

01:13:30,470 --> 01:13:28,880

choice

2043

01:13:33,270 --> 01:13:30,480

plays a very special role the axiom of

2044

01:13:35,110 --> 01:13:33,280

choice is basically uh an embodiment of

2045

01:13:36,550 --> 01:13:35,120

that very principle that i said that we

2046

01:13:38,709 --> 01:13:36,560

should avoid

2047

01:13:40,709 --> 01:13:38,719

namely this this conceit that we're able

2048

01:13:41,990 --> 01:13:40,719

to do an infinite number of things you

2049

01:13:43,350 --> 01:13:42,000

know you're not able to do an infinite

2050

01:13:45,750 --> 01:13:43,360

number of things so there's no point in

2051  
01:13:47,430 --> 01:13:45,760  
pretending but the axiom of choice you

2052  
01:13:49,669 --> 01:13:47,440  
know puts the finger on and says let us

2053  
01:13:51,830 --> 01:13:49,679  
all officially pretend that we can do an

2054  
01:13:53,750 --> 01:13:51,840  
infinite number of independent things

2055  
01:13:55,990 --> 01:13:53,760  
everybody agreed

2056  
01:13:58,550 --> 01:13:56,000  
okay we're all agreed okay now that so

2057  
01:14:00,709 --> 01:13:58,560  
yeah sure that allows you to do to to do

2058  
01:14:01,910 --> 01:14:00,719  
all kinds of things but do in quotes

2059  
01:14:03,510 --> 01:14:01,920  
you're not actually doing them you're

2060  
01:14:05,270 --> 01:14:03,520  
talking about things

2061  
01:14:06,470 --> 01:14:05,280  
you know because you still can't do an

2062  
01:14:08,390 --> 01:14:06,480  
infinite number of things you can talk

2063  
01:14:10,709 --> 01:14:08,400

about it and that's all

2064

01:14:12,830 --> 01:14:10,719

so anything that's based on the axiom of

2065

01:14:15,669 --> 01:14:12,840

choice is in my view

2066

01:14:17,110 --> 01:14:15,679

uh highly suspect

2067

01:14:19,830 --> 01:14:17,120

and unfortunately that there's quite a

2068

01:14:21,430 --> 01:14:19,840

lot of that um floating around we can

2069

01:14:24,149 --> 01:14:21,440

have another podcast just about what it

2070

01:14:26,310 --> 01:14:24,159

means to do i think that's a fun

2071

01:14:28,390 --> 01:14:26,320

just discursively speculatively before

2072

01:14:30,870 --> 01:14:28,400

we get to the audience questions what do

2073

01:14:33,030 --> 01:14:30,880

you make of penrose's argument against

2074

01:14:34,790 --> 01:14:33,040

the computational nature of reality he's

2075

01:14:37,669 --> 01:14:34,800

a huge fan of the real numbers and

2076

01:14:40,709 --> 01:14:37,679

continuity and i believe see i emailed

2077

01:14:42,310 --> 01:14:40,719

ed whitton prior to this and i said what

2078

01:14:43,830 --> 01:14:42,320

do you think of ultra finitism and

2079

01:14:45,669 --> 01:14:43,840

norman weilberger's views and i sent him

2080

01:14:47,990 --> 01:14:45,679

a video and he basically said he doesn't

2081

01:14:50,870 --> 01:14:48,000

concern himself with this

2082

01:14:52,709 --> 01:14:50,880

okay so people like penrose concern

2083

01:14:54,870 --> 01:14:52,719

himself and decide in favor of real

2084

01:14:57,189 --> 01:14:54,880

numbers people like ed whitton

2085

01:14:59,510 --> 01:14:57,199

say i'm not even concerned about it so

2086

01:15:01,110 --> 01:14:59,520

why do you think it is that some of the

2087

01:15:02,470 --> 01:15:01,120

greatest physicists in particular these

2088

01:15:05,110 --> 01:15:02,480

are only physicists that i'm outlining

2089

01:15:06,709 --> 01:15:05,120

they'll add borders on the mathematician

2090

01:15:09,270 --> 01:15:06,719

side why do you think they

2091

01:15:11,510 --> 01:15:09,280

don't pay attention to the issues that

2092

01:15:14,229 --> 01:15:11,520

you're raising i think for a very good

2093

01:15:16,470 --> 01:15:14,239

reason and i don't blame them one one

2094

01:15:18,709 --> 01:15:16,480

one iota because

2095

01:15:21,189 --> 01:15:18,719

when when we're considering uh like that

2096

01:15:23,270 --> 01:15:21,199

go back to an infinite decimal right to

2097

01:15:25,350 --> 01:15:23,280

a physicist every single

2098

01:15:27,910 --> 01:15:25,360

decimal digit is one tenth the size of

2099

01:15:29,510 --> 01:15:27,920

the previous one we're going in scale so

2100

01:15:31,830 --> 01:15:29,520

as you march down the sequence of

2101

01:15:34,709 --> 01:15:31,840

decimals those those entries are

2102

01:15:36,229 --> 01:15:34,719

becoming less and less important to the

2103

01:15:37,830 --> 01:15:36,239

actual

2104

01:15:39,910 --> 01:15:37,840

role that that number is playing in

2105

01:15:41,350 --> 01:15:39,920

whatever you're looking at

2106

01:15:43,750 --> 01:15:41,360

you know it's the first digits which are

2107

01:15:45,990 --> 01:15:43,760

most important and then then their their

2108

01:15:47,910 --> 01:15:46,000

importance decreases as we go on

2109

01:15:50,310 --> 01:15:47,920

and so by by the time we were down to

2110

01:15:52,870 --> 01:15:50,320

the 30th decimal digits

2111

01:15:55,669 --> 01:15:52,880

we have we are no longer interested in

2112

01:15:57,910 --> 01:15:55,679

in in what that that 31st digit is it

2113

01:15:59,669 --> 01:15:57,920

just doesn't interest us and and any

2114

01:16:02,070 --> 01:15:59,679

questions about whether these decimal

2115

01:16:04,149 --> 01:16:02,080

digits go on to infinity or or not is is

2116

01:16:05,990 --> 01:16:04,159

to a physicist completely irrelevant

2117

01:16:08,950 --> 01:16:06,000

because it's not going to affect them in

2118

01:16:10,709 --> 01:16:08,960

any fashion whatsoever

2119

01:16:13,110 --> 01:16:10,719

you know so the physicist is quite happy

2120

01:16:14,709 --> 01:16:13,120

to play along and we'll use e and pi and

2121

01:16:16,470 --> 01:16:14,719

so on but they'll just immediately

2122

01:16:18,390 --> 01:16:16,480

truncate them and then use some finite

2123

01:16:20,390 --> 01:16:18,400

decimal approximation to to solve

2124

01:16:22,470 --> 01:16:20,400

whatever problem they're working on so

2125

01:16:24,229 --> 01:16:22,480

it's it's still a physicist a

2126

01:16:27,750 --> 01:16:24,239

philosophical point

2127

01:16:30,709 --> 01:16:27,760

so i i i completely uh see why edwin

2128

01:16:32,550 --> 01:16:30,719

doesn't concern himself with such things

2129

01:16:35,270 --> 01:16:32,560

yeah and that was

2130

01:16:37,750 --> 01:16:35,280

what you're outlining is is my view in

2131

01:16:40,950 --> 01:16:37,760

that even theoretical physicists are

2132

01:16:43,430 --> 01:16:40,960

practical in a sense where

2133

01:16:44,390 --> 01:16:43,440

they don't care too much about whether

2134

01:16:48,709 --> 01:16:44,400

or not

2135

01:16:50,630 --> 01:16:48,719

it allows them to predict something now

2136

01:16:52,229 --> 01:16:50,640

i know theoretical views you can

2137

01:16:53,590 --> 01:16:52,239

excoriate physicists for saying well

2138

01:16:54,550 --> 01:16:53,600

your string theory doesn't predict

2139

01:16:57,430 --> 01:16:54,560

anything

2140

01:17:00,950 --> 01:16:57,440

forget about that so i was viewing the

2141

01:17:03,030 --> 01:17:00,960

reals and continuity etc as almost like

2142

01:17:04,870 --> 01:17:03,040

i mentioned like an architecture an

2143

01:17:07,110 --> 01:17:04,880

architect designs a building it's a

2144

01:17:08,390 --> 01:17:07,120

design tool and then

2145

01:17:10,229 --> 01:17:08,400

we know that later we're going to

2146

01:17:11,430 --> 01:17:10,239

approximate it it allows us to simply

2147

01:17:13,030 --> 01:17:11,440

calculate

2148

01:17:14,229 --> 01:17:13,040

so you're saying your problems aren't

2149

01:17:16,470 --> 01:17:14,239

with them your problems are mainly with

2150

01:17:18,390 --> 01:17:16,480

the pure mathematicians who believe oh

2151

01:17:20,870 --> 01:17:18,400

absolutely absolutely i i i think

2152

01:17:23,030 --> 01:17:20,880

applied mathematically physicists

2153

01:17:23,830 --> 01:17:23,040

you just carry on you're doing great um

2154

01:17:25,669 --> 01:17:23,840

you know

2155

01:17:27,510 --> 01:17:25,679

i think applied mathematics is going

2156

01:17:28,790 --> 01:17:27,520

from strength to strength it's pure

2157

01:17:31,669 --> 01:17:28,800

mathematics

2158

01:17:32,709 --> 01:17:31,679

um that has the serious problems i see i

2159

01:17:34,310 --> 01:17:32,719

see

2160

01:17:35,750 --> 01:17:34,320

yeah absolutely

2161

01:17:37,590 --> 01:17:35,760

how about we get to a couple audience

2162

01:17:38,870 --> 01:17:37,600

questions and then that's it

2163

01:17:41,030 --> 01:17:38,880

sure

2164

01:17:43,110 --> 01:17:41,040

let's see so this question comes from

2165

01:17:44,390 --> 01:17:43,120

zero six nine eight five five nine three

2166

01:17:45,510 --> 01:17:44,400

on reddit

2167

01:17:47,189 --> 01:17:45,520

how would

2168

01:17:48,950 --> 01:17:47,199

norman wildberger rephrase the

2169

01:17:53,510 --> 01:17:48,960

intermediate value theorem without the

2170

01:18:01,590 --> 01:17:55,990

um yeah that's that's a good question

2171

01:18:06,229 --> 01:18:04,149

i i would say that's

2172

01:18:08,229 --> 01:18:06,239

close to um maybe a more fundamental

2173

01:18:10,189 --> 01:18:08,239

question which is how i would uh replace

2174

01:18:13,350 --> 01:18:10,199

the fundamental theorem of

2175

01:18:16,390 --> 01:18:13,360

algebra um with without real numbers the

2176  
01:18:18,229 --> 01:18:16,400  
fundamental theorem of algebra um you

2177  
01:18:22,229 --> 01:18:18,239  
know asserts that you can

2178  
01:18:26,790 --> 01:18:23,990  
factor

2179  
01:18:29,990 --> 01:18:26,800  
polynomials and and and and you can find

2180  
01:18:32,070 --> 01:18:30,000  
zeros okay um so

2181  
01:18:35,030 --> 01:18:32,080  
i i would say that what what we want to

2182  
01:18:37,030 --> 01:18:35,040  
do is is to restate that in terms of not

2183  
01:18:38,709 --> 01:18:37,040  
finding exact zeros but finding

2184  
01:18:39,990 --> 01:18:38,719  
approximate zeros so we have to have a

2185  
01:18:42,550 --> 01:18:40,000  
sense of what it means to be an

2186  
01:18:44,709 --> 01:18:42,560  
approximate zero so for example you know

2187  
01:18:46,950 --> 01:18:44,719  
we could we could say what does it mean

2188  
01:18:49,669 --> 01:18:46,960

for for a function to have an

2189

01:18:50,709 --> 01:18:49,679

approximate zero in a certain interval

2190

01:18:51,910 --> 01:18:50,719

it's the same kind of thing that a

2191

01:18:54,310 --> 01:18:51,920

physicist would do i mean if you have

2192

01:18:56,070 --> 01:18:54,320

some something that you can't calculate

2193

01:18:57,750 --> 01:18:56,080

but you know what you're looking for for

2194

01:19:00,070 --> 01:18:57,760

some some zero you can't calculate it

2195

01:19:01,669 --> 01:19:00,080

exactly but what you want is some some

2196

01:19:04,550 --> 01:19:01,679

interval and say well it's going to

2197

01:19:05,990 --> 01:19:04,560

cross somewhere in between here and here

2198

01:19:09,189 --> 01:19:06,000

but then

2199

01:19:11,189 --> 01:19:09,199

yes but that interval is it's it's um

2200

01:19:13,189 --> 01:19:11,199

its extent is not clearly defined you

2201

01:19:15,110 --> 01:19:13,199

could you could you could look for a

2202

01:19:16,950 --> 01:19:15,120

smaller resolution smaller resolution

2203

01:19:19,110 --> 01:19:16,960

and so on and get you know better and

2204

01:19:21,750 --> 01:19:19,120

better approximations so we have to have

2205

01:19:23,430 --> 01:19:21,760

some sort of numerical analysis involved

2206

01:19:25,669 --> 01:19:23,440

so we have to have a restatement purely

2207

01:19:27,350 --> 01:19:25,679

in terms of rational numbers but it has

2208

01:19:28,790 --> 01:19:27,360

to involve intervals and it has and

2209

01:19:30,470 --> 01:19:28,800

there has to be an accompanying

2210

01:19:33,590 --> 01:19:30,480

numerical analysis

2211

01:19:37,189 --> 01:19:33,600

and it it's a it's a major major uh to

2212

01:19:39,110 --> 01:19:37,199

do in pure mathematics to to

2213

01:19:40,870 --> 01:19:39,120

to replace the fundamental theorem of

2214

01:19:43,350 --> 01:19:40,880

algebra and the intermediate value

2215

01:19:44,630 --> 01:19:43,360

theorem is along the same lines um with

2216

01:19:46,470 --> 01:19:44,640

with something that's that's accurate

2217

01:19:48,630 --> 01:19:46,480

which is purely stated in terms of

2218

01:19:49,350 --> 01:19:48,640

rational numbers and which is um you

2219

01:19:51,750 --> 01:19:49,360

know

2220

01:19:53,030 --> 01:19:51,760

which avoids all mention of infinite

2221

01:19:55,189 --> 01:19:53,040

processes

2222

01:19:55,990 --> 01:19:55,199

norman why is it that

2223

01:19:57,830 --> 01:19:56,000

if

2224

01:19:59,270 --> 01:19:57,840

mathematics as it is right now the

2225

01:20:01,189 --> 01:19:59,280

mainstream mathematics with the real

2226

01:20:03,350 --> 01:20:01,199

numbers and continuity etc why is it

2227

01:20:04,790 --> 01:20:03,360

that if it's so flawed

2228

01:20:07,030 --> 01:20:04,800

why hasn't it produced major

2229

01:20:08,709 --> 01:20:07,040

inconsistencies do you imagine that it's

2230

01:20:11,350 --> 01:20:08,719

going to topple at some point that is

2231

01:20:13,669 --> 01:20:11,360

contradictory somewhere

2232

01:20:17,189 --> 01:20:13,679

no so the the kinds of problems that it

2233

01:20:19,189 --> 01:20:17,199

has are problems of

2234

01:20:20,950 --> 01:20:19,199

ambiguity

2235

01:20:23,110 --> 01:20:20,960

you know that

2236

01:20:24,629 --> 01:20:23,120

it's not as if we've actually assumed

2237

01:20:27,350 --> 01:20:24,639

something that's that that will

2238

01:20:28,310 --> 01:20:27,360

necessarily lead to a contradiction uh

2239

01:20:32,470 --> 01:20:28,320

we

2240

01:20:35,189 --> 01:20:32,480

that obscure the the fundamental nature

2241

01:20:37,830 --> 01:20:35,199

of of our reality okay and so the

2242

01:20:40,709 --> 01:20:37,840

consequence of that is is is

2243

01:20:44,149 --> 01:20:40,719

confusion at various levels and and

2244

01:20:45,910 --> 01:20:44,159

missing out on uh a better and more

2245

01:20:46,950 --> 01:20:45,920

accurate and more powerful way of

2246

01:20:48,870 --> 01:20:46,960

thinking

2247

01:20:50,709 --> 01:20:48,880

that's that's really the price that that

2248

01:20:53,350 --> 01:20:50,719

we pay

2249

01:20:55,669 --> 01:20:53,360

because if we're really willing to face

2250

01:20:58,709 --> 01:20:55,679

the music as it is and not the way we

2251

01:21:00,310 --> 01:20:58,719

want things to be okay so yes we we may

2252

01:21:01,990 --> 01:21:00,320

have to think harder and we may have to

2253

01:21:03,830 --> 01:21:02,000

think more carefully and we may have to

2254

01:21:05,990 --> 01:21:03,840

be more precise and we may have to go

2255

01:21:08,229 --> 01:21:06,000

back down to more elementary things that

2256

01:21:10,310 --> 01:21:08,239

we thought we had figured out back in in

2257

01:21:12,470 --> 01:21:10,320

in undergraduate level

2258

01:21:15,430 --> 01:21:12,480

but as a consequence of that we can

2259

01:21:18,390 --> 01:21:15,440

discover so many new interesting things

2260

01:21:19,430 --> 01:21:18,400

and perhaps we can help the physicists

2261

01:21:20,870 --> 01:21:19,440

you know

2262

01:21:23,510 --> 01:21:20,880

i think the physicists

2263

01:21:25,910 --> 01:21:23,520

could probably use some some

2264

01:21:27,510 --> 01:21:25,920

some new ideas perhaps coming from from

2265

01:21:30,229 --> 01:21:27,520

mathematics

2266

01:21:32,470 --> 01:21:30,239

and so that the possibility of of

2267

01:21:34,470 --> 01:21:32,480

finding such new ideas and finding

2268

01:21:37,189 --> 01:21:34,480

exciting new avenues is i think

2269

01:21:38,950 --> 01:21:37,199

increased by by by being open to to

2270

01:21:40,790 --> 01:21:38,960

looking carefully at the foundational

2271

01:21:42,470 --> 01:21:40,800

issues and actually you know addressing

2272

01:21:43,990 --> 01:21:42,480

the the weaknesses and not pretending

2273

01:21:45,510 --> 01:21:44,000

that they're not there

2274

01:21:47,590 --> 01:21:45,520

okay and again for the people who are

2275

01:21:50,310 --> 01:21:47,600

watching there will be a part two with

2276

01:21:51,910 --> 01:21:50,320

norman on his new ideas of unifying math

2277

01:21:53,990 --> 01:21:51,920

and new ideas in physics so if you have

2278

01:21:55,830 --> 01:21:54,000

questions for the professor the great

2279

01:21:58,709 --> 01:21:55,840

professor then please leave them in the

2280

01:22:00,950 --> 01:21:58,719

comments and when we are lucky enough to

2281

01:22:03,189 --> 01:22:00,960

have norman on again he'll

2282

01:22:05,430 --> 01:22:03,199

hopefully answer some of those questions

2283

01:22:07,830 --> 01:22:05,440

okay now in your answer norman you use

2284

01:22:10,390 --> 01:22:07,840

the word fundamental reality and is that

2285

01:22:12,709 --> 01:22:10,400

we're confused about or not we as me and

2286

01:22:15,030 --> 01:22:12,719

you but we as in the general public or

2287

01:22:16,950 --> 01:22:15,040

general mathematicians etc that we are

2288

01:22:19,030 --> 01:22:16,960

confused about what fundamental reality

2289

01:22:20,310 --> 01:22:19,040

is but then earlier we were talking you

2290

01:22:22,229 --> 01:22:20,320

mentioned well i don't care too much

2291

01:22:23,669 --> 01:22:22,239

about existence this is not an existence

2292

01:22:25,830 --> 01:22:23,679

claim but then fundamental reality and

2293

01:22:28,629 --> 01:22:25,840

the word is to me sounds like existence

2294

01:22:30,470 --> 01:22:28,639

claims which then to me it's interesting

2295

01:22:46,070 --> 01:22:30,480

because sometimes i hear this from

2296

01:22:49,830 --> 01:22:47,510

death of the universe

2297

01:22:51,669 --> 01:22:49,840

and so therefore we should base our

2298

01:22:52,870 --> 01:22:51,679

entire mathematical system on something

2299

01:22:55,030 --> 01:22:52,880

different

2300

01:22:56,709 --> 01:22:55,040

and then that's interesting to me

2301

01:22:58,470 --> 01:22:56,719

because and i'm just saying this here

2302

01:23:00,310 --> 01:22:58,480

for the first time so please allow me to

2303

01:23:01,750 --> 01:23:00,320

fumble around reductionistically this is

2304

01:23:03,830 --> 01:23:01,760

how we ordinarily think of the universe

2305

01:23:04,950 --> 01:23:03,840

is okay if i'm to act it's because of my

2306

01:23:06,470 --> 01:23:04,960

psychology which is because of my

2307

01:23:07,990 --> 01:23:06,480

neurobiology because of my biology

2308

01:23:09,350 --> 01:23:08,000

because of the chemistry which is

2309

01:23:11,590 --> 01:23:09,360

because of the physics which is because

2310

01:23:13,110 --> 01:23:11,600

of the math not cuz of but uses the math

2311

01:23:14,790 --> 01:23:13,120

then if we're saying well our

2312

01:23:16,709 --> 01:23:14,800

mathematics needs to be practical so

2313

01:23:18,950 --> 01:23:16,719

let's look at the world and then

2314

01:23:20,950 --> 01:23:18,960

determine what our mathematics should be

2315

01:23:22,950 --> 01:23:20,960

then it's almost like we're basing our

2316

01:23:25,430 --> 01:23:22,960

mathematics in physics but the physics

2317

01:23:27,590 --> 01:23:25,440

is based in mathematics is that circular

2318

01:23:30,229 --> 01:23:27,600

in some way

2319

01:23:33,669 --> 01:23:30,239

yeah i'm not entirely sure how to

2320

01:23:37,350 --> 01:23:35,669

when someone is saying we should change

2321

01:23:39,830 --> 01:23:37,360

our framework for the mathematics in

2322

01:23:42,390 --> 01:23:39,840

order to properly reflect the physics

2323

01:23:44,070 --> 01:23:42,400

but then the physics is already based in

2324

01:23:45,510 --> 01:23:44,080

mathematics

2325

01:23:47,030 --> 01:23:45,520

so then there's an interrelated

2326

01:23:48,629 --> 01:23:47,040

definition

2327

01:23:50,629 --> 01:23:48,639

and i don't know how to make sense of

2328

01:23:51,590 --> 01:23:50,639

that so i'm just throwing that concept

2329

01:23:53,430 --> 01:23:51,600

out there yeah

2330

01:23:56,149 --> 01:23:53,440

i would say i'm not sure if if math

2331

01:23:57,590 --> 01:23:56,159

physics is based on math i i would

2332

01:24:00,470 --> 01:23:57,600

the way i would think of it is is that

2333

01:24:02,470 --> 01:24:00,480

physics is based on on observations so

2334

01:24:04,310 --> 01:24:02,480

you have these observations and this

2335

01:24:05,990 --> 01:24:04,320

data coming from from the instruments

2336

01:24:07,750 --> 01:24:06,000

and your senses and so on and then you

2337

01:24:09,590 --> 01:24:07,760

have to model it somehow so then you you

2338

01:24:11,590 --> 01:24:09,600

go to the mathematicians and you open

2339

01:24:14,229 --> 01:24:11,600

the math books and you see some some you

2340

01:24:17,350 --> 01:24:14,239

know which math theories might might

2341

01:24:19,110 --> 01:24:17,360

model this particular situation best

2342

01:24:20,950 --> 01:24:19,120

okay okay this this this particular

2343

01:24:23,030 --> 01:24:20,960

theory looks like it'll work

2344

01:24:24,709 --> 01:24:23,040

pretty pretty well but not really well

2345

01:24:26,950 --> 01:24:24,719

but

2346

01:24:29,510 --> 01:24:26,960

not bad you know okay so you adopt that

2347

01:24:31,590 --> 01:24:29,520

and then maybe it gets ingrained in in

2348

01:24:33,110 --> 01:24:31,600

successive generations but that's not to

2349

01:24:34,390 --> 01:24:33,120

say that somebody can come can't come

2350

01:24:35,350 --> 01:24:34,400

along and

2351

01:24:37,110 --> 01:24:35,360

you know

2352

01:24:39,030 --> 01:24:37,120

replace the mass with some some better

2353

01:24:40,629 --> 01:24:39,040

theory and then the physicists can can

2354

01:24:42,470 --> 01:24:40,639

readjust

2355

01:24:43,270 --> 01:24:42,480

their their thinking

2356

01:24:44,950 --> 01:24:43,280

but

2357

01:24:47,750 --> 01:24:44,960

i'm thinking that ultimately it's it's

2358

01:24:49,590 --> 01:24:47,760

the the world itself that that you have

2359

01:24:53,110 --> 01:24:49,600

to respect

2360

01:24:54,550 --> 01:24:53,120

you know your obligation is is to is to

2361

01:24:55,990 --> 01:24:54,560

is to

2362

01:24:56,709 --> 01:24:56,000

yeah um

2363

01:25:02,149 --> 01:24:56,719

be

2364

01:25:04,870 --> 01:25:02,159

to make us happy or to follow along in

2365

01:25:07,030 --> 01:25:04,880

in the way we've been doing things

2366

01:25:09,350 --> 01:25:07,040

you can use our tools when they're when

2367

01:25:12,070 --> 01:25:09,360

they're appropriate and and and modify

2368

01:25:14,310 --> 01:25:12,080

them when they're not perhaps

2369

01:25:18,149 --> 01:25:14,320

so i i think generally speaking having a

2370

01:25:19,830 --> 01:25:18,159

range of um a range of ways of thinking

2371

01:25:21,990 --> 01:25:19,840

it has got to has got to be a good thing

2372

01:25:23,910 --> 01:25:22,000

for science for physicists

2373

01:25:25,030 --> 01:25:23,920

so i would like i would like there to be

2374

01:25:26,950 --> 01:25:25,040

more

2375

01:25:28,950 --> 01:25:26,960

wider discussion about foundational

2376

01:25:30,709 --> 01:25:28,960

issues in mathematics

2377

01:25:34,229 --> 01:25:30,719

i think the computer scientists ought to

2378

01:25:35,990 --> 01:25:34,239

have a lot more say in in in in the the

2379

01:25:38,149 --> 01:25:36,000

foundational issues like people like

2380

01:25:40,629 --> 01:25:38,159

stephen wolfram right i think you know

2381

01:25:42,229 --> 01:25:40,639

he has a very deep uh feeling for

2382

01:25:44,470 --> 01:25:42,239

foundations of mathematics because

2383

01:25:47,350 --> 01:25:44,480

mathematica is all about

2384

01:25:51,189 --> 01:25:47,360

foundations of mathematics at some level

2385

01:25:52,790 --> 01:25:51,199

you know so um i think uh

2386

01:25:54,870 --> 01:25:52,800

having having a wide range of

2387

01:25:57,350 --> 01:25:54,880

possibilities can only be good for you

2388

01:25:59,590 --> 01:25:57,360

and having a little bit of debate uh um

2389

01:26:01,350 --> 01:25:59,600

and and you know and trying to find the

2390

01:26:03,110 --> 01:26:01,360

right theories you know the fact it

2391

01:26:04,950 --> 01:26:03,120

might be that there are just some some

2392

01:26:06,390 --> 01:26:04,960

theories which are much righter than

2393

01:26:07,910 --> 01:26:06,400

others and and

2394

01:26:09,910 --> 01:26:07,920

it's probably a good guess that it's

2395

01:26:13,430 --> 01:26:09,920

those theories that that are are most

2396

01:26:15,430 --> 01:26:13,440

likely to be uh useful to you

2397

01:26:17,110 --> 01:26:15,440

some people like max tegmark they do

2398

01:26:19,189 --> 01:26:17,120

believe in the mathematical universe

2399

01:26:20,550 --> 01:26:19,199

that what underlies this is mathematics

2400

01:26:22,629 --> 01:26:20,560

so are you saying

2401

01:26:25,350 --> 01:26:22,639

i'm not so sure max

2402

01:26:28,629 --> 01:26:25,360

no yeah so i i i i do think there's a

2403

01:26:30,390 --> 01:26:28,639

mathematical universe okay um i i'm i'm

2404

01:26:32,390 --> 01:26:30,400

a little bit of a

2405

01:26:34,310 --> 01:26:32,400

i will say platinus but

2406

01:26:36,229 --> 01:26:34,320

my colleague james franklin has an

2407

01:26:38,310 --> 01:26:36,239

aristotelian point of view you know that

2408

01:26:40,310 --> 01:26:38,320

that that mathematics actually can be

2409

01:26:43,110 --> 01:26:40,320

found here in the world and i i share

2410

01:26:45,189 --> 01:26:43,120

that orientation so i i'm happy to

2411

01:26:47,189 --> 01:26:45,199

believe that there's some mathematical

2412

01:26:48,790 --> 01:26:47,199

aspect to reality that reality has a

2413

01:26:51,270 --> 01:26:48,800

physical aspect and it also has a

2414

01:26:53,110 --> 01:26:51,280

mathematical aspect

2415

01:26:54,550 --> 01:26:53,120

what us mathematicians do is we take

2416

01:26:56,149 --> 01:26:54,560

this very human

2417

01:26:59,030 --> 01:26:56,159

centered point of view and we try to

2418

01:27:02,070 --> 01:26:59,040

study that that mathematical aspect and

2419

01:27:04,950 --> 01:27:02,080

try to to express it in our language in

2420

01:27:07,430 --> 01:27:04,960

our words in our vocabularies okay but

2421

01:27:09,510 --> 01:27:07,440

there there may be very

2422

01:27:11,030 --> 01:27:09,520

many possible points of view of doing

2423

01:27:12,229 --> 01:27:11,040

that

2424

01:27:14,470 --> 01:27:12,239

so

2425

01:27:16,390 --> 01:27:14,480

we're maybe studying the the same

2426

01:27:18,629 --> 01:27:16,400

mathematics but there's the potential

2427

01:27:21,189 --> 01:27:18,639

for a lot of different points of view on

2428

01:27:23,189 --> 01:27:21,199

that on that mathematical reality

2429

01:27:25,110 --> 01:27:23,199

there's not just one necessarily one

2430

01:27:26,950 --> 01:27:25,120

point of view although in for some

2431

01:27:29,189 --> 01:27:26,960

application there might be a

2432

01:27:32,310 --> 01:27:29,199

most useful or a better point of view

2433

01:27:34,229 --> 01:27:32,320

you know so i i'm an advocate of having

2434

01:27:37,030 --> 01:27:34,239

um a wider

2435

01:27:38,390 --> 01:27:37,040

and sort of more open discussion as to

2436

01:27:40,310 --> 01:27:38,400

the nature of the fact especially the

2437

01:27:41,830 --> 01:27:40,320

foundations of mathematics and i think

2438

01:27:43,669 --> 01:27:41,840

that's going to be beneficial to physics

2439

01:27:45,430 --> 01:27:43,679

for sure

2440

01:27:47,350 --> 01:27:45,440

okay we'll just ask two quick audience

2441

01:27:49,189 --> 01:27:47,360

questions and then we'll wrap it up so

2442

01:27:51,110 --> 01:27:49,199

this question comes from sam thompson

2443

01:27:52,870 --> 01:27:51,120

question for norman despite the

2444

01:27:55,430 --> 01:27:52,880

difficulties with interpreting real

2445

01:27:57,830 --> 01:27:55,440

numbers as classes of predeterminate

2446

01:27:59,990 --> 01:27:57,840

infinite sequences as highlighted by the

2447

01:28:03,189 --> 01:28:00,000

intuitionists do you see problems with

2448

01:28:05,110 --> 01:28:03,199

having infinite index sets for example

2449

01:28:07,270 --> 01:28:05,120

do you take issue with quantifying over

2450

01:28:09,590 --> 01:28:07,280

the natural numbers in referring to the

2451  
01:28:12,540 --> 01:28:09,600  
steps of a non-terminating computation

2452  
01:28:14,229 --> 01:28:12,550  
or using diagonalization arguments

2453  
01:28:16,870 --> 01:28:14,239  
[Music]

2454  
01:28:19,430 --> 01:28:16,880  
um so diagonalization arguments is maybe

2455  
01:28:21,910 --> 01:28:19,440  
something separate um

2456  
01:28:24,470 --> 01:28:21,920  
again i would try to frame that

2457  
01:28:25,830 --> 01:28:24,480  
in terms of are we assuming at some

2458  
01:28:27,030 --> 01:28:25,840  
point that we're able to do an infinite

2459  
01:28:29,270 --> 01:28:27,040  
number of things

2460  
01:28:31,270 --> 01:28:29,280  
like i i may have um you know some some

2461  
01:28:32,709 --> 01:28:31,280  
set of objects that i'm interested in uh

2462  
01:28:34,629 --> 01:28:32,719  
you know maybe some graphs and then

2463  
01:28:36,470 --> 01:28:34,639

maybe i lay i can see that there there

2464

01:28:38,629 --> 01:28:36,480

could be indexed by a natural number  $n$

2465

01:28:40,709 --> 01:28:38,639

so i have some graph  $g$  and i call this

2466

01:28:42,950 --> 01:28:40,719

graph  $g$  sub  $n$  so here's  $g$  sub one here's

2467

01:28:43,750 --> 01:28:42,960

$g$  sub 2  $g$  sub 3 et cetera

2468

01:28:45,590 --> 01:28:43,760

so

2469

01:28:46,790 --> 01:28:45,600

but is it the case that that i'm using

2470

01:28:48,149 --> 01:28:46,800

an infinite

2471

01:28:50,870 --> 01:28:48,159

um

2472

01:28:53,910 --> 01:28:50,880

set as an index no that that's that's

2473

01:28:55,990 --> 01:28:53,920

that's a big jump okay i'm using natural

2474

01:28:57,669 --> 01:28:56,000

numbers i'm saying that if you give me a

2475

01:28:58,790 --> 01:28:57,679

natural number you write down a natural

2476

01:29:00,390 --> 01:28:58,800

number

2477

01:29:02,790 --> 01:29:00,400

please do okay you write down a natural

2478

01:29:04,550 --> 01:29:02,800

number okay now i can find uh one of my

2479

01:29:06,470 --> 01:29:04,560

graphs over here that corresponds to

2480

01:29:09,110 --> 01:29:06,480

that natural number here's the graph

2481

01:29:10,790 --> 01:29:09,120

that corresponds to your natural number

2482

01:29:12,550 --> 01:29:10,800

i don't have to make any claims as to

2483

01:29:14,070 --> 01:29:12,560

whether the natural numbers go on to

2484

01:29:15,830 --> 01:29:14,080

infinity or not in order to make that

2485

01:29:17,830 --> 01:29:15,840

statement

2486

01:29:20,070 --> 01:29:17,840

so this is a very common confusion that

2487

01:29:22,310 --> 01:29:20,080

that that people make is that they think

2488

01:29:24,149 --> 01:29:22,320

because i want to talk about arbitrary

2489

01:29:26,229 --> 01:29:24,159

integers that i want to talk about every

2490

01:29:28,709 --> 01:29:26,239

integer as if they're all in some big

2491

01:29:30,229 --> 01:29:28,719

basket somewhere you know and then i

2492

01:29:33,350 --> 01:29:30,239

just pick i'm just picking one out of

2493

01:29:37,750 --> 01:29:35,590

rather what it is is that there's a road

2494

01:29:39,590 --> 01:29:37,760

and i can walk down this road and i can

2495

01:29:41,590 --> 01:29:39,600

you know and i can pick up an integer

2496

01:29:43,030 --> 01:29:41,600

that's there and then i can walk back

2497

01:29:44,310 --> 01:29:43,040

and if i want a bigger integer whether i

2498

01:29:46,149 --> 01:29:44,320

have to go down the road again i have to

2499

01:29:48,470 --> 01:29:46,159

go further and i grab this bigger one

2500

01:29:50,629 --> 01:29:48,480

and and come back with it

2501

01:29:52,629 --> 01:29:50,639

um but that's all there is there's

2502

01:29:55,350 --> 01:29:52,639

always this road there's no there's no

2503

01:29:57,350 --> 01:29:55,360

end of the road there's no you know uh

2504

01:29:59,270 --> 01:29:57,360

big ballpark in which which everything

2505

01:30:01,750 --> 01:29:59,280

here is happening

2506

01:30:04,070 --> 01:30:01,760

this reminds me of someone i forget his

2507

01:30:07,110 --> 01:30:04,080

first name lucas is his last name and he

2508

01:30:08,950 --> 01:30:07,120

was the precursor to penrose's girdle

2509

01:30:10,229 --> 01:30:08,960

argument saying that because of girdles

2510

01:30:12,470 --> 01:30:10,239

in completeness theorem it means the

2511

01:30:14,229 --> 01:30:12,480

mind is not like a machine as far as we

2512

01:30:17,350 --> 01:30:14,239

understand what a machine is and he used

2513

01:30:20,070 --> 01:30:17,360

the phrase that a machine can emulate

2514

01:30:22,709 --> 01:30:20,080

any aspect of a human but it cannot

2515

01:30:24,550 --> 01:30:22,719

emulate every aspect of a human

2516

01:30:26,149 --> 01:30:24,560

and so when you said well we can use any

2517

01:30:28,870 --> 01:30:26,159

natural number but we can't use every

2518

01:30:30,870 --> 01:30:28,880

natural number it reminded me of that

2519

01:30:32,390 --> 01:30:30,880

yeah to the child who is listening to

2520

01:30:33,990 --> 01:30:32,400

this they may say well

2521

01:30:35,590 --> 01:30:34,000

norman if you're saying infinity doesn't

2522

01:30:37,590 --> 01:30:35,600

exist then you're saying that only

2523

01:30:40,149 --> 01:30:37,600

finite exists so that implies that

2524

01:30:41,830 --> 01:30:40,159

there's a maximum number

2525

01:30:43,590 --> 01:30:41,840

what is that maximum number why can't i

2526

01:30:45,669 --> 01:30:43,600

plus one yeah i know people people say

2527

01:30:47,430 --> 01:30:45,679

that a lot and they they want to turn

2528

01:30:49,189 --> 01:30:47,440

the argument into a finance argument so

2529

01:30:51,430 --> 01:30:49,199

first of all i'm not a finitist i

2530

01:30:53,669 --> 01:30:51,440

wouldn't say that i'm i'm a finitist i i

2531

01:30:56,149 --> 01:30:53,679

do not believe uh that there is

2532

01:30:57,110 --> 01:30:56,159

necessarily a biggest natural number

2533

01:30:58,629 --> 01:30:57,120

um

2534

01:31:01,110 --> 01:30:58,639

what what i

2535

01:31:02,709 --> 01:31:01,120

i'm more likely to think is that as as

2536

01:31:04,310 --> 01:31:02,719

you carry on

2537

01:31:05,910 --> 01:31:04,320

into the realm of bigger and bigger

2538

01:31:07,510 --> 01:31:05,920

natural numbers it was you will slow

2539

01:31:09,430 --> 01:31:07,520

down and it will eventually overwhelm

2540

01:31:11,590 --> 01:31:09,440

you and at what point you have to stop

2541

01:31:13,510 --> 01:31:11,600

by the side of the road and come back it

2542

01:31:15,270 --> 01:31:13,520

is dependent on your

2543

01:31:17,110 --> 01:31:15,280

your patience and your machine cetera

2544

01:31:18,870 --> 01:31:17,120

but you're not gonna you're not you're

2545

01:31:21,910 --> 01:31:18,880

not in a position to reach the end so

2546

01:31:24,229 --> 01:31:21,920

i'm not i'm not a finitist but i'm i'm

2547

01:31:26,229 --> 01:31:24,239

i'm it's more like a classical greek

2548

01:31:27,990 --> 01:31:26,239

thinker i i recognize that there's this

2549

01:31:30,550 --> 01:31:28,000

this road ahead and has an unbounded

2550

01:31:33,030 --> 01:31:30,560

aspect and i'm agnostic as to you know

2551  
01:31:33,910 --> 01:31:33,040  
what what's down that road beyond my

2552  
01:31:35,669 --> 01:31:33,920  
view

2553  
01:31:37,669 --> 01:31:35,679  
so maybe i should say like i have in my

2554  
01:31:40,149 --> 01:31:37,679  
math foundation series i have a string

2555  
01:31:42,070 --> 01:31:40,159  
of videos on on big numbers where like i

2556  
01:31:43,590 --> 01:31:42,080  
look at seriously big numbers like

2557  
01:31:46,229 --> 01:31:43,600  
something like uh

2558  
01:31:46,950 --> 01:31:46,239  
canoes arrow notations such like this

2559  
01:31:48,470 --> 01:31:46,960  
and

2560  
01:31:50,950 --> 01:31:48,480  
so you can generate these these

2561  
01:31:52,950 --> 01:31:50,960  
incredibly uh you know big expressions

2562  
01:31:54,390 --> 01:31:52,960  
that are just mind-bogglingly um you

2563  
01:31:55,990 --> 01:31:54,400

know big but

2564

01:31:58,310 --> 01:31:56,000

um

2565

01:32:00,070 --> 01:31:58,320

the existence or or the validity of such

2566

01:32:02,390 --> 01:32:00,080

numbers is highly in question because

2567

01:32:05,270 --> 01:32:02,400

you can't reach those numbers by an

2568

01:32:07,189 --> 01:32:05,280

inductive step-by-step process you have

2569

01:32:09,990 --> 01:32:07,199

to reach them by towers of towers of

2570

01:32:12,310 --> 01:32:10,000

towers of exponentials etc so you're

2571

01:32:13,910 --> 01:32:12,320

leap frogging the the the fundamental

2572

01:32:17,110 --> 01:32:13,920

inductive process which sort of

2573

01:32:19,189 --> 01:32:17,120

underlies most most arguments implicitly

2574

01:32:20,629 --> 01:32:19,199

so it you know it's a it's a question

2575

01:32:21,990 --> 01:32:20,639

even whether you know 10 to the 10 to

2576

01:32:23,590 --> 01:32:22,000

the 10 to the 10 to the 10 to the 10

2577

01:32:26,149 --> 01:32:23,600

whether that's actually a valid number

2578

01:32:27,590 --> 01:32:26,159

or not you know that's a and a computer

2579

01:32:29,189 --> 01:32:27,600

scientist would fully understand that

2580

01:32:30,550 --> 01:32:29,199

because most computer programs are not

2581

01:32:32,390 --> 01:32:30,560

going to be able to deal with that thing

2582

01:32:34,629 --> 01:32:32,400

just like my program was not able to

2583

01:32:35,910 --> 01:32:34,639

deal with with it

2584

01:32:36,950 --> 01:32:35,920

you know

2585

01:32:38,470 --> 01:32:36,960

so

2586

01:32:41,350 --> 01:32:38,480

now the last question this one comes

2587

01:32:43,590 --> 01:32:41,360

from divergent koshi that's the username

2588

01:32:45,350 --> 01:32:43,600

it's great username i'll give you yeah

2589

01:32:47,590 --> 01:32:45,360

you can choose between so

2590

01:32:49,510 --> 01:32:47,600

what he so firstly

2591

01:32:52,070 --> 01:32:49,520

some apparently some cranks quote

2592

01:32:54,149 --> 01:32:52,080

unquote people use your videos to prove

2593

01:32:56,390 --> 01:32:54,159

math is bs it's like what are your views

2594

01:32:57,990 --> 01:32:56,400

on that you can choose to answer that or

2595

01:33:00,470 --> 01:32:58,000

would you call yourself an idealist or a

2596

01:33:01,830 --> 01:33:00,480

platonist

2597

01:33:04,310 --> 01:33:01,840

um

2598

01:33:06,229 --> 01:33:04,320

so uh so the first question yeah look if

2599

01:33:07,990 --> 01:33:06,239

you put a lot of stuff up on youtube and

2600

01:33:09,830 --> 01:33:08,000

you have uh sort of non-standard

2601  
01:33:11,110 --> 01:33:09,840  
orientation you have to be prepared for

2602  
01:33:11,830 --> 01:33:11,120  
people saying all kinds of things about

2603  
01:33:12,790 --> 01:33:11,840  
you

2604  
01:33:14,790 --> 01:33:12,800  
and i think

2605  
01:33:16,550 --> 01:33:14,800  
that's okay and i'm i'm i'm willing to

2606  
01:33:18,310 --> 01:33:16,560  
wear that um you know it doesn't bother

2607  
01:33:19,830 --> 01:33:18,320  
me overly um

2608  
01:33:20,709 --> 01:33:19,840  
so you know

2609  
01:33:22,950 --> 01:33:20,719  
um

2610  
01:33:25,590 --> 01:33:22,960  
as to the the uh second question

2611  
01:33:26,790 --> 01:33:25,600  
idealist or plaintiff i maybe i'm i'm

2612  
01:33:28,709 --> 01:33:26,800  
not sure if i'm

2613  
01:33:31,350 --> 01:33:28,719

happy to be in any any either of those

2614

01:33:33,830 --> 01:33:31,360

categories i i i think categories are

2615

01:33:35,830 --> 01:33:33,840

often maybe as

2616

01:33:36,550 --> 01:33:35,840

not as helpful as people might imagine

2617

01:33:38,629 --> 01:33:36,560

and

2618

01:33:39,590 --> 01:33:38,639

it's best to um

2619

01:33:41,990 --> 01:33:39,600

just

2620

01:33:43,430 --> 01:33:42,000

try to be honest and uh and

2621

01:33:45,750 --> 01:33:43,440

and clear and

2622

01:33:47,350 --> 01:33:45,760

and careful you know

2623

01:33:48,310 --> 01:33:47,360

but those aren't categories those are

2624

01:33:51,669 --> 01:33:48,320

sort of

2625

01:33:53,510 --> 01:33:51,679

attributes that one strives for

2626

01:33:54,390 --> 01:33:53,520

professor thank you so much

2627

01:33:56,470 --> 01:33:54,400

for

2628

01:33:57,990 --> 01:33:56,480

being so generous with your time

2629

01:33:59,510 --> 01:33:58,000

it went by quickly i don't even know how

2630

01:34:01,270 --> 01:33:59,520

much time went by but it was much more

2631

01:34:02,709 --> 01:34:01,280

than an hour

2632

01:34:04,550 --> 01:34:02,719

yeah well kurt thanks for all those

2633

01:34:06,310 --> 01:34:04,560

great questions it's been uh

2634

01:34:08,149 --> 01:34:06,320

really fun chatting with you and i look

2635

01:34:09,750 --> 01:34:08,159

forward to doing it again

2636

01:34:12,149 --> 01:34:09,760

thank you

2637

01:34:14,709 --> 01:34:12,159

yeah really i really enjoyed it uh yeah

2638

01:34:16,070 --> 01:34:14,719

the time has gone flown by um

2639

01:34:18,070 --> 01:34:16,080

usually after an hour i would sort of

2640

01:34:19,830 --> 01:34:18,080

fade but i i feel as if yeah it's been

2641

01:34:21,750 --> 01:34:19,840

so much the same with me

2642

01:34:23,590 --> 01:34:21,760

usually like i know it sounds like no

2643

01:34:25,430 --> 01:34:23,600

because i do

2644

01:34:27,430 --> 01:34:25,440

four or five hours but

2645

01:34:29,270 --> 01:34:27,440

after an hour i can feel when the hour

2646

01:34:30,550 --> 01:34:29,280

has passed but i didn't feel do you have

2647

01:34:33,110 --> 01:34:30,560

any notes for me anything you'd like me

2648

01:34:35,110 --> 01:34:33,120

to take out or no no just just use your

2649

01:34:37,110 --> 01:34:35,120

own judgment um i'm sure whatever you

2650

01:34:38,950 --> 01:34:37,120

put together will be will be great

2651  
01:34:40,550 --> 01:34:38,960  
okay and thanks again for for doing all

2652  
01:34:42,310 --> 01:34:40,560  
of this stuff you're you're you're

2653  
01:34:44,310 --> 01:34:42,320  
really a champion

2654  
01:34:46,709 --> 01:34:44,320  
and i hope that you're you know you'll

2655  
01:34:49,669 --> 01:34:46,719  
continue to to expand your

2656  
01:34:50,790 --> 01:34:49,679  
your base and uh

2657  
01:34:52,229 --> 01:34:50,800  
you know

2658  
01:34:53,990 --> 01:34:52,239  
really make it happen

2659  
01:34:55,270 --> 01:34:54,000  
it's really good

2660  
01:34:57,270 --> 01:34:55,280  
thank you

2661  
01:34:59,270 --> 01:34:57,280  
yeah yeah and about that last question

2662  
01:35:00,709 --> 01:34:59,280  
about the cranks i've gotten the reason

2663  
01:35:03,510 --> 01:35:00,719

why i ask you this because

2664

01:35:05,030 --> 01:35:03,520

because i interview people on a fairly

2665

01:35:06,470 --> 01:35:05,040

wide spectrum

2666

01:35:08,149 --> 01:35:06,480

if someone's a materialist you know what

2667

01:35:09,990 --> 01:35:08,159

a materialist is so there's materialism

2668

01:35:11,830 --> 01:35:10,000

versus idealism if i interview a

2669

01:35:13,109 --> 01:35:11,840

materialist the idealists in the comment

2670

01:35:14,790 --> 01:35:13,119

section will say why are you wasting

2671

01:35:16,629 --> 01:35:14,800

your time with these people and then the

2672

01:35:18,390 --> 01:35:16,639

materialists will say to the idealist

2673

01:35:20,390 --> 01:35:18,400

yeah i i can't believe you entertained

2674

01:35:22,550 --> 01:35:20,400

such a woo and it's so difficult to not

2675

01:35:24,470 --> 01:35:22,560

respond to negative comments it's so

2676

01:35:26,149 --> 01:35:24,480

difficult norman for me

2677

01:35:28,149 --> 01:35:26,159

yeah i have to takes everything from me

2678

01:35:30,790 --> 01:35:28,159

but this person said i that i platform

2679

01:35:31,830 --> 01:35:30,800

cult leaders and right-wing nuts because

2680

01:35:33,669 --> 01:35:31,840

i had on

2681

01:35:36,310 --> 01:35:33,679

chris lange who apparently has

2682

01:35:38,790 --> 01:35:36,320

right-wing views and i'm just oh man

2683

01:35:40,070 --> 01:35:38,800

jeez jeez louise

2684

01:35:40,790 --> 01:35:40,080

i don't know one of the things i've

2685

01:35:42,310 --> 01:35:40,800

learned

2686

01:35:44,790 --> 01:35:42,320

is that you have to sort of develop a

2687

01:35:46,390 --> 01:35:44,800

thick skin in in this in this sort of

2688

01:35:48,550 --> 01:35:46,400

environment you know like you're putting

2689

01:35:51,430 --> 01:35:48,560

your thoughts and your efforts out there

2690

01:35:52,550 --> 01:35:51,440

on youtube and and people can respond

2691

01:35:54,629 --> 01:35:52,560

you know

2692

01:35:55,990 --> 01:35:54,639

anonymously and and

2693

01:35:58,550 --> 01:35:56,000

you know they can get away with saying

2694

01:36:00,310 --> 01:35:58,560

all kinds of things and and everybody

2695

01:36:02,070 --> 01:36:00,320

has not everybody a lot of people have

2696

01:36:04,790 --> 01:36:02,080

their agendas that they're they're

2697

01:36:06,709 --> 01:36:04,800

trying to push you know and they see

2698

01:36:08,709 --> 01:36:06,719

comments as a way of trying to try to

2699

01:36:10,790 --> 01:36:08,719

move things in one direction or another

2700

01:36:13,030 --> 01:36:10,800

you know so okay

2701  
01:36:14,790 --> 01:36:13,040  
but i guess we just have to wear that as

2702  
01:36:17,590 --> 01:36:14,800  
as as part of the

2703  
01:36:19,350 --> 01:36:17,600  
part of the environment uh yeah it was

2704  
01:36:21,189 --> 01:36:19,360  
taking me i've been you know

2705  
01:36:23,350 --> 01:36:21,199  
putting out youtube videos for 15 years

2706  
01:36:25,990 --> 01:36:23,360  
so i've had plenty of

2707  
01:36:27,750 --> 01:36:26,000  
opportunity of

2708  
01:36:29,189 --> 01:36:27,760  
batting away uh you know negative

2709  
01:36:30,950 --> 01:36:29,199  
comments and so on and eventually you

2710  
01:36:32,950 --> 01:36:30,960  
get used to the use of them you know it

2711  
01:36:34,709 --> 01:36:32,960  
probably initially it bothered me too

2712  
01:36:36,470 --> 01:36:34,719  
but yeah after a while you just get you

2713  
01:36:38,390 --> 01:36:36,480

get more just ignore it now

2714

01:36:40,790 --> 01:36:38,400

yeah you just ignore them yeah

2715

01:36:43,109 --> 01:36:40,800

so generally i i because i get lots of

2716

01:36:44,950 --> 01:36:43,119

comments i i try to answer the questions

2717

01:36:48,070 --> 01:36:44,960

that are sort of worth

2718

01:36:49,830 --> 01:36:48,080

you know the answer the good questions

2719

01:36:50,629 --> 01:36:49,840

or the good or you know

2720

01:36:52,950 --> 01:36:50,639

the good

2721

01:36:55,270 --> 01:36:52,960

i think the vast majority of people can

2722

01:36:56,629 --> 01:36:55,280

can appreciate you know what what what

2723

01:36:58,550 --> 01:36:56,639

we're doing and

2724

01:37:00,550 --> 01:36:58,560

we may not agree with with everything

2725

01:37:03,430 --> 01:37:00,560

with just fine you know we don't need to

2726  
01:37:04,830 --> 01:37:03,440  
have unanimity of thought as much as we

2727  
01:37:07,910 --> 01:37:04,840  
do i think

2728  
01:37:09,830 --> 01:37:07,920  
um and by the way at some point i i'd

2729  
01:37:11,590 --> 01:37:09,840  
love to to to talk with you about about

2730  
01:37:12,629 --> 01:37:11,600  
all this ufo stuff which which interests

2731  
01:37:15,030 --> 01:37:12,639  
me

2732  
01:37:15,990 --> 01:37:15,040  
not not in in in a public fashion but

2733  
01:37:17,270 --> 01:37:16,000  
just

2734  
01:37:19,189 --> 01:37:17,280  
you know um

2735  
01:37:20,870 --> 01:37:19,199  
because i i'm not i don't have any

2736  
01:37:23,030 --> 01:37:20,880  
opinions worth

2737  
01:37:25,430 --> 01:37:23,040  
saying about them

2738  
01:37:28,310 --> 01:37:25,440

but i it it really i i think it's such

2739

01:37:30,870 --> 01:37:28,320

an interesting um topic and um

2740

01:37:33,350 --> 01:37:30,880

and such an important topic i mean it's

2741

01:37:35,990 --> 01:37:33,360

it seems to me remarkable that it's not

2742

01:37:37,830 --> 01:37:36,000

on everybody's tongue you know

2743

01:37:39,669 --> 01:37:37,840

why why why aren't we all talking about

2744

01:37:41,830 --> 01:37:39,679

this you know why aren't we it's like

2745

01:37:43,270 --> 01:37:41,840

incredible but

2746

01:37:45,350 --> 01:37:43,280

for whatever reason when i started

2747

01:37:46,870 --> 01:37:45,360

interviewing ufo people i initially was

2748

01:37:48,870 --> 01:37:46,880

doing it because

2749

01:37:50,470 --> 01:37:48,880

i'm interested is is there something to

2750

01:37:52,470 --> 01:37:50,480

this whether

2751

01:37:53,910 --> 01:37:52,480

obvious these crap if they are physical

2752

01:37:55,750 --> 01:37:53,920

seem to break the laws of physics the

2753

01:37:57,910 --> 01:37:55,760

conservative momentum if they have any

2754

01:37:59,750 --> 01:37:57,920

mass conservation of momentum and if

2755

01:38:01,830 --> 01:37:59,760

they're indeed physical

2756

01:38:03,510 --> 01:38:01,840

or just or you know or just or just

2757

01:38:05,510 --> 01:38:03,520

false reports

2758

01:38:07,430 --> 01:38:05,520

but i i do think it's it's it's really

2759

01:38:10,070 --> 01:38:07,440

uh interesting and

2760

01:38:12,629 --> 01:38:10,080

um but probably you you've heard so many

2761

01:38:13,910 --> 01:38:12,639

points of view that you've probably um

2762

01:38:15,510 --> 01:38:13,920

you're probably in possession now of

2763

01:38:17,030 --> 01:38:15,520

quite a lot of facts

2764

01:38:18,310 --> 01:38:17,040

you know about it you're probably a

2765

01:38:19,510 --> 01:38:18,320

minor expert

2766

01:38:21,669 --> 01:38:19,520

well

2767

01:38:23,830 --> 01:38:21,679

you mentioned that

2768

01:38:26,629 --> 01:38:23,840

that you like to simplify and the way

2769

01:38:29,510 --> 01:38:26,639

that my brain works is that i

2770

01:38:32,390 --> 01:38:29,520

i i have such a confused ontology of

2771

01:38:33,750 --> 01:38:32,400

what exists so like we mentioned max tag

2772

01:38:35,430 --> 01:38:33,760

my beliefs math like i don't know what

2773

01:38:37,910 --> 01:38:35,440

the heck is what exists i don't know

2774

01:38:39,830 --> 01:38:37,920

what it means to exist and often many

2775

01:38:41,510 --> 01:38:39,840

facts even mathematical facts i'll

2776

01:38:43,350 --> 01:38:41,520

understand them but i'll quickly lose

2777

01:38:45,910 --> 01:38:43,360

them and i feel like it's because i'm

2778

01:38:47,510 --> 01:38:45,920

floating around in a in a void

2779

01:38:49,430 --> 01:38:47,520

i've never had this problem until about

2780

01:38:51,830 --> 01:38:49,440

a year and a half ago when i started to

2781

01:38:54,390 --> 01:38:51,840

do this channel it's actually extremely

2782

01:38:57,030 --> 01:38:54,400

taxing for me to learn someone's theory

2783

01:38:58,550 --> 01:38:57,040

sorry that's false it's it's ordinary

2784

01:38:59,990 --> 01:38:58,560

for me to learn someone's theory it's

2785

01:39:01,590 --> 01:39:00,000

taxing for me to remember it it's

2786

01:39:03,910 --> 01:39:01,600

because i don't have i don't have a

2787

01:39:06,470 --> 01:39:03,920

place to slot new information in it's

2788

01:39:08,550 --> 01:39:06,480

all floating and slowly i get glimpses

2789

01:39:10,470 --> 01:39:08,560

so when you ask well what's going on

2790

01:39:12,390 --> 01:39:10,480

with your folsom i have i have no clue i

2791

01:39:14,550 --> 01:39:12,400

can we can talk about some of the

2792

01:39:15,910 --> 01:39:14,560

theories out there some of them are wild

2793

01:39:17,189 --> 01:39:15,920

some of them make sense with other

2794

01:39:18,629 --> 01:39:17,199

accounts

2795

01:39:20,470 --> 01:39:18,639

but hopefully i'll be able to say

2796

01:39:23,350 --> 01:39:20,480

something useful i don't think so but

2797

01:39:25,430 --> 01:39:23,360

we'll see okay professor i i should get

2798

01:39:26,790 --> 01:39:25,440

that was so much fun yeah so let's do it

2799

01:39:30,709 --> 01:39:26,800

again sometime but you know whenever for

2800

01:39:34,390 --> 01:39:32,709

the podcast is now finished if you'd

2801

01:39:37,590 --> 01:39:34,400

like to support conversations like this

2802

01:39:41,669 --> 01:39:37,600

then do consider going to [patreon.com](https://patreon.com)

2803

01:39:44,310 --> 01:39:41,679

c-u-r-t j-a-i

2804

01:39:46,070 --> 01:39:44,320

that is kurt jaimungle it's support from

2805

01:39:47,910 --> 01:39:46,080

the patrons and from the sponsors that