



WHAT?! YOU

DON'T JUST

"SET"

$c=1=\hbar$

1
00:00:03,889 --> 00:00:02,149
all right let's get into this what are

2
00:00:06,110 --> 00:00:03,899
natural units in order to understand

3
00:00:10,430 --> 00:00:06,120
what natural units are we want to know

4
00:00:14,690 --> 00:00:10,440
what are units so for example what is a

5
00:00:17,510 --> 00:00:14,700
meter or if you're being Canadian a

6
00:00:21,830 --> 00:00:17,520
meter I'm based in Toronto if that

7
00:00:25,370 --> 00:00:21,840
wasn't clear already what is a second

8
00:00:29,390 --> 00:00:27,050
now you'll get fairly frenzied if you

9
00:00:31,490 --> 00:00:29,400
think about this for quite some time as

10
00:00:34,310 --> 00:00:31,500
I have that is metaphysically what the

11
00:00:37,069 --> 00:00:34,320
heck is a second what is a meter what is

12
00:00:40,549 --> 00:00:37,079
length a science doesn't answer what is

13
00:00:42,770 --> 00:00:40,559

questions it's operational science is

14

00:00:44,209 --> 00:00:42,780

metaphysically agnostic meaning that it

15

00:00:46,010 --> 00:00:44,219

doesn't actually make a claim onto

16

00:00:47,930 --> 00:00:46,020

ontology it doesn't tell you what is

17

00:00:50,569 --> 00:00:47,940

instead science gives operational

18

00:00:52,250 --> 00:00:50,579

meanings so what is a second it says

19

00:00:54,170 --> 00:00:52,260

here the second is equal to the duration

20

00:00:56,270 --> 00:00:54,180

of nine one nine two six three one

21

00:00:58,430 --> 00:00:56,280

periods of the radiation corresponding

22

00:01:00,110 --> 00:00:58,440

to the transition between hyperfine

23

00:01:02,510 --> 00:01:00,120

levels of the unperturbed ground state

24

00:01:03,709 --> 00:01:02,520

of cesium atom a certain isotope of a

25

00:01:05,750 --> 00:01:03,719

system atom

26

00:01:09,890 --> 00:01:05,760

okay so then the natural question that

27

00:01:11,510 --> 00:01:09,900

comes up is why this number

28

00:01:14,750 --> 00:01:11,520

so why this and not some other number

29

00:01:17,210 --> 00:01:14,760

and the reason is because in London many

30

00:01:18,950 --> 00:01:17,220

decades ago someone in some back alley

31

00:01:20,810 --> 00:01:18,960

took methamphetamine on a Tuesday night

32

00:01:22,429 --> 00:01:20,820

and came up with that number now I'm not

33

00:01:24,649 --> 00:01:22,439

kidding it may as well be that to

34

00:01:26,030 --> 00:01:24,659

someone studying high energy physics in

35

00:01:27,950 --> 00:01:26,040

the same way that

36

00:01:31,609 --> 00:01:27,960

well what the heck is a kilogram what is

37

00:01:33,590 --> 00:01:31,619

a kilogram it means you go to Paris you

38

00:01:37,850 --> 00:01:33,600

go outside Paris actually it's on the

39

00:01:40,969 --> 00:01:39,649

and you deal with people being

40

00:01:42,890 --> 00:01:40,979

condescending too because you don't

41

00:01:45,410 --> 00:01:42,900

speak French then you duplicate this

42

00:01:47,990 --> 00:01:45,420

little metal slab that's in Paris you

43

00:01:49,670 --> 00:01:48,000

duplicate it 67 times so that you have

44

00:01:52,010 --> 00:01:49,680

68 of them in total

45

00:01:53,690 --> 00:01:52,020

I'm just being quick with my writing 68

46

00:01:56,270 --> 00:01:53,700

of them is in total and then you measure

47

00:01:58,190 --> 00:01:56,280

yourself on a scale and these two

48

00:02:00,350 --> 00:01:58,200

numbers will coincide that's what it

49

00:02:02,510 --> 00:02:00,360

means it's an operational definition now

50

00:02:06,469 --> 00:02:02,520

physicists like to use units that appear

51
00:02:10,790 --> 00:02:06,479
in nature so units that appear

52
00:02:12,350 --> 00:02:10,800
and those we call Natural units there's

53
00:02:14,330 --> 00:02:12,360
some controversy with what's considered

54
00:02:15,650 --> 00:02:14,340
natural because when someone comes to

55
00:02:17,390 --> 00:02:15,660
you with a

56
00:02:19,490 --> 00:02:17,400
some dish and they say this is a natural

57
00:02:21,229 --> 00:02:19,500
dish and that's unnatural well what do

58
00:02:23,270 --> 00:02:21,239
you mean that that those Doritos that

59
00:02:25,010 --> 00:02:23,280
are unnatural did they come from outside

60
00:02:26,390 --> 00:02:25,020
this universe from some void because

61
00:02:28,490 --> 00:02:26,400
it's in everything in this universe

62
00:02:30,770 --> 00:02:28,500
natural aren't we a product of Nature

63
00:02:33,110 --> 00:02:30,780

and so what we create is natural okay

64

00:02:35,089 --> 00:02:33,120

what a physicist means by natural is

65

00:02:37,010 --> 00:02:35,099

that it's invariants across the universe

66

00:02:39,290 --> 00:02:37,020

as far as we can tell to be extremely

67

00:02:41,869 --> 00:02:39,300

precise what we mean when we say natural

68

00:02:44,030 --> 00:02:41,879

units natural in the natural units is

69

00:02:45,530 --> 00:02:44,040

natural with respect to our current

70

00:02:48,229 --> 00:02:45,540

understanding in order to make certain

71

00:02:50,750 --> 00:02:48,239

equations simpler and remove arbitrary

72

00:02:56,270 --> 00:02:50,760

human qualities

73

00:02:58,430 --> 00:02:56,280

some sense even an electron is a human

74

00:03:00,830 --> 00:02:58,440

construct in the sense that it's there

75

00:03:02,809 --> 00:03:00,840

because it nature doesn't parse itself

76

00:03:05,570 --> 00:03:02,819

out into these elements I mean you can

77

00:03:07,369 --> 00:03:05,580

say elementary elementary seems to be an

78

00:03:08,449 --> 00:03:07,379

objective quality because of the way

79

00:03:10,009 --> 00:03:08,459

that we Define what an elementary

80

00:03:11,869 --> 00:03:10,019

particle is it's an irreducible

81

00:03:13,430 --> 00:03:11,879

representation of something so the fact

82

00:03:15,649 --> 00:03:13,440

that it's irreducible means if it could

83

00:03:17,570 --> 00:03:15,659

be reduced in this block Matrix form

84

00:03:19,610 --> 00:03:17,580

then we can just decompose it and we'd

85

00:03:21,949 --> 00:03:19,620

say those elements are Elementary but

86

00:03:24,050 --> 00:03:21,959

the reason why we set aside some special

87

00:03:27,050 --> 00:03:24,060

canonical place for the electron is

88

00:03:28,790 --> 00:03:27,060

because it's useful for us it makes our

89

00:03:31,009 --> 00:03:28,800

models easier to understand simpler

90

00:03:33,350 --> 00:03:31,019

outcomes razor Etc there's plenty of

91

00:03:34,910 --> 00:03:33,360

philosophy that undergirds natural this

92

00:03:36,410 --> 00:03:34,920

is not usually explained and you'll be

93

00:03:38,030 --> 00:03:36,420

led astray if you don't understand that

94

00:03:40,110 --> 00:03:38,040

point now here's another Point that's

95

00:03:42,470 --> 00:03:40,120

ordinarily not explained observables

96

00:03:44,050 --> 00:03:42,480

[Music]

97

00:03:47,270 --> 00:03:44,060

have

98

00:03:48,310 --> 00:03:47,280

null units

99

00:03:49,430 --> 00:03:48,320

there

100

00:03:54,410 --> 00:03:49,440

[Music]

101
00:03:58,850 --> 00:03:56,630
let's say slash ratios

102
00:04:01,009 --> 00:03:58,860
Okay now what's meant by that again when

103
00:04:02,750 --> 00:04:01,019
you say that you weigh 68 kilograms it

104
00:04:04,490 --> 00:04:02,760
means you take 68 of some other

105
00:04:08,869 --> 00:04:04,500
reference

106
00:04:11,089 --> 00:04:08,879
then you stack 68 of them and then you

107
00:04:14,570 --> 00:04:11,099
get yourself it's actually 68 it's not

108
00:04:16,490 --> 00:04:14,580
68 kilograms per se you can also think

109
00:04:18,289 --> 00:04:16,500
of this in another way if you wanted to

110
00:04:20,390 --> 00:04:18,299
speak to aliens which by the way is

111
00:04:23,030 --> 00:04:20,400
another topic on this channel not

112
00:04:26,689 --> 00:04:23,040
speaking to aliens per se but UFOs then

113
00:04:29,450 --> 00:04:26,699

it would be foolish to say I weigh 68 of

114

00:04:31,370 --> 00:04:29,460

some product from France now you can

115

00:04:32,570 --> 00:04:31,380

reverse this and imagine an alien is

116

00:04:34,370 --> 00:04:32,580

speaking to you and you say well how

117

00:04:36,890 --> 00:04:34,380

much does your craft weigh and they say

118

00:04:38,210 --> 00:04:36,900

oh it weighs four garbars and then

119

00:04:39,590 --> 00:04:38,220

you're like what the heck is a garvar

120

00:04:41,930 --> 00:04:39,600

then they say well that's how much

121

00:04:44,030 --> 00:04:41,940

liquid we release from our vorbins every

122

00:04:46,490 --> 00:04:44,040

two farkles it doesn't provide much

123

00:04:48,710 --> 00:04:46,500

information so instead we do what you

124

00:04:51,469 --> 00:04:48,720

see colloquially which is C equals H bar

125

00:04:53,030 --> 00:04:51,479

equals one okay let's get to some myths

126

00:04:55,310 --> 00:04:53,040

about natural units before exploring

127

00:04:58,490 --> 00:04:55,320

exactly what that means so firstly one

128

00:05:02,330 --> 00:04:58,500

of the myths is that we just simply set

129

00:05:03,770 --> 00:05:02,340

C to equal 1 to equal \hbar this is a

130

00:05:06,230 --> 00:05:03,780

meaningless statement as it's written

131

00:05:09,350 --> 00:05:06,240

and the reason is it doesn't they can't

132

00:05:11,870 --> 00:05:09,360

equal one it means we're now using

133

00:05:14,030 --> 00:05:11,880

the speed of light and \hbar as a

134

00:05:15,530 --> 00:05:14,040

reference for some other quantity that

135

00:05:17,689 --> 00:05:15,540

we're trying to develop if you're

136

00:05:18,890 --> 00:05:17,699

confused about this now then that means

137

00:05:20,570 --> 00:05:18,900

you're thinking about this correctly

138

00:05:22,249 --> 00:05:20,580

because it's not ordinarily explained

139

00:05:24,409 --> 00:05:22,259

it's left ambiguous

140

00:05:26,689 --> 00:05:24,419

let's look at this let's imagine what is

141

00:05:27,529 --> 00:05:26,699

the speed of let's say some car on the

142

00:05:31,730 --> 00:05:27,539

highway

143

00:05:35,450 --> 00:05:31,740

equals we would say 100

144

00:05:39,409 --> 00:05:37,490

per hour

145

00:05:41,749 --> 00:05:39,419

these are the units

146

00:05:44,210 --> 00:05:41,759

and that's the magnitude with respect to

147

00:05:45,890 --> 00:05:44,220

those units so if I wanted to say what

148

00:05:47,510 --> 00:05:45,900

is the speed

149

00:05:49,370 --> 00:05:47,520

sorry that's already speed what is the

150

00:05:52,730 --> 00:05:49,380

speed of light

151

00:05:55,370 --> 00:05:52,740

what we mean is two nine nine seven nine

152

00:05:57,230 --> 00:05:55,380

two four five eight again it's one of

153

00:05:58,850 --> 00:05:57,240

those numbers you try to show how clever

154

00:06:02,629 --> 00:05:58,860

you are when you're a child by

155

00:06:05,930 --> 00:06:02,639

memorizing meters per second

156

00:06:08,990 --> 00:06:05,940

now look this is actually what C is C

157

00:06:11,990 --> 00:06:09,000

refers to all of this C doesn't just

158

00:06:13,850 --> 00:06:12,000

refer to the magnitude C refers to the

159

00:06:16,430 --> 00:06:13,860

entirety of it including the units so

160

00:06:19,129 --> 00:06:16,440

when someone says C equals one C equals

161

00:06:21,710 --> 00:06:19,139

one what they actually mean is that we

162

00:06:25,010 --> 00:06:21,720

are now using units where we've taken

163

00:06:28,670 --> 00:06:25,020

that two nine nine seven nine two four

164

00:06:30,830 --> 00:06:28,680

five eight meters per second and we've

165

00:06:33,469 --> 00:06:30,840

placed it in here so we've taken this

166

00:06:36,110 --> 00:06:33,479

guy and we've placed it in here see all

167

00:06:37,070 --> 00:06:36,120

of this is not ordinarily explained and

168

00:06:40,070 --> 00:06:37,080

it's because

169

00:06:42,529 --> 00:06:40,080

as an undergraduate you're especially

170

00:06:45,050 --> 00:06:42,539

used to writing with reference to a

171

00:06:47,029 --> 00:06:45,060

coordinate basis which is why I said try

172

00:06:48,590 --> 00:06:47,039

to do everything you can coordinate free

173

00:06:50,150 --> 00:06:48,600

if you have an instructor you're lucky

174

00:06:52,309 --> 00:06:50,160

enough to have an instructor you always

175

00:06:54,350 --> 00:06:52,319

ask how can you represent these

176
00:06:55,790 --> 00:06:54,360
equations coordinate free another way of

177
00:06:57,890 --> 00:06:55,800
thinking about this is that we have

178
00:07:00,050 --> 00:06:57,900
graphs in physics and math constantly

179
00:07:01,610 --> 00:07:00,060
plot and those etchings are akin to

180
00:07:04,189 --> 00:07:01,620
choosing a unit the fact that we put

181
00:07:06,650 --> 00:07:04,199
lines with etchings means we've chosen a

182
00:07:10,129 --> 00:07:06,660
coordinate so these etchings outward are

183
00:07:12,050 --> 00:07:10,139
it implicitly a choice of coordinates

184
00:07:13,909 --> 00:07:12,060
but nature but if you look again like I

185
00:07:15,469 --> 00:07:13,919
mentioned that there's no detector that

186
00:07:17,270 --> 00:07:15,479
can detect the coordinates much like if

187
00:07:18,830 --> 00:07:17,280
you take a picture with your phone and

188
00:07:20,930 --> 00:07:18,840

you then look at it on the screen and

189

00:07:22,430 --> 00:07:20,940

you zoom in you see pixels the pixels

190

00:07:24,050 --> 00:07:22,440

are an artifact of you taking a picture

191

00:07:26,390 --> 00:07:24,060

and trying to manipulate it in some

192

00:07:28,670 --> 00:07:26,400

manner the world itself is not pixelated

193

00:07:30,770 --> 00:07:28,680

unless you're to believe Thomas Campbell

194

00:07:32,510 --> 00:07:30,780

or Donald Hoffman another reason to

195

00:07:34,430 --> 00:07:32,520

think coordinate free is you'll start to

196

00:07:36,890 --> 00:07:34,440

construct constructions that actually

197

00:07:38,270 --> 00:07:36,900

depend on your coordinates when they in

198

00:07:39,710 --> 00:07:38,280

fact don't in nature and then you'll

199

00:07:42,529 --> 00:07:39,720

wonder why are you getting an incorrect

200

00:07:44,089 --> 00:07:42,539

answer so for example in physics and so

201

00:07:47,270 --> 00:07:44,099

on we often use

202

00:07:49,490 --> 00:07:47,280

let's see this and then we represent it

203

00:07:51,950 --> 00:07:49,500

in some symmetry this is how theoretical

204

00:07:53,330 --> 00:07:51,960

physicists generally reference matrices

205

00:07:55,850 --> 00:07:53,340

they don't like them so they call them

206

00:07:57,830 --> 00:07:55,860

symmetries these rows and columns but

207

00:07:59,870 --> 00:07:57,840

then you also would reference this same

208

00:08:02,570 --> 00:07:59,880

object

209

00:08:04,070 --> 00:08:02,580

with numbers in a similar manner

210

00:08:06,710 --> 00:08:04,080

however they transform completely

211

00:08:08,629 --> 00:08:06,720

differently so one is an endomorphism

212

00:08:10,370 --> 00:08:08,639

then the other is a two form or a

213

00:08:11,809 --> 00:08:10,380

bilinear form and they transform

214

00:08:13,670 --> 00:08:11,819

completely differently and which is why

215

00:08:15,710 --> 00:08:13,680

you have transpose which is it's not an

216

00:08:17,749 --> 00:08:15,720

ill-defined object but it's a strangely

217

00:08:21,409 --> 00:08:17,759

defined object the inverse of a matrix

218

00:08:24,950 --> 00:08:21,419

is more copacetic but the transpose is a

219

00:08:28,610 --> 00:08:24,960

strange one so this one is a two form a

220

00:08:30,890 --> 00:08:28,620

bilinear form the metric in the with the

221

00:08:33,230 --> 00:08:30,900

Einstein equations is a 2 4 is a

222

00:08:35,209 --> 00:08:33,240

bilinear form and also the determinants

223

00:08:37,250 --> 00:08:35,219

of endomorphism is a completely

224

00:08:39,290 --> 00:08:37,260

different object it's invariant compared

225

00:08:41,269 --> 00:08:39,300

to the determinants of a two form or a

226

00:08:43,130 --> 00:08:41,279

bilinear form and then as you start to

227

00:08:44,570 --> 00:08:43,140

understand this coordinate free you'll

228

00:08:46,190 --> 00:08:44,580

realize that there's a special place in

229

00:08:48,530 --> 00:08:46,200

hell for the person who developed the

230

00:08:50,930 --> 00:08:48,540

transpose it's an unwieldy object

231

00:08:52,610 --> 00:08:50,940

another one that will confuse you if you

232

00:08:54,350 --> 00:08:52,620

think in terms of coordinates is that

233

00:08:56,090 --> 00:08:54,360

the wave function you ordinarily think

234

00:09:01,190 --> 00:08:56,100

of the wave function that's going from

235

00:09:09,230 --> 00:09:03,050

to

236

00:09:12,350 --> 00:09:09,240

guy is a section

237

00:09:13,550 --> 00:09:12,360

on a \mathbb{C} line bundle and you need to

238

00:09:15,470 --> 00:09:13,560

understand bundles in order to

239

00:09:16,970 --> 00:09:15,480

understand it coordinate free so that

240

00:09:18,410 --> 00:09:16,980

you can do not only polar coordinates

241

00:09:19,970 --> 00:09:18,420

and you wonder why the heck does the

242

00:09:21,290 --> 00:09:19,980

derivative change well that makes sense

243

00:09:22,670 --> 00:09:21,300

when you understand it in terms of a

244

00:09:25,550 --> 00:09:22,680

principal bundle and then the associated

245

00:09:27,110 --> 00:09:25,560

bundle but also in terms of no longer

246

00:09:29,269 --> 00:09:27,120

staying in \mathbb{R}^d what if you want to move

247

00:09:30,590 --> 00:09:29,279

to a curved space for quantum mechanics

248

00:09:32,750 --> 00:09:30,600

what if you want to do quantum mechanics

249

00:09:34,730 --> 00:09:32,760

on a curved space this is why one should

250

00:09:36,410 --> 00:09:34,740

try their best to understand what the

251
00:09:38,210 --> 00:09:36,420
heck is going on without reference to

252
00:09:39,530 --> 00:09:38,220
coordinates and then go to coordinates

253
00:09:41,570 --> 00:09:39,540
when you're actually making a

254
00:09:43,610 --> 00:09:41,580
calculation that's why this is a myth we

255
00:09:45,350 --> 00:09:43,620
just simply set C to equal one to equal

256
00:09:46,970 --> 00:09:45,360
 H bar by the way what is h bar well

257
00:09:48,829 --> 00:09:46,980
that's a bit more abstract you don't

258
00:09:51,170 --> 00:09:48,839
need to understand that for the sake of

259
00:09:53,329 --> 00:09:51,180
this video but this is an ill-defined

260
00:09:55,370 --> 00:09:53,339
equation there's actually a caveat here

261
00:09:57,110 --> 00:09:55,380
that will come into play later another

262
00:09:59,930 --> 00:09:57,120
way of thinking about it is imagine you

263
00:10:03,230 --> 00:09:59,940

have one USD one US dollar

264

00:10:06,710 --> 00:10:03,240

sometimes you would say it equals 127

265

00:10:08,389 --> 00:10:06,720

Yen it doesn't actually equal 127 Yen

266

00:10:11,150 --> 00:10:08,399

otherwise when you have a US dollar it

267

00:10:13,370 --> 00:10:11,160

would just be 127 Yen what it means is

268

00:10:14,870 --> 00:10:13,380

that there's something called value or

269

00:10:17,030 --> 00:10:14,880

some monetary equivalent that's another

270

00:10:18,710 --> 00:10:17,040

way of thinking about it conversion what

271

00:10:20,690 --> 00:10:18,720

it means that you go here with some

272

00:10:22,130 --> 00:10:20,700

mapping let's say m and then here with

273

00:10:23,570 --> 00:10:22,140

some mapping that's that's called let's

274

00:10:26,389 --> 00:10:23,580

say m Prime

275

00:10:28,430 --> 00:10:26,399

what it means is that you do

276

00:10:31,070 --> 00:10:28,440

let's say m Prime

277

00:10:33,290 --> 00:10:31,080

inverse see we have to make all these

278

00:10:34,790 --> 00:10:33,300

constructions now and then that's after

279

00:10:37,370 --> 00:10:34,800

you've already done M so you've gone

280

00:10:39,949 --> 00:10:37,380

from here and then you go back up there

281

00:10:41,389 --> 00:10:39,959

they're not the same so another way of

282

00:10:43,070 --> 00:10:41,399

thinking about this is imagine you want

283

00:10:44,389 --> 00:10:43,080

to change lengths instead of using

284

00:10:45,889 --> 00:10:44,399

meters because you think meters are

285

00:10:47,810 --> 00:10:45,899

strange for some reason you want to

286

00:10:49,970 --> 00:10:47,820

measure everyone in terms of Lady Gaga

287

00:10:51,350 --> 00:10:49,980

so you have Lady Gaga here which I'm

288

00:10:54,530 --> 00:10:51,360

going to call

289

00:10:55,970 --> 00:10:54,540

LG so now let's say we want to measure

290

00:10:59,030 --> 00:10:55,980

someone else let's say some let's say

291

00:11:01,790 --> 00:10:59,040

Goku so what is Goku Goku

292

00:11:03,889 --> 00:11:01,800

equals maybe one and a half Lady Gaga's

293

00:11:05,210 --> 00:11:03,899

in length so you take half of Lady Gaga

294

00:11:07,430 --> 00:11:05,220

and you stack that again on Lady Gaga

295

00:11:09,829 --> 00:11:07,440

and you get a Goku in terms of Link how

296

00:11:12,110 --> 00:11:09,839

about Tony Robbins well that's let's say

297

00:11:14,090 --> 00:11:12,120

two Lady Gaga's now what we're doing

298

00:11:16,490 --> 00:11:14,100

here is we're saying I'm going to make

299

00:11:18,410 --> 00:11:16,500

all my future length measurements in

300

00:11:20,990 --> 00:11:18,420

terms of Lady Gaga for whatever reason

301
00:11:23,030 --> 00:11:21,000
in the same way that generally speaking

302
00:11:24,769 --> 00:11:23,040
prices can be made in reference to the

303
00:11:26,870 --> 00:11:24,779
US dollar and then you do some

304
00:11:29,990 --> 00:11:26,880
conversion to find out its equivalent

305
00:11:31,190 --> 00:11:30,000
monetary value in some other currency in

306
00:11:32,750 --> 00:11:31,200
the same way what we're doing right here

307
00:11:34,790 --> 00:11:32,760
is we're referencing everyone's height

308
00:11:36,470 --> 00:11:34,800
in terms of Lady Gaga's height and it

309
00:11:39,470 --> 00:11:36,480
just as foolish as it would be to say

310
00:11:41,269 --> 00:11:39,480
Lady Gaga equals one equals the USD just

311
00:11:43,730 --> 00:11:41,279
as foolish as this equation is it's

312
00:11:45,889 --> 00:11:43,740
tantamount to saying C equals one equals

313
00:11:47,630 --> 00:11:45,899

H bar there's so much that goes into a

314

00:11:49,250 --> 00:11:47,640

statement like that that's just seeing

315

00:11:51,410 --> 00:11:49,260

that gives the impression oh physicists

316

00:11:53,269 --> 00:11:51,420

are just setting it equal to one so no

317

00:11:55,370 --> 00:11:53,279

this statement is foolish and what's

318

00:11:57,590 --> 00:11:55,380

underneath that is saying hey I'm going

319

00:11:58,910 --> 00:11:57,600

to now measure everything in terms of

320

00:12:01,310 --> 00:11:58,920

the speed of light so I want to measure

321

00:12:02,630 --> 00:12:01,320

my car maybe it's a millionth of the

322

00:12:03,769 --> 00:12:02,640

speed of light I don't know I don't want

323

00:12:05,449 --> 00:12:03,779

to do the calculation right now but

324

00:12:07,550 --> 00:12:05,459

let's say it's a millionth of a speed of

325

00:12:10,069 --> 00:12:07,560

light so then I say well the speed of

326

00:12:14,829 --> 00:12:10,079

walking let's say

327

00:12:20,509 --> 00:12:18,290

0.0005 I'm making this up of these speed

328

00:12:23,930 --> 00:12:20,519

of light units that's what it means okay

329

00:12:29,509 --> 00:12:23,940

so this is all including by the way this

330

00:12:32,810 --> 00:12:31,069

you have to understand what's lurking

331

00:12:34,130 --> 00:12:32,820

underneath so in this example the value

332

00:12:35,810 --> 00:12:34,140

is what's being referenced when I see

333

00:12:36,769 --> 00:12:35,820

the real world that's what I mean is

334

00:12:39,110 --> 00:12:36,779

that there's something else that's

335

00:12:42,050 --> 00:12:39,120

tangible that I'm trying to represent my

336

00:12:44,449 --> 00:12:42,060

quantity in reference to so from now on

337

00:12:46,490 --> 00:12:44,459

we're going to no longer say that this

338

00:12:48,110 --> 00:12:46,500

is moving at 500 meters per second we're

339

00:12:49,670 --> 00:12:48,120

going to say that this is moving at a

340

00:12:51,290 --> 00:12:49,680

fraction of the speed of light by the

341

00:12:53,870 --> 00:12:51,300

way this should be a definition and that

342

00:12:56,329 --> 00:12:53,880

refers to the entire object there not

343

00:12:57,949 --> 00:12:56,339

just this this is just the magnitude and

344

00:12:59,690 --> 00:12:57,959

that's where this is misleading because

345

00:13:01,430 --> 00:12:59,700

it's just showing you the magnitude how

346

00:13:03,470 --> 00:13:01,440

the heck can c equal this in the same

347

00:13:06,350 --> 00:13:03,480

way how the heck can Lady Gaga equal the

348

00:13:08,449 --> 00:13:06,360

US equals one that is myth number one

349

00:13:09,889 --> 00:13:08,459

now myth number two is that the

350

00:13:11,449 --> 00:13:09,899

advantage

351

00:13:13,610 --> 00:13:11,459

welcome to the theories of everything

352

00:13:15,410 --> 00:13:13,620

podcast you just watched a clip from a

353

00:13:16,730 --> 00:13:15,420

much larger two hour video Lesson

354

00:13:18,530 --> 00:13:16,740

including what to do with these natural

355

00:13:20,569 --> 00:13:18,540

units such as how to calculate the

356

00:13:22,910 --> 00:13:20,579

radius of a black hole in five seconds

357

00:13:24,110 --> 00:13:22,920

no joke as well as the vacuum energy of

358

00:13:26,210 --> 00:13:24,120

the universe as well as the pressure

359

00:13:28,370 --> 00:13:26,220

inside a neutron star some facts about

360

00:13:30,470 --> 00:13:28,380

extra dimensions and quantum gravity to

361

00:13:32,509 --> 00:13:30,480

watch it [click here](#) and also [this video](#)

362

00:13:33,829 --> 00:13:32,519

was sponsored by brilliant brilliant is

363

00:13:35,389 --> 00:13:33,839

a website where you can go to learn math

364

00:13:37,009 --> 00:13:35,399

science and engineering through these

365

00:13:38,930 --> 00:13:37,019

bite-sized Interactive Learning

366

00:13:40,970 --> 00:13:38,940

experiences I keep saying this on the

367

00:13:42,590 --> 00:13:40,980

show and I mean it that at some point I

368

00:13:45,050 --> 00:13:42,600

would like to speak to Chiara marletto

369

00:13:47,329 --> 00:13:45,060

or David Deutsch on Constructor Theory

370

00:13:49,550 --> 00:13:47,339

and that's heavily based in information

371

00:13:50,870 --> 00:13:49,560

Theory and thus as preparation for that

372

00:13:52,730 --> 00:13:50,880

I went through brillian's course on

373

00:13:55,490 --> 00:13:52,740

information Theory and random variables

374

00:13:57,710 --> 00:13:55,500

and from there I was able to finally see

375

00:13:59,269 --> 00:13:57,720

why the formula for entropy is the way

376

00:14:01,129 --> 00:13:59,279

that it is it's handed to you on high

377

00:14:02,930 --> 00:14:01,139

from above and it looks Baroque and

378

00:14:04,190 --> 00:14:02,940

highly manufactured but after going

379

00:14:06,710 --> 00:14:04,200

through their course you can see that

380

00:14:09,829 --> 00:14:06,720

it's an extremely organic choice for a

381

00:14:12,710 --> 00:14:09,839

formula visit the link brilliant.org toe

382

00:14:14,030 --> 00:14:12,720

to get 20 off your annual subscription I

383

00:14:16,850 --> 00:14:14,040

personally recommend that you don't stop

384

00:14:17,990 --> 00:14:16,860

before four lessons keep going even if

385

00:14:20,269 --> 00:14:18,000

you feel like you're not making progress

386

00:14:22,009 --> 00:14:20,279

on the first second or third go to four

387

00:14:24,050 --> 00:14:22,019

and you'll be extremely surprised that