

UNDERGRAD, IN 2 HOURS
MASTERCCLASS

$c=1=\hbar$

1
00:00:05,749 --> 00:00:03,190
okay this video will outline how and why

2
00:00:07,430 --> 00:00:05,759
to use natural units to determine

3
00:00:11,589 --> 00:00:07,440
a numerical value

4
00:00:13,430 --> 00:00:11,599
physical observable that's macroscopic

5
00:00:15,509 --> 00:00:13,440
that you would like in my opinion this

6
00:00:17,269 --> 00:00:15,519
should be taught first in physics but

7
00:00:18,870 --> 00:00:17,279
for whatever reason there's no single

8
00:00:20,710 --> 00:00:18,880
lesson there's no single chapter in a

9
00:00:22,630 --> 00:00:20,720
book there's no single lecture in a

10
00:00:24,150 --> 00:00:22,640
lecture series on this instead it's

11
00:00:26,070 --> 00:00:24,160
strewn across

12
00:00:28,390 --> 00:00:26,080
several and you start to intuit it you

13
00:00:29,669 --> 00:00:28,400

start to understand it implicitly as a

14

00:00:31,349 --> 00:00:29,679

physics student

15

00:00:33,510 --> 00:00:31,359

rather than it being made explicit which

16

00:00:35,190 --> 00:00:33,520

it is being made explicit here and

17

00:00:36,790 --> 00:00:35,200

that's because it can serve you in the

18

00:00:38,709 --> 00:00:36,800

beginning of your understanding of

19

00:00:40,310 --> 00:00:38,719

physics and even in the middle of your

20

00:00:42,549 --> 00:00:40,320

misunderstanding of physics which is

21

00:00:45,030 --> 00:00:42,559

where we all are generally this video is

22

00:00:47,110 --> 00:00:45,040

meant to change the way that you view

23

00:00:49,029 --> 00:00:47,120

physics and even the world and that's

24

00:00:50,790 --> 00:00:49,039

the point the point of view shift this

25

00:00:52,790 --> 00:00:50,800

perspective shift is the point of this

26

00:00:55,910 --> 00:00:52,800

video while it's outwardly about

27

00:00:57,910 --> 00:00:55,920

calculations it's truly about

28

00:00:59,510 --> 00:00:57,920

developing a different stance on nature

29

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

for those of you who are unfamiliar with

30

00:01:03,270 --> 00:01:01,760

me my name is kirchey mungle i'm a

31

00:01:05,030 --> 00:01:03,280

filmmaker with a background in

32

00:01:07,350 --> 00:01:05,040

mathematical physics and i run this

33

00:01:09,429 --> 00:01:07,360

channel called theories of everything

34

00:01:11,109 --> 00:01:09,439

which is a podcast it's a podcast first

35

00:01:12,310 --> 00:01:11,119

and foremost so don't subscribe to this

36

00:01:14,390 --> 00:01:12,320

if you're not interested in the rest of

37

00:01:16,550 --> 00:01:14,400

the content and the rest of the content

38

00:01:18,469 --> 00:01:16,560

is about making comprehensible the

39

00:01:20,630 --> 00:01:18,479

different toes that exist the different

40

00:01:23,030 --> 00:01:20,640

theories of everything so for example

41

00:01:25,350 --> 00:01:23,040

wolfram's theory of everything or

42

00:01:27,030 --> 00:01:25,360

geometric unity that's coming up or

43

00:01:30,070 --> 00:01:27,040

quantum gravity well that's the

44

00:01:32,630 --> 00:01:30,080

seedlings of a toe string theory e8 etc

45

00:01:33,990 --> 00:01:32,640

etc we even cover the more larger

46

00:01:35,749 --> 00:01:34,000

philosophical ones because i'm

47

00:01:37,350 --> 00:01:35,759

interested in consciousness what role

48

00:01:39,109 --> 00:01:37,360

does that have to play with physics or

49

00:01:41,429 --> 00:01:39,119

can it be derived from physics what

50

00:01:43,590 --> 00:01:41,439

about free will what about god so you

51
00:01:44,710 --> 00:01:43,600
can think of this as largely what is

52
00:01:46,789 --> 00:01:44,720
reality

53
00:01:48,789 --> 00:01:46,799
okay let's contextualize the rest of

54
00:01:51,109 --> 00:01:48,799
this video because much of the

55
00:01:53,510 --> 00:01:51,119
misapprehension in learning comes

56
00:01:55,429 --> 00:01:53,520
generally from not understanding the

57
00:01:57,270 --> 00:01:55,439
context of what's being presented or

58
00:01:59,350 --> 00:01:57,280
worse the context isn't given to you at

59
00:02:00,550 --> 00:01:59,360
all there are time stamps here in every

60
00:02:02,789 --> 00:02:00,560
one of the toe videos and they're

61
00:02:04,389 --> 00:02:02,799
meticulously written so you can skip

62
00:02:05,910 --> 00:02:04,399
around if you like by the end of this

63
00:02:07,990 --> 00:02:05,920

you'll be able to calculate virtually

64

00:02:10,150 --> 00:02:08,000

any phenomenon as well as have some

65

00:02:12,229 --> 00:02:10,160

understanding of it specifically by the

66

00:02:14,470 --> 00:02:12,239

end of the next let's say 60 minutes

67

00:02:16,710 --> 00:02:14,480

with just high school mathematics you'll

68

00:02:18,790 --> 00:02:16,720

be able to answer the following without

69

00:02:22,070 --> 00:02:18,800

memorization in fact with derivation

70

00:02:25,030 --> 00:02:22,080

which is superior why is there only time

71

00:02:26,710 --> 00:02:25,040

so why is it that only time exists i

72

00:02:28,309 --> 00:02:26,720

could have said or i could have said

73

00:02:30,390 --> 00:02:28,319

only energy exists or i could have said

74

00:02:32,070 --> 00:02:30,400

only seconds or only length exists i

75

00:02:33,830 --> 00:02:32,080

just didn't want to come out of the gate

76
00:02:35,830 --> 00:02:33,840
sounding like a buddhist by saying hey

77
00:02:37,350 --> 00:02:35,840
all that exists is energy but you can

78
00:02:39,509 --> 00:02:37,360
equally replace that there what is the

79
00:02:40,630 --> 00:02:39,519
vacuum energy expectation i'm sure

80
00:02:42,790 --> 00:02:40,640
you've heard that this is the worst

81
00:02:45,030 --> 00:02:42,800
prediction in physics etc what are the

82
00:02:47,589 --> 00:02:45,040
bounds on extra dimensions why saying

83
00:02:49,910 --> 00:02:47,599
gravity is weak is worse than a false

84
00:02:53,430 --> 00:02:49,920
statement it's meaningless statement

85
00:02:55,509 --> 00:02:53,440
that deserves a bolded exclamation point

86
00:02:57,110 --> 00:02:55,519
great the neutron star pressure what is

87
00:02:58,309 --> 00:02:57,120
the pressure inside a neutron star by

88
00:03:00,949 --> 00:02:58,319

the end of this video you'll be able to

89

00:03:02,550 --> 00:03:00,959

answer that in almost a second

90

00:03:03,990 --> 00:03:02,560

microtubules for consciousness will

91

00:03:06,149 --> 00:03:04,000

delve a little bit into that that's

92

00:03:07,910 --> 00:03:06,159

penrose's theory why was magnetism

93

00:03:10,470 --> 00:03:07,920

understood so late that's a historical

94

00:03:12,149 --> 00:03:10,480

fact but you can actually derive it from

95

00:03:13,750 --> 00:03:12,159

fundamental principles we'll explain

96

00:03:15,589 --> 00:03:13,760

what that means what is the size of the

97

00:03:18,470 --> 00:03:15,599

earth yes you can derive the size of the

98

00:03:20,309 --> 00:03:18,480

earth approximately napkin calculations

99

00:03:22,070 --> 00:03:20,319

casmir pressure i'm sure you've heard

100

00:03:23,589 --> 00:03:22,080

that hey if you take some plates and

101

00:03:25,910 --> 00:03:23,599

then there's some mode that goes in

102

00:03:27,910 --> 00:03:25,920

between there are more modes outside and

103

00:03:30,070 --> 00:03:27,920

so the plates come together in a vacuum

104

00:03:32,630 --> 00:03:30,080

we'll also be covering knots and quantum

105

00:03:34,710 --> 00:03:32,640

gravity at least a modicum we'll also

106

00:03:37,190 --> 00:03:34,720

cover the schwinger limit and salvator

107

00:03:39,270 --> 00:03:37,200

pius's super force or the planck force

108

00:03:40,789 --> 00:03:39,280

we'll also talk about black holes now

109

00:03:42,229 --> 00:03:40,799

all of these facts look like they belong

110

00:03:43,750 --> 00:03:42,239

under the umbrella of physics except

111

00:03:45,750 --> 00:03:43,760

perhaps maybe the consciousness one

112

00:03:47,990 --> 00:03:45,760

penrose disagrees but all of them belong

113

00:03:49,589 --> 00:03:48,000

to physics and disparate fields and you

114

00:03:51,750 --> 00:03:49,599

would need to apply completely different

115

00:03:53,190 --> 00:03:51,760

frameworks to properly understand them

116

00:03:55,589 --> 00:03:53,200

that's true if you want to make a

117

00:03:57,509 --> 00:03:55,599

precise calculation then yes but if what

118

00:03:59,429 --> 00:03:57,519

you want is an estimate a napkin

119

00:04:00,390 --> 00:03:59,439

calculation then you don't need this you

120

00:04:03,350 --> 00:04:00,400

can use

121

00:04:05,589 --> 00:04:03,360

natural units now this video is akin to

122

00:04:07,350 --> 00:04:05,599

an introduction to the next video which

123

00:04:09,429 --> 00:04:07,360

is coming out perhaps a few months from

124

00:04:11,190 --> 00:04:09,439

now i don't plan on doing these lecture

125

00:04:12,710 --> 00:04:11,200

type videos like i mentioned this is a

126

00:04:15,509 --> 00:04:12,720

podcast channel don't plan on doing

127

00:04:18,069 --> 00:04:15,519

these much the next video will be about

128

00:04:19,110 --> 00:04:18,079

how to analyze and comprehend

129

00:04:24,629 --> 00:04:19,120

a

130

00:04:26,230 --> 00:04:24,639

beyond your current level of

131

00:04:28,550 --> 00:04:26,240

understanding so i'll be going through

132

00:04:30,230 --> 00:04:28,560

geometric unity and giving tips on

133

00:04:31,990 --> 00:04:30,240

learning physics and mathematics in

134

00:04:34,070 --> 00:04:32,000

general now let's get on to the approach

135

00:04:35,590 --> 00:04:34,080

of this video so number one what's

136

00:04:37,110 --> 00:04:35,600

different about this number one is that

137

00:04:39,189 --> 00:04:37,120

there will be

138

00:04:42,150 --> 00:04:39,199

quite a few digressions because it will

139

00:04:43,990 --> 00:04:42,160

be about how to think that is how to

140

00:04:45,430 --> 00:04:44,000

think about physics problems in general

141

00:04:48,629 --> 00:04:45,440

rather than how to just solve certain

142

00:04:51,590 --> 00:04:48,639

ones with natural units number two this

143

00:04:53,749 --> 00:04:51,600

is great for theory yes but and it's

144

00:04:55,110 --> 00:04:53,759

also great because it's practical the

145

00:04:56,230 --> 00:04:55,120

reason is that whenever you're dealing

146

00:04:58,390 --> 00:04:56,240

with numbers whenever you're dealing

147

00:05:00,469 --> 00:04:58,400

with units it's akin to a choice of a

148

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

basis in the theoretical end you should

149

00:05:04,710 --> 00:05:02,240

try to construct whatever you're doing

150

00:05:07,029 --> 00:05:04,720

without reference to a choice of basis

151
00:05:08,710 --> 00:05:07,039
much of your existence in physics so far

152
00:05:11,590 --> 00:05:08,720
has taken place

153
00:05:13,110 --> 00:05:11,600
with an implicit choice of a basis when

154
00:05:14,870 --> 00:05:13,120
you're talking about some transpiration

155
00:05:17,110 --> 00:05:14,880
let's say you say it's well it's three

156
00:05:18,790 --> 00:05:17,120
meters to the left and two meters up but

157
00:05:20,550 --> 00:05:18,800
then the question is well three meters

158
00:05:22,550 --> 00:05:20,560
to the left from where two meters up

159
00:05:24,790 --> 00:05:22,560
from where and then also what is up what

160
00:05:27,189 --> 00:05:24,800
is left what are those directions per se

161
00:05:28,629 --> 00:05:27,199
now the real world per se doesn't care

162
00:05:30,390 --> 00:05:28,639
about your choice of coordinates doesn't

163
00:05:32,469 --> 00:05:30,400

care about the chart that you choose

164

00:05:33,990 --> 00:05:32,479

it's what we do in order to communicate

165

00:05:36,550 --> 00:05:34,000

with others as well as it makes it

166

00:05:37,990 --> 00:05:36,560

psychologically easier on ourselves but

167

00:05:40,710 --> 00:05:38,000

don't confuse the coordinates with the

168

00:05:42,790 --> 00:05:40,720

real world there is no detector that

169

00:05:44,390 --> 00:05:42,800

detects the coordinates in theoretical

170

00:05:46,710 --> 00:05:44,400

physics there's a saying that there's

171

00:05:49,430 --> 00:05:46,720

nothing noble in choosing a basis true

172

00:05:52,230 --> 00:05:49,440

nobility is being coordinate free number

173

00:05:54,390 --> 00:05:52,240

three it will be important for us to be

174

00:05:56,070 --> 00:05:54,400

precise so the reason is that otherwise

175

00:05:57,909 --> 00:05:56,080

you'll be confused and you won't realize

176

00:05:59,270 --> 00:05:57,919

where your confusion lies much of the

177

00:06:01,909 --> 00:05:59,280

time when you're a student and you're

178

00:06:03,350 --> 00:06:01,919

going to a professor or a lecturer or

179

00:06:04,550 --> 00:06:03,360

your tutor

180

00:06:06,070 --> 00:06:04,560

and they say well what is it that you

181

00:06:07,990 --> 00:06:06,080

don't understand sometimes you don't

182

00:06:09,909 --> 00:06:08,000

know where your misunderstanding is and

183

00:06:11,189 --> 00:06:09,919

so it's difficult to learn a subject and

184

00:06:13,510 --> 00:06:11,199

much of the time that comes from the

185

00:06:15,270 --> 00:06:13,520

subject not being explained specifically

186

00:06:16,950 --> 00:06:15,280

to you throughout this video i'll be

187

00:06:18,469 --> 00:06:16,960

throwing out tidbits perhaps different

188

00:06:19,990 --> 00:06:18,479

pieces of terminology that you don't

189

00:06:21,189 --> 00:06:20,000

understand that's okay it's for those

190

00:06:22,790 --> 00:06:21,199

who want to learn

191

00:06:24,950 --> 00:06:22,800

slightly more and i'll also be going

192

00:06:26,870 --> 00:06:24,960

through the specific steps i won't skip

193

00:06:28,390 --> 00:06:26,880

a step as often as i can and that's

194

00:06:30,790 --> 00:06:28,400

because i don't want you to be as

195

00:06:32,710 --> 00:06:30,800

confused as myself when i was learning

196

00:06:34,150 --> 00:06:32,720

much of this often steps are glossed

197

00:06:35,350 --> 00:06:34,160

over because the presenter is so

198

00:06:36,870 --> 00:06:35,360

familiar with them that they've

199

00:06:38,950 --> 00:06:36,880

forgotten what it's like to not

200

00:06:41,189 --> 00:06:38,960

understand a subject so for me when it's

201
00:06:43,590 --> 00:06:41,199
delineated specifically here you go from

202
00:06:45,430 --> 00:06:43,600
here to a to b to c rather than from

203
00:06:47,270 --> 00:06:45,440
rather than from b to d let's say then

204
00:06:49,350 --> 00:06:47,280
because the logical progression is made

205
00:06:51,830 --> 00:06:49,360
painstakingly clear you understand it

206
00:06:53,590 --> 00:06:51,840
better for example we will not be using

207
00:06:55,430 --> 00:06:53,600
this symbol

208
00:06:58,230 --> 00:06:55,440
what the heck is this

209
00:06:59,909 --> 00:06:58,240
what the heck

210
00:07:03,189 --> 00:06:59,919
is this

211
00:07:05,749 --> 00:07:03,199
now that deserves a bolded

212
00:07:07,510 --> 00:07:05,759
exclamation point the reason is that

213
00:07:09,270 --> 00:07:07,520

well is zero

214

00:07:10,070 --> 00:07:09,280

approximately one

215

00:07:12,550 --> 00:07:10,080

is

216

00:07:14,550 --> 00:07:12,560

one approximately ten ask the person

217

00:07:17,029 --> 00:07:14,560

who's teaching you please define this

218

00:07:18,550 --> 00:07:17,039

guy specifically what the heck is that

219

00:07:21,029 --> 00:07:18,560

this is not a mathematically well

220

00:07:22,870 --> 00:07:21,039

defined symbol this quote-unquote

221

00:07:24,550 --> 00:07:22,880

approximately symbol so instead what

222

00:07:27,670 --> 00:07:24,560

we'll use is this

223

00:07:29,749 --> 00:07:27,680

which means on the order of so 10 is on

224

00:07:33,029 --> 00:07:29,759

the order of 90. they have the same

225

00:07:36,469 --> 00:07:33,039

amount of digits 102 is on the same

226
00:07:38,629 --> 00:07:36,479
order of 999 for example in the interest

227
00:07:40,390 --> 00:07:38,639
of being precise technically this video

228
00:07:42,309 --> 00:07:40,400
should be titled how to approximately

229
00:07:44,390 --> 00:07:42,319
solve every physics question regarding

230
00:07:46,550 --> 00:07:44,400
observables but that's unwieldy and

231
00:07:48,950 --> 00:07:46,560
doesn't fit the title character count

232
00:07:52,070 --> 00:07:48,960
number four is will be s chewing

233
00:07:53,990 --> 00:07:52,080
exercises in favor of a point of view

234
00:07:55,510 --> 00:07:54,000
shift now generally when i watch videos

235
00:07:58,070 --> 00:07:55,520
online they're generally given by

236
00:07:59,990 --> 00:07:58,080
lecturers to university students and

237
00:08:01,510 --> 00:08:00,000
then they say okay we'll leave this as

238
00:08:04,390 --> 00:08:01,520

an exercise to you if you want to learn

239

00:08:06,629 --> 00:08:04,400

more do this as an exercise however even

240

00:08:08,469 --> 00:08:06,639

highly highly motivated people don't do

241

00:08:10,309 --> 00:08:08,479

those exercises generally you're trying

242

00:08:12,390 --> 00:08:10,319

to get an overview and the lecturer is

243

00:08:14,150 --> 00:08:12,400

used to assigning problems to students

244

00:08:15,990 --> 00:08:14,160

so they think that the viewer is going

245

00:08:17,589 --> 00:08:16,000

to actually do them but they don't and

246

00:08:19,909 --> 00:08:17,599

it's tedious and so what's more

247

00:08:21,990 --> 00:08:19,919

nourishing is to instead provide a point

248

00:08:24,230 --> 00:08:22,000

of view shift so that when you're going

249

00:08:25,909 --> 00:08:24,240

about your life you can convert all of

250

00:08:28,230 --> 00:08:25,919

these measurements that you see to

251
00:08:30,150 --> 00:08:28,240
energy for example rather than assigning

252
00:08:33,589 --> 00:08:30,160
exercises which almost no one does

253
00:08:36,790 --> 00:08:33,599
anyway so as chewing exercises

254
00:08:38,389 --> 00:08:36,800
in favor of point of view firstly

255
00:08:39,990 --> 00:08:38,399
it's easier to get this shift of

256
00:08:41,829 --> 00:08:40,000
perspective and number two it's more

257
00:08:43,670 --> 00:08:41,839
enjoyable it's fun number three it's

258
00:08:45,990 --> 00:08:43,680
more practical the fifth point is that

259
00:08:47,110 --> 00:08:46,000
it will be extremely lean and what i

260
00:08:49,350 --> 00:08:47,120
mean by that is that there will be

261
00:08:51,269 --> 00:08:49,360
little fat there will be little that's

262
00:08:53,110 --> 00:08:51,279
extraneous this is meant to be a video

263
00:08:54,790 --> 00:08:53,120

that you can watch you can re-watch not

264

00:08:56,389 --> 00:08:54,800

only when you've

265

00:08:57,590 --> 00:08:56,399

forgotten about natural units and you

266

00:08:59,030 --> 00:08:57,600

want to

267

00:09:00,790 --> 00:08:59,040

get some understanding get some handle

268

00:09:03,350 --> 00:09:00,800

on how to calculate with them do napkin

269

00:09:04,949 --> 00:09:03,360

calculations but also

270

00:09:07,110 --> 00:09:04,959

when you've lost some motivation to

271

00:09:10,470 --> 00:09:07,120

learn mathematics or physics there will

272

00:09:12,630 --> 00:09:10,480

be myriad points throughout about

273

00:09:15,350 --> 00:09:12,640

how to think about mathematics and

274

00:09:17,110 --> 00:09:15,360

physics in terms of a general approach

275

00:09:19,269 --> 00:09:17,120

to learning like i mentioned before this

276

00:09:20,949 --> 00:09:19,279

latter point will be expanded upon in

277

00:09:22,790 --> 00:09:20,959

some video that i'll release in a few

278

00:09:23,910 --> 00:09:22,800

months about going through a physics

279

00:09:25,829 --> 00:09:23,920

paper that you currently don't

280

00:09:27,829 --> 00:09:25,839

understand some theoretical physics one

281

00:09:29,990 --> 00:09:27,839

and i believe i'll be doing geometric

282

00:09:30,790 --> 00:09:30,000

unity number six now this one's more for

283

00:09:34,710 --> 00:09:30,800

you

284

00:09:36,790 --> 00:09:34,720

a part of this video that's fine keep

285

00:09:39,350 --> 00:09:36,800

pushing this comes from wheeler the

286

00:09:40,710 --> 00:09:39,360

point is not to drink from the fire hose

287

00:09:43,430 --> 00:09:40,720

that's what we think we're supposed to

288

00:09:44,230 --> 00:09:43,440

do but instead you're simply supposed to

289

00:09:45,350 --> 00:09:44,240

get

290

00:09:46,870 --> 00:09:45,360

wet

291

00:09:48,470 --> 00:09:46,880

same with watching the podcasts on this

292

00:09:50,870 --> 00:09:48,480

channel sometimes they're extremely

293

00:09:53,190 --> 00:09:50,880

technical people say well i i can't

294

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

understand so and so that's fine just

295

00:09:57,350 --> 00:09:55,440

keep watching the first passage is

296

00:09:59,670 --> 00:09:57,360

generally to just know where are you

297

00:10:01,430 --> 00:09:59,680

going so that you can contextualize the

298

00:10:02,949 --> 00:10:01,440

understanding that comes earlier much of

299

00:10:04,870 --> 00:10:02,959

the time we're told look physics and

300

00:10:06,550 --> 00:10:04,880

mathematics you build upon it and you

301
00:10:08,710 --> 00:10:06,560
have to know the foundations otherwise

302
00:10:10,470 --> 00:10:08,720
the top will be shaky and that's true

303
00:10:12,870 --> 00:10:10,480
but it's

304
00:10:14,870 --> 00:10:12,880
it's often useful to keep going even

305
00:10:17,030 --> 00:10:14,880
when you don't understand simply so that

306
00:10:18,310 --> 00:10:17,040
you can know where are you going because

307
00:10:20,230 --> 00:10:18,320
your misapprehension about the

308
00:10:21,430 --> 00:10:20,240
fundamental steps

309
00:10:23,910 --> 00:10:21,440
come from not being able to

310
00:10:25,829 --> 00:10:23,920
contextualize it so it's fine keep going

311
00:10:27,590 --> 00:10:25,839
don't feel like i can't drink quote

312
00:10:30,150 --> 00:10:27,600
unquote from the fire hose the point is

313
00:10:31,750 --> 00:10:30,160

simply get soaked and trust that the

314

00:10:33,670 --> 00:10:31,760

learning will occur

315

00:10:35,590 --> 00:10:33,680

all right let's get into this what are

316

00:10:37,829 --> 00:10:35,600

natural units in order to understand

317

00:10:42,069 --> 00:10:37,839

what natural units are we want to know

318

00:10:43,350 --> 00:10:42,079

what are units so for example what is a

319

00:10:44,150 --> 00:10:43,360

meter

320

00:10:47,670 --> 00:10:44,160

or

321

00:10:49,590 --> 00:10:47,680

if you're being canadian a meter

322

00:10:50,949 --> 00:10:49,600

i'm based in toronto if that wasn't

323

00:10:53,910 --> 00:10:50,959

clear already

324

00:10:57,430 --> 00:10:53,920

what is a second

325

00:11:01,670 --> 00:10:58,949

now you'll get fairly frenzied if you

326

00:11:03,430 --> 00:11:01,680

think about this for quite some time as

327

00:11:06,550 --> 00:11:03,440

i have that is metaphysically what the

328

00:11:08,949 --> 00:11:06,560

heck is a second what is a meter what is

329

00:11:11,910 --> 00:11:08,959

length science actually doesn't answer

330

00:11:13,990 --> 00:11:11,920

what is questions and this is something

331

00:11:15,829 --> 00:11:14,000

that's not taught to you science isn't

332

00:11:17,350 --> 00:11:15,839

materialistic science isn't

333

00:11:19,910 --> 00:11:17,360

immaterialistic

334

00:11:21,110 --> 00:11:19,920

it's operational and this is a point

335

00:11:22,550 --> 00:11:21,120

that

336

00:11:24,230 --> 00:11:22,560

many people don't seem to understand

337

00:11:26,470 --> 00:11:24,240

including scientists science is

338

00:11:27,990 --> 00:11:26,480

metaphysically agnostic meaning that it

339

00:11:30,230 --> 00:11:28,000

doesn't actually make a claim onto

340

00:11:31,990 --> 00:11:30,240

ontology it doesn't tell you what is

341

00:11:34,069 --> 00:11:32,000

instead science gives operational

342

00:11:35,829 --> 00:11:34,079

meanings so what is a second it's

343

00:11:38,230 --> 00:11:35,839

something like nine

344

00:11:39,910 --> 00:11:38,240

comma one nine two comma i don't know

345

00:11:41,509 --> 00:11:39,920

those three seven seven zero it's one of

346

00:11:43,190 --> 00:11:41,519

those numbers you memorize as a child to

347

00:11:45,509 --> 00:11:43,200

show how clever you are let's look it up

348

00:11:49,110 --> 00:11:45,519

on wikipedia

349

00:11:50,949 --> 00:11:49,120

so let's do this wikipedia a second

350

00:11:53,910 --> 00:11:50,959

it says here the second is equal to the

351
00:11:55,030 --> 00:11:53,920
duration of 9 192 631 that's what i

352
00:11:56,790 --> 00:11:55,040
forgot

353
00:11:58,710 --> 00:11:56,800
seven seven zero periods of the

354
00:12:00,550 --> 00:11:58,720
radiation corresponding to the

355
00:12:02,389 --> 00:12:00,560
transition between hyperfine levels of

356
00:12:04,150 --> 00:12:02,399
the unperturbed ground state of a

357
00:12:05,750 --> 00:12:04,160
cystium atom a certain isotope of a

358
00:12:07,509 --> 00:12:05,760
cystium atom

359
00:12:09,509 --> 00:12:07,519
okay so then the natural question that

360
00:12:10,389 --> 00:12:09,519
comes up is why

361
00:12:11,829 --> 00:12:10,399
this

362
00:12:16,790 --> 00:12:11,839
number

363
00:12:19,190 --> 00:12:16,800

and the reason is because in london many

364

00:12:21,110 --> 00:12:19,200

decades ago someone in some back alley

365

00:12:22,790 --> 00:12:21,120

took methamphetamine on a tuesday night

366

00:12:24,550 --> 00:12:22,800

and came up with that number now i'm not

367

00:12:26,629 --> 00:12:24,560

kidding it may as well be that to

368

00:12:28,230 --> 00:12:26,639

someone studying high energy physics in

369

00:12:29,990 --> 00:12:28,240

the same way that

370

00:12:31,190 --> 00:12:30,000

well what the heck is a kilogram what is

371

00:12:32,949 --> 00:12:31,200

a kilogram

372

00:12:35,430 --> 00:12:32,959

it means you go to

373

00:12:37,190 --> 00:12:35,440

paris you go outside paris actually so

374

00:12:40,389 --> 00:12:37,200

on the borders of paris you go to some

375

00:12:43,190 --> 00:12:41,910

and you deal with people being

376

00:12:45,110 --> 00:12:43,200

condescending to you because you don't

377

00:12:47,750 --> 00:12:45,120

speaking english then you duplicate this

378

00:12:50,389 --> 00:12:47,760

little metal slab that's in paris you

379

00:12:53,190 --> 00:12:50,399

duplicate it 67 times so that you have

380

00:12:55,509 --> 00:12:53,200

68 of them in total i'm just being quick

381

00:12:58,069 --> 00:12:55,519

with my writing 68 of them is in total

382

00:13:00,230 --> 00:12:58,079

then you measure yourself on a scale

383

00:13:01,910 --> 00:13:00,240

and these two numbers will coincide

384

00:13:04,310 --> 00:13:01,920

that's what it means it's an operational

385

00:13:07,190 --> 00:13:04,320

definition now physicists like to use

386

00:13:09,509 --> 00:13:07,200

units that appear in nature so units

387

00:13:11,350 --> 00:13:09,519

that appear

388

00:13:12,629 --> 00:13:11,360

and those we call

389

00:13:13,990 --> 00:13:12,639

natural

390

00:13:15,509 --> 00:13:14,000

units

391

00:13:17,030 --> 00:13:15,519

now there is some

392

00:13:18,470 --> 00:13:17,040

at least with me there's some

393

00:13:20,470 --> 00:13:18,480

controversy with what's considered

394

00:13:22,069 --> 00:13:20,480

natural because when someone comes to

395

00:13:23,750 --> 00:13:22,079

you with a

396

00:13:25,590 --> 00:13:23,760

some dish and they say this is a natural

397

00:13:27,829 --> 00:13:25,600

dish and that's unnatural well what do

398

00:13:29,670 --> 00:13:27,839

you mean that that those doritos that

399

00:13:31,509 --> 00:13:29,680

are unnatural did they come from outside

400

00:13:32,790 --> 00:13:31,519

this universe from some void because

401
00:13:34,870 --> 00:13:32,800
isn't everything in this universe

402
00:13:36,949 --> 00:13:34,880
natural aren't we a product of nature

403
00:13:39,350 --> 00:13:36,959
and so what we create is natural

404
00:13:41,269 --> 00:13:39,360
okay what a physicist means by natural

405
00:13:43,110 --> 00:13:41,279
is that it's invariant across the

406
00:13:45,269 --> 00:13:43,120
universe as far as we can tell to be

407
00:13:47,829 --> 00:13:45,279
extremely precise what we mean when we

408
00:13:50,389 --> 00:13:47,839
say natural units natural in the natural

409
00:13:51,990 --> 00:13:50,399
units is natural with respect to our

410
00:13:54,310 --> 00:13:52,000
current understanding in order to make

411
00:13:57,670 --> 00:13:54,320
certain equations simpler and remove

412
00:14:00,870 --> 00:13:57,680
arbitrary human qualities

413
00:14:03,189 --> 00:14:00,880

and not just human qualities well in

414

00:14:05,269 --> 00:14:03,199

some sense even an electron is a human

415

00:14:06,470 --> 00:14:05,279

construct in the sense that it's there

416

00:14:08,069 --> 00:14:06,480

because it

417

00:14:09,990 --> 00:14:08,079

nature doesn't parse itself out into

418

00:14:12,550 --> 00:14:10,000

these elements i mean you can say

419

00:14:14,310 --> 00:14:12,560

elementary elementary seems to be an

420

00:14:15,670 --> 00:14:14,320

objective quality because of the way

421

00:14:17,110 --> 00:14:15,680

that we define what an elementary

422

00:14:18,949 --> 00:14:17,120

particle is it's an irreducible

423

00:14:20,470 --> 00:14:18,959

representation of something so the fact

424

00:14:23,030 --> 00:14:20,480

that it's irreducible means if it could

425

00:14:24,629 --> 00:14:23,040

be reduced in this block matrix form

426
00:14:26,710 --> 00:14:24,639
then we can just decompose it and we'd

427
00:14:29,350 --> 00:14:26,720
say those elements are elementary but

428
00:14:31,269 --> 00:14:29,360
the reason why we set aside some special

429
00:14:33,990 --> 00:14:31,279
canonical place for the electron is

430
00:14:36,069 --> 00:14:34,000
because it's useful for us it makes

431
00:14:38,150 --> 00:14:36,079
our models easier to understand simpler

432
00:14:40,790 --> 00:14:38,160
outcomes razer etcetera there's plenty

433
00:14:42,550 --> 00:14:40,800
of philosophy that undergirds natural

434
00:14:43,910 --> 00:14:42,560
again this is not usually explained and

435
00:14:45,670 --> 00:14:43,920
you'll be led astray if you don't

436
00:14:47,509 --> 00:14:45,680
understand that point now here's another

437
00:14:51,030 --> 00:14:47,519
point that's ordinarily not explained

438
00:14:53,590 --> 00:14:52,550

have

439

00:14:56,829 --> 00:14:53,600

no

440

00:14:56,839 --> 00:15:02,949

they're dimensionless

441

00:15:07,269 --> 00:15:05,269

let's say slash ratios

442

00:15:09,509 --> 00:15:07,279

okay now what's meant by that again when

443

00:15:11,430 --> 00:15:09,519

you say that you weigh 68 kilograms it

444

00:15:13,189 --> 00:15:11,440

means you take 68 of some other

445

00:15:17,350 --> 00:15:13,199

reference

446

00:15:19,750 --> 00:15:17,360

then you stack 68 of them and then you

447

00:15:20,870 --> 00:15:19,760

get yourself it's actually 68 it's not

448

00:15:22,550 --> 00:15:20,880

68

449

00:15:24,150 --> 00:15:22,560

kilograms per se

450

00:15:26,230 --> 00:15:24,160

you can also think of this in another

451

00:15:27,829 --> 00:15:26,240

way if you wanted to speak to aliens

452

00:15:29,670 --> 00:15:27,839

which by the way is another

453

00:15:32,870 --> 00:15:29,680

topic on this channel not speaking to

454

00:15:36,470 --> 00:15:32,880

aliens per se but ufos then it would be

455

00:15:38,870 --> 00:15:36,480

foolish to say i way 68 of some

456

00:15:40,790 --> 00:15:38,880

product from france now you can reverse

457

00:15:42,230 --> 00:15:40,800

this and imagine an alien is speaking to

458

00:15:44,550 --> 00:15:42,240

you and you say well how much does your

459

00:15:46,389 --> 00:15:44,560

craft weigh and they say oh it weighs

460

00:15:48,150 --> 00:15:46,399

four gar bars and then you're like what

461

00:15:49,269 --> 00:15:48,160

the heck is a garbar then they say well

462

00:15:51,030 --> 00:15:49,279

that's how much

463

00:15:53,030 --> 00:15:51,040

liquid we release from our bourbons

464

00:15:55,590 --> 00:15:53,040

every two farkles it doesn't provide

465

00:15:57,910 --> 00:15:55,600

much information so instead we do what

466

00:16:00,470 --> 00:15:57,920

you see colloquially which is c equals h

467

00:16:02,069 --> 00:16:00,480

bar equals one okay let's get to some

468

00:16:03,749 --> 00:16:02,079

myths about natural units before

469

00:16:06,150 --> 00:16:03,759

exploring exactly what that means so

470

00:16:08,150 --> 00:16:06,160

firstly one of the myths is that we just

471

00:16:11,590 --> 00:16:08,160

simply set

472

00:16:13,749 --> 00:16:11,600

c to equal one to equal h bar this is a

473

00:16:15,910 --> 00:16:13,759

meaningless statement as it's written

474

00:16:19,269 --> 00:16:15,920

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

475

00:16:21,430 --> 00:16:19,279

equal one it means we're now using

476
00:16:23,749 --> 00:16:21,440
the speed of light and \hbar as a

477
00:16:25,189 --> 00:16:23,759
reference for some other quantity that

478
00:16:27,430 --> 00:16:25,199
we're trying to develop if you're

479
00:16:28,710 --> 00:16:27,440
confused about this now then that means

480
00:16:30,470 --> 00:16:28,720
you're thinking about this correctly

481
00:16:32,230 --> 00:16:30,480
because it's not ordinarily explained

482
00:16:34,069 --> 00:16:32,240
it's left ambiguous

483
00:16:36,470 --> 00:16:34,079
let's look at this let's imagine what is

484
00:16:37,590 --> 00:16:36,480
the speed of let's say some car on the

485
00:16:42,389 --> 00:16:37,600
highway

486
00:16:45,670 --> 00:16:42,399
equals we would say 100

487
00:16:47,829 --> 00:16:46,550
per

488
00:16:49,670 --> 00:16:47,839

hour

489

00:16:51,910 --> 00:16:49,680

these are the units

490

00:16:54,310 --> 00:16:51,920

and that's the magnitude with respect to

491

00:16:56,310 --> 00:16:54,320

those units so if i wanted to say what

492

00:16:57,670 --> 00:16:56,320

is the speed

493

00:16:59,829 --> 00:16:57,680

sorry that's already speed what is the

494

00:17:03,350 --> 00:16:59,839

speed of light

495

00:17:06,549 --> 00:17:03,360

what we mean is two nine nine seven nine

496

00:17:08,309 --> 00:17:06,559

2 4 5 8 again it's one of those numbers

497

00:17:11,350 --> 00:17:08,319

you try to show how clever you are when

498

00:17:13,350 --> 00:17:11,360

you're a child by memorizing meters per

499

00:17:16,390 --> 00:17:13,360

second

500

00:17:19,510 --> 00:17:16,400

now look this is actually what c is c

501
00:17:22,470 --> 00:17:19,520
refers to all of this c doesn't just

502
00:17:24,390 --> 00:17:22,480
refer to the magnitude c refers to the

503
00:17:27,029 --> 00:17:24,400
entirety of it including the units so

504
00:17:29,750 --> 00:17:27,039
when someone says c equals one c equals

505
00:17:32,390 --> 00:17:29,760
one what they actually mean is that we

506
00:17:35,830 --> 00:17:32,400
are now using units where we've taken

507
00:17:39,430 --> 00:17:35,840
that two nine nine seven nine two four

508
00:17:41,669 --> 00:17:39,440
five eight meters per second and we've

509
00:17:44,310 --> 00:17:41,679
placed it in here so we've taken this

510
00:17:46,950 --> 00:17:44,320
guy and we've placed it in here see all

511
00:17:48,549 --> 00:17:46,960
of this is not ordinarily explained and

512
00:17:51,029 --> 00:17:48,559
it's because

513
00:17:53,350 --> 00:17:51,039

as an undergraduate you're especially

514

00:17:56,150 --> 00:17:53,360

used to writing with reference to a

515

00:17:58,390 --> 00:17:56,160

coordinate basis which is why i said try

516

00:17:59,669 --> 00:17:58,400

to do everything you can coordinate free

517

00:18:01,430 --> 00:17:59,679

if you have an instructor you're lucky

518

00:18:03,430 --> 00:18:01,440

enough to have an instructor you always

519

00:18:05,510 --> 00:18:03,440

ask how can you represent these

520

00:18:07,029 --> 00:18:05,520

equations coordinate free another way of

521

00:18:09,190 --> 00:18:07,039

thinking about this is that you we have

522

00:18:11,270 --> 00:18:09,200

graphs in physics and math constantly

523

00:18:12,950 --> 00:18:11,280

plot and those etchings are akin to

524

00:18:15,510 --> 00:18:12,960

choosing a unit the fact that we put

525

00:18:17,909 --> 00:18:15,520

lines with etchings means we've chosen a

526

00:18:21,750 --> 00:18:17,919

coordinate so these etchings outward are

527

00:18:23,350 --> 00:18:21,760

it implicitly a choice of coordinates

528

00:18:25,350 --> 00:18:23,360

but nature but if you look again like i

529

00:18:27,029 --> 00:18:25,360

mentioned there's no detector that can

530

00:18:29,029 --> 00:18:27,039

detect the coordinates much like if you

531

00:18:30,470 --> 00:18:29,039

take a picture with your phone and you

532

00:18:32,789 --> 00:18:30,480

then look at it on the screen and you

533

00:18:34,230 --> 00:18:32,799

zoom in you see pixels the pixels are an

534

00:18:36,230 --> 00:18:34,240

artifact of you taking a picture and

535

00:18:38,549 --> 00:18:36,240

trying to manipulate it in some manner

536

00:18:39,350 --> 00:18:38,559

the world itself is not pixelated unless

537

00:18:41,190 --> 00:18:39,360

you're

538

00:18:42,630 --> 00:18:41,200

to believe thomas campbell or donald

539

00:18:44,310 --> 00:18:42,640

hoffman another reason to think

540

00:18:46,310 --> 00:18:44,320

coordinate free is you'll start to

541

00:18:48,630 --> 00:18:46,320

construct constructions that actually

542

00:18:49,990 --> 00:18:48,640

depend on your coordinates when they in

543

00:18:51,669 --> 00:18:50,000

fact don't in nature and then you'll

544

00:18:54,390 --> 00:18:51,679

wonder why are you getting an incorrect

545

00:18:58,070 --> 00:18:54,400

answer so for example in physics and so

546

00:19:00,070 --> 00:18:58,080

on we often use let's say this

547

00:19:01,510 --> 00:19:00,080

and then we represent it in some

548

00:19:02,549 --> 00:19:01,520

symmetry this is how theoretical

549

00:19:04,470 --> 00:19:02,559

physicist

550

00:19:06,390 --> 00:19:04,480

generally reference matrices they don't

551
00:19:08,549 --> 00:19:06,400
like them so they call them symmetries

552
00:19:09,990 --> 00:19:08,559
these rows and columns but then

553
00:19:12,230 --> 00:19:10,000
you also would reference this same

554
00:19:14,870 --> 00:19:12,240
object

555
00:19:16,390 --> 00:19:14,880
with numbers in a similar manner

556
00:19:19,110 --> 00:19:16,400
however they transform completely

557
00:19:20,870 --> 00:19:19,120
differently so one is an endomorphism

558
00:19:22,789 --> 00:19:20,880
and then the other is a two form or a

559
00:19:24,230 --> 00:19:22,799
bilinear form and they transform

560
00:19:25,990 --> 00:19:24,240
completely differently and which is why

561
00:19:28,150 --> 00:19:26,000
you have transpose which is it's not an

562
00:19:30,310 --> 00:19:28,160
ill-defined object but it's a strangely

563
00:19:31,510 --> 00:19:30,320

defined object the inverse of a matrix

564

00:19:33,029 --> 00:19:31,520

is more

565

00:19:35,669 --> 00:19:33,039

copacetic but the

566

00:19:37,110 --> 00:19:35,679

transpose is a strange one so this one

567

00:19:40,710 --> 00:19:37,120

is a two form

568

00:19:43,110 --> 00:19:40,720

a bilinear form the metric in the s

569

00:19:45,270 --> 00:19:43,120

within einstein equations is a two form

570

00:19:47,510 --> 00:19:45,280

it's a bilinear form and also the

571

00:19:48,710 --> 00:19:47,520

determinants of endomorphism is a

572

00:19:50,870 --> 00:19:48,720

completely different object it's

573

00:19:53,350 --> 00:19:50,880

invariant compared to the determinant of

574

00:19:54,710 --> 00:19:53,360

a two form or a bilinear form and then

575

00:19:56,390 --> 00:19:54,720

as you start to understand this

576

00:19:57,990 --> 00:19:56,400

coordinate free you'll realize that

577

00:19:59,909 --> 00:19:58,000

there's a special place in hell for the

578

00:20:02,870 --> 00:19:59,919

person who developed the transpose it's

579

00:20:04,630 --> 00:20:02,880

an unwieldy object another one that will

580

00:20:06,549 --> 00:20:04,640

confuse you if you think in terms of

581

00:20:07,830 --> 00:20:06,559

coordinates is that the wave function

582

00:20:10,470 --> 00:20:07,840

you ordinarily think of the wave

583

00:20:14,630 --> 00:20:10,480

function as going from some rd or some

584

00:20:20,070 --> 00:20:16,390

to

585

00:20:22,630 --> 00:20:20,080

complex numbers but actually this guy is

586

00:20:23,750 --> 00:20:22,640

a section

587

00:20:25,990 --> 00:20:23,760

on a c

588

00:20:27,750 --> 00:20:26,000

line bundle and you need to understand

589

00:20:29,430 --> 00:20:27,760

bundles in order to understand it

590

00:20:31,029 --> 00:20:29,440

coordinate free so that you can do not

591

00:20:32,630 --> 00:20:31,039

only polar coordinates and you wonder

592

00:20:33,669 --> 00:20:32,640

why the heck does the derivative change

593

00:20:34,950 --> 00:20:33,679

well that makes sense when you

594

00:20:36,710 --> 00:20:34,960

understand it in terms of a principle

595

00:20:39,430 --> 00:20:36,720

bundle and then the associated bundle

596

00:20:40,950 --> 00:20:39,440

but also in terms of no longer staying

597

00:20:42,950 --> 00:20:40,960

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

598

00:20:44,470 --> 00:20:42,960

curved space for quantum mechanics what

599

00:20:46,549 --> 00:20:44,480

if you want to do quantum mechanics on a

600

00:20:48,549 --> 00:20:46,559

curved space this is why one should try

601
00:20:50,070 --> 00:20:48,559
their best to understand what the heck

602
00:20:51,909 --> 00:20:50,080
is going on without reference to

603
00:20:53,110 --> 00:20:51,919
coordinates and then go to coordinates

604
00:20:55,110 --> 00:20:53,120
when you're actually making a

605
00:20:57,190 --> 00:20:55,120
calculation so that's why this is a myth

606
00:20:59,029 --> 00:20:57,200
we just simply set c to equal one to

607
00:21:00,630 --> 00:20:59,039
equal \hbar by the way what is \hbar

608
00:21:02,390 --> 00:21:00,640
well that's a bit more abstract you

609
00:21:03,669 --> 00:21:02,400
don't need to understand that for the

610
00:21:05,750 --> 00:21:03,679
sake of this video

611
00:21:07,669 --> 00:21:05,760
but this is an ill-defined equation

612
00:21:09,750 --> 00:21:07,679
there's actually a caveat here that will

613
00:21:11,270 --> 00:21:09,760

come into play later another way of

614

00:21:14,149 --> 00:21:11,280

thinking about it is imagine you have

615

00:21:16,350 --> 00:21:14,159

one usd one us dollar

616

00:21:20,630 --> 00:21:16,360

sometimes you would say it equals

617

00:21:22,390 --> 00:21:20,640

127 yen it doesn't actually equal 127

618

00:21:25,270 --> 00:21:22,400

yen otherwise when you have a us dollar

619

00:21:27,430 --> 00:21:25,280

it would just be 127 yen what it means

620

00:21:29,110 --> 00:21:27,440

is that there's something called value

621

00:21:29,990 --> 00:21:29,120

or some monetary equivalent that's

622

00:21:31,190 --> 00:21:30,000

another way of thinking about it

623

00:21:33,110 --> 00:21:31,200

conversion

624

00:21:35,029 --> 00:21:33,120

what it means that you go here with some

625

00:21:36,549 --> 00:21:35,039

mapping let's say m and then here with

626
00:21:38,149 --> 00:21:36,559
some mapping that's that's called let's

627
00:21:41,110 --> 00:21:38,159
say m prime

628
00:21:43,190 --> 00:21:41,120
what it means is that you do

629
00:21:45,430 --> 00:21:43,200
let's say m prime

630
00:21:47,990 --> 00:21:45,440
inverse see we have to make all these

631
00:21:49,350 --> 00:21:48,000
constructions now and then that's after

632
00:21:52,630 --> 00:21:49,360
you've already done m so you've gone

633
00:21:54,549 --> 00:21:52,640
from here and then you go back up there

634
00:21:55,990 --> 00:21:54,559
they're not the same so another way of

635
00:21:57,750 --> 00:21:56,000
thinking about this is imagine you want

636
00:21:59,029 --> 00:21:57,760
to change lengths instead of using

637
00:22:00,549 --> 00:21:59,039
meters because you think meters are

638
00:22:02,950 --> 00:22:00,559

strange for some reason you want to

639

00:22:04,789 --> 00:22:02,960

measure everyone in terms of lady gaga

640

00:22:06,470 --> 00:22:04,799

so you have lady gaga here which i'm

641

00:22:08,149 --> 00:22:06,480

going to call

642

00:22:09,350 --> 00:22:08,159

lg

643

00:22:10,870 --> 00:22:09,360

so then let's say we want to measure

644

00:22:14,230 --> 00:22:10,880

someone else let's say some let's say

645

00:22:16,870 --> 00:22:14,240

goku so what is goku goku

646

00:22:19,029 --> 00:22:16,880

equals maybe one and a half lady gaga's

647

00:22:20,470 --> 00:22:19,039

in length so you take half of lady gaga

648

00:22:22,630 --> 00:22:20,480

and you stack that again on lady gag and

649

00:22:25,190 --> 00:22:22,640

you get a goku in terms of length how

650

00:22:28,070 --> 00:22:25,200

about tony robbins well that's let's say

651
00:22:30,149 --> 00:22:28,080
two lady gagas now what we're doing here

652
00:22:32,230 --> 00:22:30,159
is we're saying i'm going to make all my

653
00:22:34,390 --> 00:22:32,240
future length measurements in terms of

654
00:22:36,710 --> 00:22:34,400
lady gaga for whatever reason in the

655
00:22:38,789 --> 00:22:36,720
same way that generally speaking the

656
00:22:40,870 --> 00:22:38,799
prices on the internet can be made in

657
00:22:42,710 --> 00:22:40,880
reference to the us dollar and then you

658
00:22:45,590 --> 00:22:42,720
do some conversion to find out its

659
00:22:47,270 --> 00:22:45,600
equivalent monetary value in some other

660
00:22:48,470 --> 00:22:47,280
currency in the same way what we're

661
00:22:50,070 --> 00:22:48,480
doing right here is we're referencing

662
00:22:52,390 --> 00:22:50,080
everyone's height in terms of lady

663
00:22:54,630 --> 00:22:52,400

gaga's height and it just as foolish as

664

00:22:57,110 --> 00:22:54,640

it would be to say lady gaga equals one

665

00:22:59,590 --> 00:22:57,120

equals the \hbar just as foolish as this

666

00:23:01,830 --> 00:22:59,600

equation is it's tantamount to saying c

667

00:23:03,669 --> 00:23:01,840

equals one equals \hbar there's so much

668

00:23:04,950 --> 00:23:03,679

that goes into a statement like that

669

00:23:06,630 --> 00:23:04,960

that's just seeing that gives the

670

00:23:08,789 --> 00:23:06,640

impression oh physicists are just

671

00:23:10,310 --> 00:23:08,799

setting it equal to one so no this

672

00:23:12,310 --> 00:23:10,320

statement is foolish and what's

673

00:23:14,549 --> 00:23:12,320

underneath that is saying hey i'm going

674

00:23:16,149 --> 00:23:14,559

to now measure everything in terms of

675

00:23:18,230 --> 00:23:16,159

the speed of light so i want to measure

676

00:23:19,590 --> 00:23:18,240

my car maybe it's a millionth of the

677

00:23:20,789 --> 00:23:19,600

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

678

00:23:22,549 --> 00:23:20,799

to do the calculation right now but

679

00:23:24,870 --> 00:23:22,559

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

680

00:23:27,590 --> 00:23:24,880

light so then i say well the speed of

681

00:23:28,630 --> 00:23:27,600

walking let's say

682

00:23:38,149 --> 00:23:28,640

is

683

00:23:40,149 --> 00:23:38,159

light units that's what it means okay so

684

00:23:42,870 --> 00:23:40,159

this is all including

685

00:23:44,390 --> 00:23:42,880

by the way this right here

686

00:23:47,110 --> 00:23:44,400

this is all

687

00:23:50,390 --> 00:23:48,549

you have to understand what's lurking

688

00:23:51,590 --> 00:23:50,400

underneath so in this example the value

689

00:23:53,350 --> 00:23:51,600

is what's being referenced when i say

690

00:23:54,390 --> 00:23:53,360

the real world that's what i mean is

691

00:23:57,029 --> 00:23:54,400

that there's something else that's

692

00:23:59,990 --> 00:23:57,039

tangible that i'm trying to represent my

693

00:24:02,230 --> 00:24:00,000

quantity in reference to so from now on

694

00:24:04,230 --> 00:24:02,240

we're going to no longer say that this

695

00:24:05,750 --> 00:24:04,240

is moving at 500 meters per second we're

696

00:24:07,430 --> 00:24:05,760

going to say that this is moving at a

697

00:24:09,110 --> 00:24:07,440

fraction of the speed of light by the

698

00:24:11,750 --> 00:24:09,120

way this should be a definition and that

699

00:24:14,149 --> 00:24:11,760

refers to the entire object there not

700

00:24:15,909 --> 00:24:14,159

just this this is just the magnitude and

701
00:24:17,430 --> 00:24:15,919
that's where this is misleading because

702
00:24:19,110 --> 00:24:17,440
it's just showing you the magnitude but

703
00:24:21,029 --> 00:24:19,120
how the heck can c equal this in the

704
00:24:22,470 --> 00:24:21,039
same way how the heck can lady gaga

705
00:24:24,630 --> 00:24:22,480
equal the us

706
00:24:30,230 --> 00:24:24,640
equals one that is myth number one now

707
00:24:33,510 --> 00:24:31,190
of

708
00:24:34,710 --> 00:24:33,520
natural

709
00:24:36,470 --> 00:24:34,720
units by the way it doesn't matter

710
00:24:40,149 --> 00:24:36,480
whether you capitalize it or not the

711
00:24:40,950 --> 00:24:40,159
advantage of natural units is that

712
00:24:44,830 --> 00:24:40,960
it

713
00:24:49,669 --> 00:24:46,630

equations

714

00:24:54,230 --> 00:24:51,590

where is the myth here

715

00:24:56,789 --> 00:24:54,240

the myth is one of these words it's an

716

00:24:59,110 --> 00:24:56,799

article it's the definite article the

717

00:25:02,070 --> 00:24:59,120

the advantage that's one it should

718

00:25:03,909 --> 00:25:02,080

actually be a advantage or an advantage

719

00:25:05,909 --> 00:25:03,919

the primary advantage is that it allows

720

00:25:08,070 --> 00:25:05,919

you to understand the world in a much

721

00:25:10,390 --> 00:25:08,080

more elegant manner that allows you to

722

00:25:12,470 --> 00:25:10,400

grasp to understand physical quantities

723

00:25:14,310 --> 00:25:12,480

much more intuitively with these napkin

724

00:25:16,310 --> 00:25:14,320

calculations and by the way i say napkin

725

00:25:18,310 --> 00:25:16,320

calculations and not back of the

726

00:25:19,830 --> 00:25:18,320

envelope calculations because when

727

00:25:21,510 --> 00:25:19,840

you're outside and you're doing one of

728

00:25:22,549 --> 00:25:21,520

these why where are you going to find an

729

00:25:24,549 --> 00:25:22,559

envelope i don't think i've written on

730

00:25:26,549 --> 00:25:24,559

an envelope or the back of one in my

731

00:25:27,990 --> 00:25:26,559

entire life and then

732

00:25:29,590 --> 00:25:28,000

okay so you take a napkin and you do

733

00:25:31,430 --> 00:25:29,600

your calculation on it what the heck is

734

00:25:32,710 --> 00:25:31,440

the front of a napkin versus the back

735

00:25:34,070 --> 00:25:32,720

it's not like you choose the front or

736

00:25:36,470 --> 00:25:34,080

the back or you can even tell most of

737

00:25:38,310 --> 00:25:36,480

the time so it's a napkin calculation

738

00:25:40,549 --> 00:25:38,320

now let's think about what did i say

739

00:25:43,510 --> 00:25:40,559

over here which is that it allows you

740

00:25:45,669 --> 00:25:43,520

to have only time or only energy etc etc

741

00:25:46,870 --> 00:25:45,679

well there's some conversion equations

742

00:25:50,789 --> 00:25:46,880

it's best to think of them in terms of

743

00:25:54,149 --> 00:25:52,149

these are the central equations that

744

00:25:56,549 --> 00:25:54,159

allow you to convert so let's give them

745

00:25:59,510 --> 00:25:56,559

a special symbol a special kind of one

746

00:26:00,470 --> 00:25:59,520

number one is e equals

747

00:26:02,710 --> 00:26:00,480

you can

748

00:26:06,149 --> 00:26:02,720

guess this e equals m c squared number

749

00:26:07,830 --> 00:26:06,159

two and then let's also make it special

750

00:26:08,950 --> 00:26:07,840

is

751
00:26:10,789 --> 00:26:08,960
x

752
00:26:13,190 --> 00:26:10,799
p

753
00:26:15,830 --> 00:26:13,200
well now i'm going to use this

754
00:26:17,990 --> 00:26:15,840
which means on the order of so actually

755
00:26:20,310 --> 00:26:18,000
let's get rid of this guy

756
00:26:22,470 --> 00:26:20,320
put him on the order of there's also the

757
00:26:25,430 --> 00:26:22,480
compton wavelength which will give

758
00:26:26,549 --> 00:26:25,440
another fancy symbol

759
00:26:27,669 --> 00:26:26,559
which is

760
00:26:31,269 --> 00:26:27,679
lambda

761
00:26:33,909 --> 00:26:31,990
and

762
00:26:36,470 --> 00:26:33,919
notice right now what have we done we've

763
00:26:38,630 --> 00:26:36,480

already set c to equal one look i'm i'm

764

00:26:40,549 --> 00:26:38,640

making the mistake notice what have we

765

00:26:43,190 --> 00:26:40,559

done already we're already going to be

766

00:26:45,430 --> 00:26:43,200

using units where c of light is

767

00:26:47,190 --> 00:26:45,440

expressed in those units as one

768

00:26:49,590 --> 00:26:47,200

so we're only making reference to c of

769

00:26:51,590 --> 00:26:49,600

light to speed of light

770

00:26:53,750 --> 00:26:51,600

that means that right here we can remove

771

00:26:55,590 --> 00:26:53,760

that because that equals one right here

772

00:26:57,269 --> 00:26:55,600

we can change that to one right here we

773

00:26:59,269 --> 00:26:57,279

can change that to one and then we can

774

00:27:01,430 --> 00:26:59,279

get rid of that because it's the same a

775

00:27:02,230 --> 00:27:01,440

zero with order equation

776
00:27:04,630 --> 00:27:02,240
is

777
00:27:05,510 --> 00:27:04,640
well the speed of light equals

778
00:27:08,789 --> 00:27:05,520
some

779
00:27:11,590 --> 00:27:08,799
spatial amount over this now since we're

780
00:27:13,750 --> 00:27:11,600
setting this to equal one

781
00:27:16,230 --> 00:27:13,760
this means that any time that you have a

782
00:27:17,110 --> 00:27:16,240
distance we can express it in terms of a

783
00:27:18,950 --> 00:27:17,120
speed

784
00:27:21,750 --> 00:27:18,960
for example you can let's imagine that's

785
00:27:22,549 --> 00:27:21,760
the earth and then we're going

786
00:27:24,549 --> 00:27:22,559
to

787
00:27:28,950 --> 00:27:24,559
one light year away or one light second

788
00:27:32,070 --> 00:27:30,630

i can either say hey that's two nine

789

00:27:34,710 --> 00:27:32,080

nine seven nine two four five eight

790

00:27:36,470 --> 00:27:34,720

meters away or i can say that's one

791

00:27:39,510 --> 00:27:36,480

light second that means that it's now

792

00:27:41,510 --> 00:27:39,520

converting distance into time any

793

00:27:44,310 --> 00:27:41,520

distance measure that you give me i can

794

00:27:46,470 --> 00:27:44,320

give you an equivalent time measure it's

795

00:27:48,630 --> 00:27:46,480

not the same it's a conversion but you

796

00:27:53,669 --> 00:27:48,640

can convert it to time

797

00:27:57,190 --> 00:27:54,389

of

798

00:27:59,669 --> 00:27:57,909

to

799

00:28:01,029 --> 00:27:59,679

time

800

00:28:02,870 --> 00:28:01,039

and back because you can do the same

801
00:28:05,190 --> 00:28:02,880
thing forward or backward and then this

802
00:28:08,710 --> 00:28:05,200
one also allows a conversion

803
00:28:12,710 --> 00:28:10,549
to mass

804
00:28:15,110 --> 00:28:12,720
so i can tell you this is one gram or i

805
00:28:16,789 --> 00:28:15,120
can give you its energy equivalent or

806
00:28:18,630 --> 00:28:16,799
you can give me some energy and i can

807
00:28:20,070 --> 00:28:18,640
tell you well that what makes up that

808
00:28:22,389 --> 00:28:20,080
energy is the equivalent of a certain

809
00:28:24,070 --> 00:28:22,399
amount of mass

810
00:28:27,909 --> 00:28:24,080
now this one is also interesting because

811
00:28:32,230 --> 00:28:27,919
it gives a conversion of length

812
00:28:35,590 --> 00:28:33,669
i noticed that i didn't explain where

813
00:28:37,590 --> 00:28:35,600

this one comes from and it's the famous

814

00:28:39,510 --> 00:28:37,600

heisenberg uncertainty equation where

815

00:28:41,909 --> 00:28:39,520

you're told that the objects of space

816

00:28:43,990 --> 00:28:41,919

and momentum don't commute however even

817

00:28:46,389 --> 00:28:44,000

this is a misnomer since it makes no

818

00:28:48,549 --> 00:28:46,399

sense to say quote unquote objects don't

819

00:28:50,710 --> 00:28:48,559

commute it should be stated precisely

820

00:28:52,549 --> 00:28:50,720

that the operations with those objects

821

00:28:54,870 --> 00:28:52,559

or operations on those objects don't

822

00:28:57,029 --> 00:28:54,880

commute how can an object be commutative

823

00:28:58,870 --> 00:28:57,039

or not without the extra structure of

824

00:29:00,789 --> 00:28:58,880

the group operation again i'm being

825

00:29:02,549 --> 00:29:00,799

pedantic because i was extremely

826

00:29:04,630 --> 00:29:02,559

confused learning all of this and you

827

00:29:08,950 --> 00:29:04,640

may be as well and as best these

828

00:29:14,630 --> 00:29:12,549

clearly it's inversed and then this one

829

00:29:17,430 --> 00:29:14,640

gives a conversion

830

00:29:21,269 --> 00:29:19,669

to mass

831

00:29:24,230 --> 00:29:21,279

now how many different types of units do

832

00:29:27,350 --> 00:29:24,240

we have here we have length 1 2 time 3

833

00:29:29,029 --> 00:29:27,360

mass 4 energy 5 momentum and we have

834

00:29:31,110 --> 00:29:29,039

four equations

835

00:29:32,470 --> 00:29:31,120

which means that we have five unknowns

836

00:29:34,310 --> 00:29:32,480

and four equations which means that we

837

00:29:36,630 --> 00:29:34,320

can represent we only actually have one

838

00:29:38,710 --> 00:29:36,640

unknown so we can represent any of these

839

00:29:40,870 --> 00:29:38,720

in terms of any quantity that we like

840

00:29:43,990 --> 00:29:40,880

and thus we can represent

841

00:29:46,230 --> 00:29:44,000

all of our quantities mass time length

842

00:29:47,990 --> 00:29:46,240

energy in terms of one or the other

843

00:29:49,669 --> 00:29:48,000

there are many reasons why a high energy

844

00:29:51,590 --> 00:29:49,679

physicist just chooses energy though

845

00:29:54,870 --> 00:29:51,600

they equivalently could have chosen time

846

00:29:56,549 --> 00:29:54,880

could have chosen length etc it's just

847

00:29:58,070 --> 00:29:56,559

for the purposes of this video and for

848

00:29:59,510 --> 00:29:58,080

you to have a different point of view on

849

00:30:01,990 --> 00:29:59,520

the world it's better to think in terms

850

00:30:04,070 --> 00:30:02,000

of energy because of a well because of a

851

00:30:07,750 --> 00:30:04,080

series of accidents the unit that they

852

00:30:09,830 --> 00:30:07,760

like to use is giga electron volts gev

853

00:30:13,110 --> 00:30:09,840

and that's the units we'll be using

854

00:30:15,110 --> 00:30:13,990

we

855

00:30:16,389 --> 00:30:15,120

will

856

00:30:21,110 --> 00:30:16,399

use

857

00:30:22,870 --> 00:30:21,120

one want to convert to gev constantly

858

00:30:24,789 --> 00:30:22,880

because if you were to give me the mass

859

00:30:26,389 --> 00:30:24,799

of this in grams i don't know what that

860

00:30:28,310 --> 00:30:26,399

means but if you were to give me it in

861

00:30:30,310 --> 00:30:28,320

terms of gev i can tell you how many

862

00:30:32,710 --> 00:30:30,320

nucleons are in here so what does that

863

00:30:35,830 --> 00:30:32,720

mean firstly notice this accident again

864

00:30:38,389 --> 00:30:35,840

it's perhaps an accident but perhaps not

865

00:30:39,750 --> 00:30:38,399

one proton

866

00:30:41,510 --> 00:30:39,760

mass

867

00:30:42,789 --> 00:30:41,520

equivalent remember it's not just this

868

00:30:45,029 --> 00:30:42,799

is something else that needs to be

869

00:30:47,430 --> 00:30:45,039

emphasized it's not the mass of a proton

870

00:30:51,669 --> 00:30:47,440

it's it's energy equivalent so once

871

00:30:53,870 --> 00:30:51,679

proton mass is energy equivalent is

872

00:30:59,990 --> 00:30:53,880

let's say i think it's

873

00:31:05,830 --> 00:31:03,350

okay we go to wikipedia and we see

874

00:31:08,310 --> 00:31:05,840

what is the mass of a proton so then we

875

00:31:09,510 --> 00:31:08,320

look at the protons mass and it's this

876
00:31:12,230 --> 00:31:09,520
right here

877
00:31:15,350 --> 00:31:12,240
and that's the same as 0.93

878
00:31:16,789 --> 00:31:15,360
gev if you just know it gigamines versus

879
00:31:18,870 --> 00:31:16,799
mega

880
00:31:21,269 --> 00:31:18,880
and why is this useful at all because

881
00:31:23,909 --> 00:31:21,279
it's almost equal to one

882
00:31:26,549 --> 00:31:23,919
so if i want it to be sloppy i would say

883
00:31:29,190 --> 00:31:26,559
equals to one but instead i will say on

884
00:31:31,990 --> 00:31:29,200
the order of one gev

885
00:31:35,350 --> 00:31:32,000
now we wanna know what is a gev so

886
00:31:38,230 --> 00:31:37,190
well you can look all of these up and

887
00:31:40,070 --> 00:31:38,240
i'm going to be giving you these

888
00:31:42,149 --> 00:31:40,080

practical steps by searching because

889

00:31:43,990 --> 00:31:42,159

that's actually what it's like to do

890

00:31:45,509 --> 00:31:44,000

physics or any research in general you

891

00:31:46,710 --> 00:31:45,519

go to wikipedia as one of your first

892

00:31:49,990 --> 00:31:46,720

sources

893

00:31:52,389 --> 00:31:50,000

so it says here ev means electron volt

894

00:31:54,070 --> 00:31:52,399

is a measure of an amount of kinetic

895

00:31:55,590 --> 00:31:54,080

energy gained by a single electron

896

00:31:57,830 --> 00:31:55,600

accelerating through an electric

897

00:31:59,909 --> 00:31:57,840

potential difference of one volt

898

00:32:00,789 --> 00:31:59,919

what that means is that let's imagine we

899

00:32:03,509 --> 00:32:00,799

have

900

00:32:04,470 --> 00:32:03,519

some potential difference here this is

901
00:32:05,909 --> 00:32:04,480
one

902
00:32:08,789 --> 00:32:05,919
volt

903
00:32:10,870 --> 00:32:08,799
and here's an electron it's at rest

904
00:32:12,470 --> 00:32:10,880
then it will accelerate a certain amount

905
00:32:15,190 --> 00:32:12,480
once it gets here it will have a new

906
00:32:17,430 --> 00:32:15,200
speed because the first speed was zero

907
00:32:19,029 --> 00:32:17,440
it will have a new speed and associated

908
00:32:21,029 --> 00:32:19,039
with that speed is an energy and then

909
00:32:23,190 --> 00:32:21,039
that energy now that it has well let me

910
00:32:25,750 --> 00:32:23,200
just do this converts to energy

911
00:32:27,029 --> 00:32:25,760
then the energy the kinetic energy of it

912
00:32:32,789 --> 00:32:27,039
is one

913
00:32:35,590 --> 00:32:32,799

why is this useful at all the reason is

914

00:32:38,549 --> 00:32:35,600

that we have now made a connection

915

00:32:41,269 --> 00:32:38,559

between one proton

916

00:32:44,870 --> 00:32:41,279

one proton's mass

917

00:32:46,710 --> 00:32:44,880

energy let's say mass energy equivalent

918

00:32:48,870 --> 00:32:46,720

remember that's important it's not it's

919

00:32:50,710 --> 00:32:48,880

energy per se it's it's

920

00:32:52,389 --> 00:32:50,720

energy equivalent we've made an

921

00:32:55,430 --> 00:32:52,399

association between this

922

00:32:57,350 --> 00:32:55,440

and one giga electron volt and then

923

00:32:59,590 --> 00:32:57,360

there's this connection which is

924

00:33:01,190 --> 00:32:59,600

implicit but i'm making it explicit this

925

00:33:02,870 --> 00:33:01,200

is what nema didn't emphasize the

926
00:33:05,029 --> 00:33:02,880
connection isn't actually here the

927
00:33:08,470 --> 00:33:05,039
connection is that this is well i'm

928
00:33:10,470 --> 00:33:08,480
going to be sloppy and say approximately

929
00:33:13,029 --> 00:33:10,480
because it's truly

930
00:33:16,470 --> 00:33:14,549
the connection is that

931
00:33:17,909 --> 00:33:16,480
this number one

932
00:33:19,830 --> 00:33:17,919
is readily

933
00:33:21,509 --> 00:33:19,840
cognitively graspable meaning that we

934
00:33:23,350 --> 00:33:21,519
can chunk it it's easier for me to think

935
00:33:24,909 --> 00:33:23,360
in terms of one lip balm than it is for

936
00:33:27,669 --> 00:33:24,919
me to think in terms of

937
00:33:28,870 --> 00:33:27,679
0.825 lip balms the reason why this

938
00:33:30,470 --> 00:33:28,880

ladder point well if it's not

939

00:33:32,470 --> 00:33:30,480

self-evident one of the reasons why this

940

00:33:34,389 --> 00:33:32,480

ladder point is important is that you'll

941

00:33:36,549 --> 00:33:34,399

see in physics constantly there's an

942

00:33:38,630 --> 00:33:36,559

effort to reduce some convoluted

943

00:33:40,470 --> 00:33:38,640

equation into linear algebra and that's

944

00:33:42,630 --> 00:33:40,480

because linear algebra is extremely

945

00:33:44,470 --> 00:33:42,640

cognitively graspable it's understood

946

00:33:47,029 --> 00:33:44,480

it's one of the few areas of math if not

947

00:33:49,110 --> 00:33:47,039

the only area of math that's well

948

00:33:51,430 --> 00:33:49,120

understood that means anytime you have a

949

00:33:53,269 --> 00:33:51,440

complex equation if you can linearize it

950

00:33:54,789 --> 00:33:53,279

you understand it much better in the

951
00:33:57,029 --> 00:33:54,799
same way that anytime we have some

952
00:33:58,789 --> 00:33:57,039
complicated phenomenon we can put it to

953
00:34:01,029 --> 00:33:58,799
something that's

954
00:34:02,630 --> 00:34:01,039
in terms of gev means we understand it

955
00:34:04,950 --> 00:34:02,640
in terms of protons

956
00:34:06,789 --> 00:34:04,960
it's akin to feynman saying that the

957
00:34:08,550 --> 00:34:06,799
number one lesson for some future

958
00:34:10,230 --> 00:34:08,560
civilization if you had to impart one

959
00:34:12,069 --> 00:34:10,240
piece of knowledge to them the best

960
00:34:13,669 --> 00:34:12,079
knowledge the best bang for your buck in

961
00:34:16,069 --> 00:34:13,679
terms of facts would be to tell them

962
00:34:18,470 --> 00:34:16,079
that the world comprises atoms and from

963
00:34:20,389 --> 00:34:18,480

that fact many other laws of nature come

964

00:34:21,669 --> 00:34:20,399

now i don't know about that because to

965

00:34:24,230 --> 00:34:21,679

me that would imply that you would have

966

00:34:26,389 --> 00:34:24,240

some fact like let's say the atom fact

967

00:34:27,909 --> 00:34:26,399

and then we have the space of all facts

968

00:34:30,149 --> 00:34:27,919

and then you have to have some measure

969

00:34:31,990 --> 00:34:30,159

on the space of all facts in order for

970

00:34:34,389 --> 00:34:32,000

you to say that this is this one fact

971

00:34:36,389 --> 00:34:34,399

implies the most facts

972

00:34:38,470 --> 00:34:36,399

and that's somewhat dubious but you at

973

00:34:40,470 --> 00:34:38,480

least understand informally what feynman

974

00:34:42,310 --> 00:34:40,480

meant it's one of the reasons why in the

975

00:34:44,310 --> 00:34:42,320

theories of everything podcast what i'm

976

00:34:46,230 --> 00:34:44,320

trying to do constantly you'll see me

977

00:34:48,230 --> 00:34:46,240

asking the

978

00:34:49,430 --> 00:34:48,240

professor who has some extremely

979

00:34:52,389 --> 00:34:49,440

intricate

980

00:34:54,069 --> 00:34:52,399

baroque equation or concept

981

00:34:56,310 --> 00:34:54,079

i'm frequently saying okay what does it

982

00:34:57,750 --> 00:34:56,320

mean in terms of billiard balls so let's

983

00:35:00,069 --> 00:34:57,760

imagine that this has a charge and this

984

00:35:01,990 --> 00:35:00,079

one does too what's going on there it's

985

00:35:03,430 --> 00:35:02,000

the same trying to reduce down to some

986

00:35:05,430 --> 00:35:03,440

fundamentals that you understand in

987

00:35:06,950 --> 00:35:05,440

order to properly understand it then

988

00:35:08,470 --> 00:35:06,960

there's another

989

00:35:11,349 --> 00:35:08,480

somewhat of an accident maybe it's not

990

00:35:15,670 --> 00:35:11,359

heisenberg said there is isospin so that

991

00:35:18,550 --> 00:35:16,390

has

992

00:35:20,390 --> 00:35:18,560

similar

993

00:35:21,190 --> 00:35:20,400

mass

994

00:35:31,750 --> 00:35:21,200

to

995

00:35:33,510 --> 00:35:31,760

units for these napkin calculations

996

00:35:35,750 --> 00:35:33,520

i'm being extremely specific and

997

00:35:37,750 --> 00:35:35,760

somewhat pedantic because much of this

998

00:35:39,030 --> 00:35:37,760

is glossed over and then you'll start at

999

00:35:41,030 --> 00:35:39,040

least if you're like me you'll start to

1000

00:35:42,790 --> 00:35:41,040

be confused at a much later point and

1001
00:35:44,310 --> 00:35:42,800
you won't realize that some of these

1002
00:35:45,670 --> 00:35:44,320
fundamentals weren't explained

1003
00:35:48,150 --> 00:35:45,680
specifically

1004
00:35:50,390 --> 00:35:48,160
now let's go through a conversion chart

1005
00:35:54,870 --> 00:35:50,400
conversion

1006
00:35:54,880 --> 00:35:58,230
here we go

1007
00:36:04,870 --> 00:36:02,150
one meter is the equivalent of

1008
00:36:06,950 --> 00:36:04,880
well on the order of 10 to the 16 geV

1009
00:36:08,950 --> 00:36:06,960
inverse ah now i haven't explained what

1010
00:36:10,950 --> 00:36:08,960
the inverses mean here at our equation

1011
00:36:12,790 --> 00:36:10,960
bolded number one and then bolded number

1012
00:36:15,270 --> 00:36:12,800
three we have an equivalence between

1013
00:36:18,069 --> 00:36:15,280

energy and mass so you say one

1014

00:36:19,430 --> 00:36:18,079

giga electron volt and that can mean

1015

00:36:21,030 --> 00:36:19,440

a certain amount of mass okay you can

1016

00:36:22,870 --> 00:36:21,040

convert between them but you can also

1017

00:36:24,470 --> 00:36:22,880

convert between the mass and then the

1018

00:36:27,109 --> 00:36:24,480

length but this is an inverse

1019

00:36:29,990 --> 00:36:27,119

relationship so that means that length

1020

00:36:31,750 --> 00:36:30,000

actually has inverse energy units so

1021

00:36:33,589 --> 00:36:31,760

anytime you give a length you can also

1022

00:36:36,470 --> 00:36:33,599

have given the same quantity an inverse

1023

00:36:37,750 --> 00:36:36,480

energy any time you have a second

1024

00:36:40,069 --> 00:36:37,760

you could do the same you can give that

1025

00:36:41,270 --> 00:36:40,079

in terms of inverse energy any time you

1026
00:36:43,910 --> 00:36:41,280
have a mass this one's simple you can

1027
00:36:45,829 --> 00:36:43,920
give it in terms of energy now this m_p

1028
00:36:48,150 --> 00:36:45,839
is the planck

1029
00:36:49,190 --> 00:36:48,160
mass not the proton mass remember proton

1030
00:36:51,030 --> 00:36:49,200
mass is

1031
00:36:53,030 --> 00:36:51,040
1 gev

1032
00:36:55,190 --> 00:36:53,040
just for fun you can do the calculation

1033
00:36:57,349 --> 00:36:55,200
of a gram and

1034
00:36:59,030 --> 00:36:57,359
it's this much you can do hertz which is

1035
00:37:01,109 --> 00:36:59,040
inverse time and by the way because

1036
00:37:03,349 --> 00:37:01,119
you're in inverse time you have regular

1037
00:37:05,109 --> 00:37:03,359
energy units which means frequency is

1038
00:37:06,630 --> 00:37:05,119

actually a unit of energy anytime

1039

00:37:08,150 --> 00:37:06,640

someone gives you a frequency you can

1040

00:37:09,910 --> 00:37:08,160

just convert that straight to energy

1041

00:37:12,550 --> 00:37:09,920

we're going to be doing these by the way

1042

00:37:15,349 --> 00:37:12,560

i didn't actually do this but for

1043

00:37:20,230 --> 00:37:17,589

you can see that this is an

1044

00:37:22,150 --> 00:37:20,240

it's a dimensionless quantity it's

1045

00:37:24,230 --> 00:37:22,160

information it should be dimensionless

1046

00:37:25,750 --> 00:37:24,240

because it's dimensionless then from the

1047

00:37:27,589 --> 00:37:25,760

boltzmann constant you can get that

1048

00:37:29,109 --> 00:37:27,599

kelvin is also a unit of energy so

1049

00:37:30,310 --> 00:37:29,119

temperature is a unit of energy which

1050

00:37:32,069 --> 00:37:30,320

somewhat makes sense because you've

1051

00:37:34,310 --> 00:37:32,079

heard that temperature

1052

00:37:36,069 --> 00:37:34,320

is some function of the average kinetic

1053

00:37:38,470 --> 00:37:36,079

energy of the molecules in a room or in

1054

00:37:40,390 --> 00:37:38,480

a box but that statement alone isn't

1055

00:37:41,990 --> 00:37:40,400

enough to say that it's units of energy

1056

00:37:43,349 --> 00:37:42,000

because just because it's a function of

1057

00:37:45,670 --> 00:37:43,359

energy doesn't necessarily mean the

1058

00:37:48,310 --> 00:37:45,680

units of it are energy

1059

00:37:50,150 --> 00:37:48,320

however it does turn out to be the case

1060

00:37:51,910 --> 00:37:50,160

this means you can convert from energy

1061

00:37:54,790 --> 00:37:51,920

to temperature and vice versa all of

1062

00:37:56,310 --> 00:37:54,800

these are vice versa

1063

00:37:58,390 --> 00:37:56,320

and then one we may use later is

1064

00:37:59,910 --> 00:37:58,400

nanometers equals this by the way if any

1065

00:38:00,950 --> 00:37:59,920

of these are incorrect well then please

1066

00:38:02,390 --> 00:38:00,960

just write the correct one in the

1067

00:38:04,630 --> 00:38:02,400

comment section when you look at these

1068

00:38:06,630 --> 00:38:04,640

conversion charts online some of them

1069

00:38:08,710 --> 00:38:06,640

have a plus or minus one in the units

1070

00:38:10,710 --> 00:38:08,720

and that's because we're using this

1071

00:38:14,710 --> 00:38:10,720

symbol which means we don't actually

1072

00:38:19,030 --> 00:38:16,230

remember that this is all about napkin

1073

00:38:22,150 --> 00:38:19,040

calculations nz's we're just doing nc's

1074

00:38:24,230 --> 00:38:22,160

to be extremely concrete you can say

1075

00:38:25,750 --> 00:38:24,240

your desk in front of you is one meter

1076

00:38:27,829 --> 00:38:25,760

approximately let's say approximately

1077

00:38:30,069 --> 00:38:27,839

one meter long or you can give it in

1078

00:38:31,270 --> 00:38:30,079

terms of gev it's 10 to the 16 gev

1079

00:38:33,589 --> 00:38:31,280

inverses

1080

00:38:36,710 --> 00:38:33,599

and that means that

1081

00:38:40,150 --> 00:38:36,720

if you stacked stack

1082

00:38:43,030 --> 00:38:40,160

10 to the 16 protons

1083

00:38:49,270 --> 00:38:43,040

so you get proton proton proton proton

1084

00:38:53,589 --> 00:38:51,190

then you get your desk

1085

00:38:55,109 --> 00:38:53,599

so it gives you an extremely concrete

1086

00:38:57,270 --> 00:38:55,119

way of understanding what your desk is

1087

00:38:59,750 --> 00:38:57,280

your desk is 10 to the 16 protons

1088

00:39:02,310 --> 00:38:59,760

stacked one after the other and by the

1089

00:39:04,150 --> 00:39:02,320

way you may say well kurt isn't gev also

1090

00:39:06,150 --> 00:39:04,160

arbitrary wasn't the whole point of

1091

00:39:08,470 --> 00:39:06,160

natural units to get away from this

1092

00:39:10,310 --> 00:39:08,480

arbitrariness well yes that's true

1093

00:39:12,230 --> 00:39:10,320

except that the other part here which is

1094

00:39:14,950 --> 00:39:12,240

a great confluence

1095

00:39:17,030 --> 00:39:14,960

is that this coincides with how

1096

00:39:18,230 --> 00:39:17,040

engineers think engineers think in terms

1097

00:39:20,550 --> 00:39:18,240

of electron volts well they think in

1098

00:39:23,030 --> 00:39:20,560

terms of volts so now you've found a

1099

00:39:24,710 --> 00:39:23,040

connection between protons between

1100

00:39:26,550 --> 00:39:24,720

something that is cognitively graspable

1101
00:39:28,870 --> 00:39:26,560
between a neutron and between what you

1102
00:39:30,310 --> 00:39:28,880
can communicate with with others

1103
00:39:31,510 --> 00:39:30,320
so engineers

1104
00:39:32,790 --> 00:39:31,520
now throughout the rest of the video

1105
00:39:35,270 --> 00:39:32,800
you'll see that many different

1106
00:39:37,430 --> 00:39:35,280
quantities physical macroscopic

1107
00:39:40,150 --> 00:39:37,440
sometimes even microscopic physical

1108
00:39:42,790 --> 00:39:40,160
observable quantities are expressed in

1109
00:39:44,630 --> 00:39:42,800
terms of these fundamental ratios now

1110
00:39:46,150 --> 00:39:44,640
notice i didn't say fundamental

1111
00:39:47,430 --> 00:39:46,160
constants and that's because i'm trying

1112
00:39:51,510 --> 00:39:47,440
to emphasize the fact that they're

1113
00:39:56,230 --> 00:39:53,910

let's analyze newton's constant

1114

00:39:58,390 --> 00:39:56,240
and others

1115

00:40:00,150 --> 00:39:58,400
here's what you do in general firstly

1116

00:40:01,910 --> 00:40:00,160
you go to wikipedia so let's do that

1117

00:40:03,990 --> 00:40:01,920
right now

1118

00:40:05,430 --> 00:40:04,000
and you type in newton's constant so

1119

00:40:07,190 --> 00:40:05,440
it's also known as the gravitational

1120

00:40:07,910 --> 00:40:07,200
constant you've seen it before it's this

1121

00:40:09,510 --> 00:40:07,920
g

1122

00:40:11,589 --> 00:40:09,520
then we take a look at what are the

1123

00:40:13,030 --> 00:40:11,599
units here we go we get newtons meters

1124

00:40:19,510 --> 00:40:13,040
squared so on and so on so let's write

1125

00:40:23,910 --> 00:40:21,190
ah and even here i noticed i made a

1126
00:40:24,870 --> 00:40:23,920
mistake because often you'll see online

1127
00:40:29,030 --> 00:40:24,880
m

1128
00:40:30,630 --> 00:40:29,040
actually a length

1129
00:40:32,390 --> 00:40:30,640
and this is a common mistake when you're

1130
00:40:34,710 --> 00:40:32,400
initially doing this so this is actually

1131
00:40:37,190 --> 00:40:34,720
mass

1132
00:40:39,109 --> 00:40:37,200
and this is length squared

1133
00:40:41,510 --> 00:40:39,119
you'll see it here that it says newtons

1134
00:40:43,430 --> 00:40:41,520
meter squared so length squared then a

1135
00:40:45,430 --> 00:40:43,440
mass squared is what it's being divided

1136
00:40:47,829 --> 00:40:45,440
by then you wonder well what the heck is

1137
00:40:50,470 --> 00:40:47,839
a newton so what we do is we go into it

1138
00:40:52,310 --> 00:40:50,480

because all of these are derived from

1139

00:40:54,630 --> 00:40:52,320

something that's much simpler usually

1140

00:40:56,390 --> 00:40:54,640

mass length or time so we go here and we

1141

00:40:59,589 --> 00:40:56,400

see that it's equal to a kilogram so

1142

00:41:05,349 --> 00:40:59,599

mass times length over time squared so

1143

00:41:09,510 --> 00:41:07,349

okay now it's as simple as doing some

1144

00:41:16,950 --> 00:41:09,520

cancellations well we can remove one of

1145

00:41:20,550 --> 00:41:18,790

all right now we want to reduce this

1146

00:41:22,470 --> 00:41:20,560

even further remember there's only

1147

00:41:24,230 --> 00:41:22,480

length or there's only time or only

1148

00:41:27,190 --> 00:41:24,240

energy let's see if we can place this in

1149

00:41:29,030 --> 00:41:27,200

terms of only energy

1150

00:41:30,630 --> 00:41:29,040

we go to our conversion equations

1151
00:41:32,390 --> 00:41:30,640
there's a correspondence between length

1152
00:41:34,390 --> 00:41:32,400
and time between energy and mass between

1153
00:41:36,150 --> 00:41:34,400
length and momentum actually this

1154
00:41:38,069 --> 00:41:36,160
correspondence is between length and

1155
00:41:40,069 --> 00:41:38,079
inverse momentum and this is between

1156
00:41:41,589 --> 00:41:40,079
length and inverse mass and you can see

1157
00:41:43,589 --> 00:41:41,599
that just from the fact that there's a

1158
00:41:45,670 --> 00:41:43,599
one over and obviously that can go one

1159
00:41:47,190 --> 00:41:45,680
over there there's also another equation

1160
00:41:51,349 --> 00:41:47,200
that will come in handy

1161
00:41:58,230 --> 00:41:54,630
which is the energy time uncertainty

1162
00:42:00,390 --> 00:41:58,240
and this gives a correspondence between

1163
00:42:01,510 --> 00:42:00,400

energy

1164

00:42:02,470 --> 00:42:01,520

and

1165

00:42:04,470 --> 00:42:02,480

time

1166

00:42:06,470 --> 00:42:04,480

however looking at the equation you can

1167

00:42:08,790 --> 00:42:06,480

see that it's inverse time

1168

00:42:11,030 --> 00:42:08,800

that means that inverse time is energy

1169

00:42:12,710 --> 00:42:11,040

inverse energy is time let's now make

1170

00:42:15,190 --> 00:42:12,720

some substitutions

1171

00:42:16,390 --> 00:42:15,200

mass is the same as energy so i'm going

1172

00:42:18,150 --> 00:42:16,400

to call it gev

1173

00:42:19,670 --> 00:42:18,160

time is the same as

1174

00:42:21,349 --> 00:42:19,680

g e v

1175

00:42:24,069 --> 00:42:21,359

inverse

1176

00:42:26,470 --> 00:42:24,079

length is the same as $g e v$

1177

00:42:28,069 --> 00:42:26,480

inverse well length is the same as mass

1178

00:42:29,990 --> 00:42:28,079

but mass is the same as energy so you

1179

00:42:32,550 --> 00:42:30,000

can make that substitution making all of

1180

00:42:36,710 --> 00:42:32,560

these substitutions you then get that g

1181

00:42:42,309 --> 00:42:36,720

the units of newtons is actually 1 over

1182

00:42:43,270 --> 00:42:42,319

$g e v$ squared or as we'll be writing it

1183

00:42:46,230 --> 00:42:43,280

simply

1184

00:42:48,309 --> 00:42:46,240

$g e v$ to the power of negative two

1185

00:42:51,109 --> 00:42:48,319

it's all simple we look and we see that

1186

00:42:54,550 --> 00:42:51,119

it's newtons times kilograms times

1187

00:42:59,190 --> 00:42:54,560

length etc actually reduces down to this

1188

00:43:01,270 --> 00:42:59,200

so let's underline that in red

1189

00:43:03,430 --> 00:43:01,280

how about entropy well entropy as we've

1190

00:43:04,710 --> 00:43:03,440

noted above is given by formula which

1191

00:43:08,630 --> 00:43:04,720

looks like

1192

00:43:16,150 --> 00:43:10,790

and these are probabilities

1193

00:43:20,309 --> 00:43:18,630

again extremely simple now much of this

1194

00:43:21,829 --> 00:43:20,319

is made complicated but if you look at

1195

00:43:23,750 --> 00:43:21,839

it through the lens of natural units as

1196

00:43:25,589 --> 00:43:23,760

well as these conversion equations all

1197

00:43:27,270 --> 00:43:25,599

of the quantities that you know and that

1198

00:43:30,309 --> 00:43:27,280

you love and that you want to work with

1199

00:43:31,750 --> 00:43:30,319

become units of energy raised to some

1200

00:43:34,630 --> 00:43:31,760

integer power

1201

00:43:35,910 --> 00:43:34,640

how about pressure

1202

00:43:39,109 --> 00:43:35,920

again let's just look that up on

1203

00:43:41,510 --> 00:43:39,119

wikipedia that's usually the first step

1204

00:43:43,430 --> 00:43:41,520

it says here newtons per meter squared

1205

00:43:45,990 --> 00:43:43,440

that makes sense because it's newton

1206

00:43:47,750 --> 00:43:46,000

which is a force unit over some area and

1207

00:43:49,430 --> 00:43:47,760

then luckily they've decomposed it

1208

00:43:53,030 --> 00:43:49,440

further for us

1209

00:43:55,990 --> 00:43:53,040

so let's write that down that is a mass

1210

00:43:59,190 --> 00:43:56,000

over a length

1211

00:44:01,109 --> 00:43:59,200

and then we have time squared

1212

00:44:03,109 --> 00:44:01,119

which then becomes which we can now do

1213

00:44:05,589 --> 00:44:03,119

in our head but we won't do that right

1214

00:44:09,030 --> 00:44:05,599

now because we're trying to not skip any

1215

00:44:11,430 --> 00:44:09,040

steps mass becomes g_{ν}

1216

00:44:14,950 --> 00:44:11,440

length becomes g_{ν} inverse so it goes to

1217

00:44:18,150 --> 00:44:14,960

the top time is also g_{ν} inverse

1218

00:44:20,829 --> 00:44:18,160

so it's g_{ν} squared and that is the same

1219

00:44:20,839 --> 00:44:27,430

g_{ν} to the fourth

1220

00:44:31,750 --> 00:44:29,589

this tells you an extremely important

1221

00:44:34,069 --> 00:44:31,760

property of pressure it's an extensive

1222

00:44:35,829 --> 00:44:34,079

property of space-time itself this is

1223

00:44:38,230 --> 00:44:35,839

one of the reasons why it's much easier

1224

00:44:40,230 --> 00:44:38,240

or much more useful to think in terms of

1225

00:44:41,910 --> 00:44:40,240

pressure rather than force because

1226

00:44:44,630 --> 00:44:41,920

pressure is a property of space time

1227

00:44:46,710 --> 00:44:44,640

itself whereas force is some derived

1228

00:44:48,230 --> 00:44:46,720

quantity that usually isn't useful in

1229

00:44:51,589 --> 00:44:48,240

fundamental physics

1230

00:44:53,190 --> 00:44:51,599

now let's do a fun one how about speed

1231

00:44:56,309 --> 00:44:53,200

well we

1232

00:44:58,950 --> 00:44:56,319

think of it as length over time

1233

00:45:01,510 --> 00:44:58,960

and then because time and length are the

1234

00:45:03,349 --> 00:45:01,520

same in our conversion chart this just

1235

00:45:05,910 --> 00:45:03,359

becomes

1236

00:45:08,230 --> 00:45:05,920

dimensionless

1237

00:45:10,950 --> 00:45:08,240

that deserves a bolded

1238

00:45:12,470 --> 00:45:10,960

exclamation point

1239

00:45:15,270 --> 00:45:12,480

then you think well how the heck is

1240

00:45:17,510 --> 00:45:15,280

speed dimensionless isn't it the case

1241

00:45:20,309 --> 00:45:17,520

that you said over here kurt c equals

1242

00:45:22,230 --> 00:45:20,319

one you can't simply say c equals one

1243

00:45:24,150 --> 00:45:22,240

yes that's true except there was a

1244

00:45:26,309 --> 00:45:24,160

caveat in the caveat is that there are

1245

00:45:28,230 --> 00:45:26,319

these conversion equations because we're

1246

00:45:30,710 --> 00:45:28,240

placing it in terms of c which is

1247

00:45:31,990 --> 00:45:30,720

invariant it means that we can tell time

1248

00:45:33,990 --> 00:45:32,000

in terms of length and we can tell

1249

00:45:36,790 --> 00:45:34,000

length in terms of time and that means

1250

00:45:38,470 --> 00:45:36,800

that this equation is correct but only

1251
00:45:40,230 --> 00:45:38,480
when you take into account the fact that

1252
00:45:43,349 --> 00:45:40,240
c is in variance and these other

1253
00:45:45,589 --> 00:45:43,359
conversion equations

1254
00:45:48,069 --> 00:45:45,599
it's usually just glossed over so plenty

1255
00:45:50,069 --> 00:45:48,079
of preamble goes into making a statement

1256
00:45:52,630 --> 00:45:50,079
as seemingly simple as c equals one

1257
00:45:54,790 --> 00:45:52,640
equals h bar so c equals one is a

1258
00:45:56,790 --> 00:45:54,800
meaningless statement unless you're

1259
00:45:58,950 --> 00:45:56,800
specifying that you're using some of

1260
00:46:00,470 --> 00:45:58,960
these as conversions and then you're

1261
00:46:01,750 --> 00:46:00,480
also emphasizing the invariance of the

1262
00:46:03,270 --> 00:46:01,760
speed of light if the speed of light

1263
00:46:05,109 --> 00:46:03,280

depends on something else you can't

1264

00:46:08,230 --> 00:46:05,119

actually use that all of this needs to

1265

00:46:10,150 --> 00:46:08,240

be explained unequivocally first

1266

00:46:12,550 --> 00:46:10,160

it's usually not and then there's an

1267

00:46:14,309 --> 00:46:12,560

abundance of befuddlement that occurs

1268

00:46:16,390 --> 00:46:14,319

much like with the brockhead notation

1269

00:46:18,150 --> 00:46:16,400

which looks graceful however there's

1270

00:46:19,510 --> 00:46:18,160

plenty of assumptions that go into it

1271

00:46:21,670 --> 00:46:19,520

which make it

1272

00:46:23,589 --> 00:46:21,680

not terribly useful

1273

00:46:25,589 --> 00:46:23,599

let's use this to calculate a practical

1274

00:46:27,109 --> 00:46:25,599

quantity so how many protons are there

1275

00:46:30,069 --> 00:46:27,119

in you at first if you were to just say

1276

00:46:32,069 --> 00:46:30,079

well i weigh 70 kilograms that doesn't

1277

00:46:33,750 --> 00:46:32,079

give much information what we can do is

1278

00:46:34,550 --> 00:46:33,760

we can use our conversion chart over

1279

00:46:37,270 --> 00:46:34,560

here

1280

00:46:40,069 --> 00:46:37,280

and say okay well look one gram

1281

00:46:43,829 --> 00:46:40,079

is this much energy so how about a

1282

00:46:46,069 --> 00:46:43,839

kilogram so a kilogram must be 10 to the

1283

00:46:48,950 --> 00:46:46,079

26 gev

1284

00:46:50,950 --> 00:46:48,960

using this we then get that 70 kilograms

1285

00:46:52,069 --> 00:46:50,960

becomes

1286

00:46:55,829 --> 00:46:52,079

70

1287

00:46:59,510 --> 00:46:55,839

times 10 to the 26 gev

1288

00:47:01,589 --> 00:46:59,520

which is on the order of 10 to the 28

1289

00:47:04,069 --> 00:47:01,599

gev

1290

00:47:06,790 --> 00:47:04,079

that means that what comprises you is 10

1291

00:47:09,190 --> 00:47:06,800

to the 28 protons and that's a much more

1292

00:47:10,790 --> 00:47:09,200

physically meaningful quantity now you

1293

00:47:12,550 --> 00:47:10,800

have some physical intuition given to

1294

00:47:13,910 --> 00:47:12,560

you by your weight whereas if it was

1295

00:47:15,589 --> 00:47:13,920

just kilograms then you have to go to

1296

00:47:17,109 --> 00:47:15,599

paris etc

1297

00:47:19,670 --> 00:47:17,119

then you may wonder well kurt don't

1298

00:47:23,589 --> 00:47:19,680

neutrons come with protons so shouldn't

1299

00:47:25,990 --> 00:47:23,599

you times two the above yes except

1300

00:47:28,150 --> 00:47:26,000

because of this we're saying on the

1301

00:47:30,150 --> 00:47:28,160

order of so we can say there are 10 to

1302

00:47:32,470 --> 00:47:30,160

the 28 nucleons that comprise you

1303

00:47:34,870 --> 00:47:32,480

protons and neutrons bound

1304

00:47:36,870 --> 00:47:34,880

there we go simple and powerful because

1305

00:47:38,550 --> 00:47:36,880

it allows these napkin calculations

1306

00:47:39,910 --> 00:47:38,560

let's do one that you may think requires

1307

00:47:41,349 --> 00:47:39,920

plenty of work but it's actually

1308

00:47:43,750 --> 00:47:41,359

extremely quick you can do it in a

1309

00:47:46,309 --> 00:47:43,760

second so what is the pressure inside a

1310

00:47:49,589 --> 00:47:46,319

neutron star

1311

00:47:52,390 --> 00:47:49,599

firstly you have to think what is

1312

00:47:54,390 --> 00:47:52,400

happening there are neutrons as far as

1313

00:47:56,150 --> 00:47:54,400

you can see and recall that neutrons are

1314

00:47:59,670 --> 00:47:56,160

the same as protons in terms of their

1315

00:48:01,910 --> 00:47:59,680

radius and mass approximately

1316

00:48:03,430 --> 00:48:01,920

then as far as you can see all you see

1317

00:48:05,109 --> 00:48:03,440

are neutrons think about what have you

1318

00:48:06,710 --> 00:48:05,119

learned about a neutron star it's that

1319

00:48:08,470 --> 00:48:06,720

the neutrons are packed so close

1320

00:48:10,470 --> 00:48:08,480

together that they can't be packed any

1321

00:48:13,030 --> 00:48:10,480

further then you think well what is the

1322

00:48:15,910 --> 00:48:13,040

units of pressure and it's gev to the

1323

00:48:21,910 --> 00:48:15,920

fourth so we have gev times uv times gev

1324

00:48:26,549 --> 00:48:24,390

pressure in a neutron star

1325

00:48:27,990 --> 00:48:26,559

is simply gev

1326

00:48:31,030 --> 00:48:28,000

to the fourth

1327

00:48:32,150 --> 00:48:31,040

okay that's it it's just gev to the

1328

00:48:33,349 --> 00:48:32,160

fourth

1329

00:48:34,950 --> 00:48:33,359

and this is something that you can

1330

00:48:37,190 --> 00:48:34,960

verify yourself if you look up what it

1331

00:48:38,549 --> 00:48:37,200

is in pascals and then do the conversion

1332

00:48:40,790 --> 00:48:38,559

and just keep in mind that some

1333

00:48:43,190 --> 00:48:40,800

conversion charts have a plus or minus

1334

00:48:44,710 --> 00:48:43,200

one on the order because sometimes

1335

00:48:45,510 --> 00:48:44,720

people round up sometimes people round

1336

00:48:46,870 --> 00:48:45,520

down

1337

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

now let's get through this much more

1338

00:48:50,230 --> 00:48:48,720

quickly because i'm re-recording

1339

00:48:52,309 --> 00:48:50,240

constantly there are many errors and my

1340

00:48:53,829 --> 00:48:52,319

facial hair is growing i've renamed this

1341

00:48:55,670 --> 00:48:53,839

for reasons that will become clear later

1342

00:48:58,150 --> 00:48:55,680

and neutron stars pressure is much more

1343

00:49:00,390 --> 00:48:58,160

copacetic so proportionate strength of

1344

00:49:01,670 --> 00:49:00,400

the forces so you know from perhaps

1345

00:49:03,109 --> 00:49:01,680

around high school that it's something

1346

00:49:04,950 --> 00:49:03,119

like the first charge times the second

1347

00:49:06,710 --> 00:49:04,960

charge so on and so on and so on let's

1348

00:49:09,510 --> 00:49:06,720

look at this in terms of the electron

1349

00:49:11,510 --> 00:49:09,520

charge so q_1 will equal q_2 will equal e

1350

00:49:14,230 --> 00:49:11,520

v is energy we know that that's

1351

00:49:16,549 --> 00:49:14,240

potential energy r is inverse energy

1352

00:49:17,510 --> 00:49:16,559

which means this equation

1353

00:49:20,390 --> 00:49:17,520

has

1354

00:49:21,349 --> 00:49:20,400

this guy here which means that this guy

1355

00:49:25,270 --> 00:49:21,359

here

1356

00:49:25,280 --> 00:49:30,230

is dimensionless

1357

00:49:36,470 --> 00:49:33,109

and this is what is usually denoted as

1358

00:49:38,870 --> 00:49:36,480

α which i'm sure you've heard is one

1359

00:49:40,390 --> 00:49:38,880

three seven inverse

1360

00:49:41,910 --> 00:49:40,400

this is the reason why the strength of

1361

00:49:43,990 --> 00:49:41,920

the electromagnetic force or the

1362

00:49:46,630 --> 00:49:44,000

electromagnetic interaction is

1363

00:49:49,430 --> 00:49:46,640

quantifiable it's dimensionless however

1364

00:49:52,390 --> 00:49:49,440

if we were to look up here

1365

00:49:55,270 --> 00:49:52,400

notice this this g newton

1366

00:49:57,750 --> 00:49:55,280

has negative mass dimension which means

1367

00:49:59,589 --> 00:49:57,760

that saying that gravity is weak is

1368

00:50:01,670 --> 00:49:59,599

actually a meaningless statement because

1369

00:50:03,349 --> 00:50:01,680

you need test masses you need two test

1370

00:50:05,270 --> 00:50:03,359

masses in order to say that usually

1371

00:50:07,349 --> 00:50:05,280

what's done in fundamental physics is

1372

00:50:09,510 --> 00:50:07,359

one takes the most massive of all the

1373

00:50:11,589 --> 00:50:09,520

particles the fundamental particles and

1374

00:50:13,510 --> 00:50:11,599

says well look compared to the weak

1375

00:50:15,430 --> 00:50:13,520

force which is the weakest of all the

1376

00:50:17,349 --> 00:50:15,440

standard model forces the gauge fields

1377

00:50:19,430 --> 00:50:17,359

gravity is so and so times weaker so

1378

00:50:21,510 --> 00:50:19,440

that's what's meant specifically by

1379

00:50:23,349 --> 00:50:21,520

gravity is weak but all of that needs to

1380

00:50:25,510 --> 00:50:23,359

be stated there are assumptions that go

1381

00:50:27,109 --> 00:50:25,520

into that you need a test mass and by

1382

00:50:29,030 --> 00:50:27,119

the way this guy here this negative

1383

00:50:30,950 --> 00:50:29,040

square mass dimension of the coupling of

1384

00:50:33,190 --> 00:50:30,960

gravity plays an extremely important

1385

00:50:35,109 --> 00:50:33,200

role in the non-renormalizability of

1386

00:50:36,950 --> 00:50:35,119

gravity let's calculate the average

1387

00:50:38,630 --> 00:50:36,960

speed of an electron so later we're

1388

00:50:40,150 --> 00:50:38,640

going to calculate the radius of an

1389

00:50:41,670 --> 00:50:40,160

electron and that's going to turn out to

1390

00:50:43,910 --> 00:50:41,680

be

1391

00:50:45,430 --> 00:50:43,920

this but this right now just looks like

1392

00:50:47,829 --> 00:50:45,440

junk because we haven't derived any of

1393

00:50:52,069 --> 00:50:47,839

this however from this we know that one

1394

00:50:56,309 --> 00:50:53,910

says that we can figure out the momentum

1395

00:50:58,390 --> 00:50:56,319

based on a length so then what is the

1396

00:51:03,349 --> 00:50:58,400

momentum of the average electron and

1397

00:51:13,750 --> 00:51:05,670

and that means that this is the average

1398

00:51:18,230 --> 00:51:15,910

and this number is the reason why

1399

00:51:20,069 --> 00:51:18,240

magnetism was discovered so much later

1400

00:51:21,990 --> 00:51:20,079

because electrons are moving relatively

1401

00:51:23,190 --> 00:51:22,000

slowly and we know that magnetism has to

1402

00:51:25,349 --> 00:51:23,200

do with the speed or has to do with

1403

00:51:27,190 --> 00:51:25,359

current changes thus from relatively

1404

00:51:29,190 --> 00:51:27,200

fundamental principles you can derive a

1405

00:51:31,030 --> 00:51:29,200

historic fact why was it that magnetism

1406

00:51:33,670 --> 00:51:31,040

was discovered much later well it's

1407

00:51:34,950 --> 00:51:33,680

because of this guy

1408

00:51:36,950 --> 00:51:34,960

and by the way you'll notice that i

1409

00:51:39,270 --> 00:51:36,960

spend quite a bit of time writing and

1410

00:51:41,109 --> 00:51:39,280

rewriting painstakingly almost and

1411

00:51:42,870 --> 00:51:41,119

that's because i know that clarity of

1412

00:51:45,589 --> 00:51:42,880

thought leads to this clarity of writing

1413

00:51:46,790 --> 00:51:45,599

and vice versa for myself and for you

1414

00:51:48,710 --> 00:51:46,800

and if you're lucky enough to have a

1415

00:51:51,270 --> 00:51:48,720

lecturer who's blessed in that area in

1416

00:51:53,030 --> 00:51:51,280

this notational refinement area then it

1417

00:51:54,950 --> 00:51:53,040

will translate directly to higher

1418

00:51:56,230 --> 00:51:54,960

comprehension for you

1419

00:52:00,390 --> 00:51:56,240

it's a

1420

00:52:02,150 --> 00:52:00,400

the logical placement of the words and

1421

00:52:03,510 --> 00:52:02,160

the formula matter and many of you are

1422

00:52:04,790 --> 00:52:03,520

trying to create your own theory of

1423

00:52:06,630 --> 00:52:04,800

everything you're advancing your own

1424

00:52:08,069 --> 00:52:06,640

you're not simply learning about others

1425

00:52:10,309 --> 00:52:08,079

it's one of the reasons why i try to be

1426

00:52:12,710 --> 00:52:10,319

specific in the podcast in general and

1427

00:52:14,470 --> 00:52:12,720

then also here as much as i can be given

1428

00:52:15,510 --> 00:52:14,480

the time constraints because generally

1429

00:52:17,990 --> 00:52:15,520

you're told

1430

00:52:19,510 --> 00:52:18,000

have truths so for example that a wave

1431

00:52:21,510 --> 00:52:19,520

function is a member of a square

1432

00:52:23,349 --> 00:52:21,520

integrable hilbert space okay but then

1433

00:52:25,190 --> 00:52:23,359

if you derive it is a square integrable

1434

00:52:27,190 --> 00:52:25,200

function necessarily square integrable

1435

00:52:28,790 --> 00:52:27,200

itself okay so then you limit it to

1436

00:52:30,870 --> 00:52:28,800

schwarz functions and then you say well

1437

00:52:32,230 --> 00:52:30,880

perhaps gelfon triples and so on and

1438

00:52:33,910 --> 00:52:32,240

then you realize well that only works

1439

00:52:35,270 --> 00:52:33,920

for pure states that a general quantum

1440

00:52:37,510 --> 00:52:35,280

mechanical state is actually an

1441

00:52:39,109 --> 00:52:37,520

endomorphism on a hilbert space and even

1442

00:52:40,230 --> 00:52:39,119

then when it's a pure state it's not a

1443

00:52:44,150 --> 00:52:40,240

unique

1444

00:52:45,670 --> 00:52:44,160

hilbert space you have to take a an

1445

00:52:47,670 --> 00:52:45,680

equivalence class so you generally take

1446

00:52:49,589 --> 00:52:47,680

them from projective hilbert spaces and

1447

00:52:51,430 --> 00:52:49,599

so on and the reason for me to be

1448

00:52:53,109 --> 00:52:51,440

extremely detailed is because many of

1449

00:52:54,470 --> 00:52:53,119

you are trying to advance your own toes

1450

00:52:56,309 --> 00:52:54,480

and if you're going to build them based

1451
00:52:58,710 --> 00:52:56,319
on some shaky foundation then you're

1452
00:53:01,430 --> 00:52:58,720
going to derive

1453
00:53:03,270 --> 00:53:01,440
fantastic formula and fantastic theories

1454
00:53:07,190 --> 00:53:03,280
based on

1455
00:53:08,870 --> 00:53:07,200
misleading you can it's akin to dividing

1456
00:53:10,630 --> 00:53:08,880
by zero you can prove the entire

1457
00:53:12,069 --> 00:53:10,640
universe from scratch if you divide by

1458
00:53:15,589 --> 00:53:12,079
zero what i found is that the

1459
00:53:18,150 --> 00:53:15,599
popularizers of science have generally

1460
00:53:19,910 --> 00:53:18,160
spent a significant amount of time on

1461
00:53:21,109 --> 00:53:19,920
let's say the wave particle duality

1462
00:53:22,790 --> 00:53:21,119
instead of telling you it's a quantum

1463
00:53:24,630 --> 00:53:22,800

mechanical object that behaves in this

1464

00:53:25,349 --> 00:53:24,640

manner well mainly

1465

00:53:29,829 --> 00:53:25,359

for

1466

00:53:31,349 --> 00:53:29,839

is because they want to evoke awe in you

1467

00:53:32,790 --> 00:53:31,359

and show you how unimaginably

1468

00:53:35,190 --> 00:53:32,800

intelligent these

1469

00:53:37,030 --> 00:53:35,200

esoteric physicists are for being able

1470

00:53:38,950 --> 00:53:37,040

to grapple with these concepts that no

1471

00:53:40,950 --> 00:53:38,960

one understands well you can understand

1472

00:53:43,430 --> 00:53:40,960

it too if it was explained

1473

00:53:45,270 --> 00:53:43,440

specifically to you and then you can

1474

00:53:46,390 --> 00:53:45,280

search the key terms so let's say i said

1475

00:53:47,829 --> 00:53:46,400

the word

1476
00:53:49,670 --> 00:53:47,839
gelphon triple you're wondering what the

1477
00:53:51,349 --> 00:53:49,680
heck is that well now you can at least

1478
00:53:53,109 --> 00:53:51,359
look that up on wikipedia and you can

1479
00:53:55,109 --> 00:53:53,119
gain a far better understanding of what

1480
00:53:56,710 --> 00:53:55,119
a quantum mechanical object is rather

1481
00:53:58,230 --> 00:53:56,720
than simply saying that it's both a wave

1482
00:54:00,630 --> 00:53:58,240
and a particle at the same time and who

1483
00:54:02,549 --> 00:54:00,640
knows what the collapse means and so on

1484
00:54:04,470 --> 00:54:02,559
by the way i talk about this here in the

1485
00:54:06,549 --> 00:54:04,480
quantum gravity section of the salvator

1486
00:54:08,230 --> 00:54:06,559
pious interview if you want i'll leave a

1487
00:54:10,150 --> 00:54:08,240
link in the description this is why

1488
00:54:12,230 --> 00:54:10,160

quantizing gravity is so difficult and

1489

00:54:14,790 --> 00:54:12,240

it's explained in in some pedantic

1490

00:54:16,309 --> 00:54:14,800

mathematical detail mainly because then

1491

00:54:18,309 --> 00:54:16,319

you can see okay this is why it's so

1492

00:54:19,829 --> 00:54:18,319

difficult and it it's not necessarily

1493

00:54:21,349 --> 00:54:19,839

because you're trying to mix the jittery

1494

00:54:22,390 --> 00:54:21,359

with the smooth and so on like what does

1495

00:54:25,109 --> 00:54:22,400

that mean

1496

00:54:26,390 --> 00:54:25,119

let's get to knots and extra dimensions

1497

00:54:27,750 --> 00:54:26,400

the whole point of this is to get

1498

00:54:29,349 --> 00:54:27,760

familiar with the different length

1499

00:54:31,190 --> 00:54:29,359

scales and the different energy scales

1500

00:54:33,510 --> 00:54:31,200

so let's take a look at this the mass of

1501

00:54:36,390 --> 00:54:33,520

the pion which you can look up online is

1502

00:54:38,790 --> 00:54:36,400

about 10 to the minus 1 gev

1503

00:54:41,990 --> 00:54:38,800

the mass of the electron which i think

1504

00:54:44,710 --> 00:54:42,000

we've used is about 10 to the minus 3

1505

00:54:47,670 --> 00:54:44,720

gev thinking of physics in the manner of

1506

00:54:49,190 --> 00:54:47,680

natural units and gevs etc

1507

00:54:50,549 --> 00:54:49,200

gives you concrete ways of thinking

1508

00:54:52,710 --> 00:54:50,559

about some phenomenon in different

1509

00:54:55,750 --> 00:54:52,720

respects so for example length scales

1510

00:54:58,390 --> 00:54:55,760

here these automatically imply that for

1511

00:55:01,349 --> 00:54:58,400

example chemistry

1512

00:55:02,950 --> 00:55:01,359

becomes important at what scale well 10

1513

00:55:04,549 --> 00:55:02,960

to the 3

1514

00:55:06,870 --> 00:55:04,559

g e v

1515

00:55:07,589 --> 00:55:06,880

inverse we simply take the inverse of

1516

00:55:09,510 --> 00:55:07,599

this

1517

00:55:10,630 --> 00:55:09,520

and then same with the straw and by the

1518

00:55:12,630 --> 00:55:10,640

way that's because the electron is

1519

00:55:17,589 --> 00:55:12,640

what's responsible for chemistry largely

1520

00:55:22,230 --> 00:55:19,430

we expect the scale that it becomes

1521

00:55:25,430 --> 00:55:22,240

relevant is 10

1522

00:55:27,829 --> 00:55:25,440

gev inverse and then we can simply do

1523

00:55:30,470 --> 00:55:27,839

our conversion over here to find out the

1524

00:55:32,230 --> 00:55:30,480

relevant length scale in terms of meters

1525

00:55:33,670 --> 00:55:32,240

let's now have a quick detour into extra

1526

00:55:39,910 --> 00:55:33,680

dimensions

1527

00:55:41,510 --> 00:55:39,920

we're dealing with one temporal time

1528

00:55:43,510 --> 00:55:41,520

dimension so you'll hear three plus one

1529

00:55:45,829 --> 00:55:43,520

or four plus one that plus one usually

1530

00:55:48,309 --> 00:55:45,839

means the time at some point in the toe

1531

00:55:50,390 --> 00:55:48,319

podcast i may do a single episode just

1532

00:55:52,789 --> 00:55:50,400

on extra dimensions if you're interested

1533

00:55:54,630 --> 00:55:52,799

let me know as well as extra temporal

1534

00:55:56,710 --> 00:55:54,640

dimensions what we're doing is looking

1535

00:55:58,390 --> 00:55:56,720

here so we're seeing that usually what

1536

00:56:00,630 --> 00:55:58,400

you've heard is that you compactify the

1537

00:56:02,230 --> 00:56:00,640

dimensions sometimes i think in the

1538

00:56:05,109 --> 00:56:02,240

string theory episode which i'll link

1539

00:56:07,109 --> 00:56:05,119

over here we talked about a collusion

1540

00:56:09,109 --> 00:56:07,119

compactification of 10 dimensional super

1541

00:56:10,150 --> 00:56:09,119

yang mills theory so that's what's being

1542

00:56:12,069 --> 00:56:10,160

referenced here when you hear about

1543

00:56:14,230 --> 00:56:12,079

occlusal klein resonance and then you

1544

00:56:15,750 --> 00:56:14,240

may wonder well look it says that we

1545

00:56:17,990 --> 00:56:15,760

have put some bounds on the extra

1546

00:56:20,230 --> 00:56:18,000

dimensions which is one tev but if we

1547

00:56:22,789 --> 00:56:20,240

take a look at what the lhc

1548

00:56:24,549 --> 00:56:22,799

the largest energy of the lhc is it says

1549

00:56:28,950 --> 00:56:24,559

here

1550

00:56:31,030 --> 00:56:28,960

it's 6.8 well times two so it's 13.6 tev

1551
00:56:33,190 --> 00:56:31,040
tv is just a thousand gev so then you

1552
00:56:35,510 --> 00:56:33,200
wonder well how is it that we've put a

1553
00:56:38,150 --> 00:56:35,520
bound of an extra dimension only at one

1554
00:56:40,230 --> 00:56:38,160
tev shouldn't it be at 13 tev well

1555
00:56:42,150 --> 00:56:40,240
strangely some of the theories of extra

1556
00:56:44,549 --> 00:56:42,160
dimensions have it such that the

1557
00:56:47,430 --> 00:56:44,559
standard model fields

1558
00:56:49,109 --> 00:56:47,440
stay within our three spatial dimensions

1559
00:56:51,109 --> 00:56:49,119
and then they leak out well gravity

1560
00:56:53,030 --> 00:56:51,119
mainly leaks out into another dimension

1561
00:56:57,750 --> 00:56:53,040
that's the add model not attention

1562
00:56:59,190 --> 00:56:57,760
deficit disorder but arkani hamed and

1563
00:57:01,109 --> 00:56:59,200

divali and then there's one more other

1564

00:57:02,549 --> 00:57:01,119

person and so it looks like this let's

1565

00:57:04,230 --> 00:57:02,559

imagine that this is a three-dimensional

1566

00:57:05,589 --> 00:57:04,240

slice

1567

00:57:07,510 --> 00:57:05,599

these are some particles and they're

1568

00:57:09,349 --> 00:57:07,520

moving together and then they hit and

1569

00:57:11,510 --> 00:57:09,359

then if a graviton is created well

1570

00:57:13,670 --> 00:57:11,520

graviton can somewhat come outward but

1571

00:57:15,349 --> 00:57:13,680

it can also leak into another dimension

1572

00:57:18,069 --> 00:57:15,359

and so that's one of the proposed

1573

00:57:20,230 --> 00:57:18,079

mechanisms to give an explanation for

1574

00:57:21,670 --> 00:57:20,240

why gravity is so comparatively quote

1575

00:57:23,190 --> 00:57:21,680

unquote weak

1576

00:57:24,549 --> 00:57:23,200

is that it's actually not it's somewhat

1577

00:57:26,950 --> 00:57:24,559

comparable it's just that it goes into

1578

00:57:29,030 --> 00:57:26,960

another dimension and because we're

1579

00:57:31,270 --> 00:57:29,040

confined here this is where we're

1580

00:57:32,789 --> 00:57:31,280

confined it's not as simple as looking

1581

00:57:34,870 --> 00:57:32,799

for an extra dimension like you can see

1582

00:57:36,390 --> 00:57:34,880

it just like you can see a

1583

00:57:37,990 --> 00:57:36,400

dna molecule

1584

00:57:40,950 --> 00:57:38,000

what we're looking for are deviations in

1585

00:57:42,789 --> 00:57:40,960

the inverse square law and this number 2

1586

00:57:44,950 --> 00:57:42,799

here is actually

1587

00:57:46,230 --> 00:57:44,960

can be generalized to higher dimensions

1588

00:57:48,630 --> 00:57:46,240

dim

1589

00:57:50,710 --> 00:57:48,640

minus 2 where i'm including time here to

1590

00:57:52,950 --> 00:57:50,720

make this simple so for us it's 4 minus

1591

00:57:54,470 --> 00:57:52,960

2 which is what gives rise to this

1592

00:57:55,829 --> 00:57:54,480

inverse square law but if we're in

1593

00:57:57,270 --> 00:57:55,839

higher dimensions then we'll see a

1594

00:57:58,870 --> 00:57:57,280

different number here

1595

00:58:00,470 --> 00:57:58,880

this becomes one over the dimension of

1596

00:58:02,390 --> 00:58:00,480

the manifold that you're on minus two

1597

00:58:03,910 --> 00:58:02,400

and in the manifold i'm including time

1598

00:58:05,589 --> 00:58:03,920

just to make it simple

1599

00:58:07,190 --> 00:58:05,599

okay as for how we derive this don't

1600

00:58:09,670 --> 00:58:07,200

worry about that you can just think of

1601
00:58:12,309 --> 00:58:09,680
the flow through a surface if we're in

1602
00:58:14,230 --> 00:58:12,319
 r^3 then a sphere around us is like a

1603
00:58:16,150 --> 00:58:14,240
shell and that's a two-dimensional

1604
00:58:18,069 --> 00:58:16,160
surface so if you're in r^3 you go one

1605
00:58:19,829 --> 00:58:18,079
dimension down if you're an r^4 you go

1606
00:58:21,829 --> 00:58:19,839
one dimension down so it's r^3 and so on

1607
00:58:23,349 --> 00:58:21,839
and so on technically to be rigorous you

1608
00:58:26,630 --> 00:58:23,359
need to show that the potential of some

1609
00:58:27,750 --> 00:58:26,640
laplacian vanishes but we can leave that

1610
00:58:30,069 --> 00:58:27,760
let's get to looking at some of the

1611
00:58:32,789 --> 00:58:30,079
papers on extra dimensions here we go so

1612
00:58:34,630 --> 00:58:32,799
firstly notice this this is inverse r

1613
00:58:36,390 --> 00:58:34,640

which is related to an energy and so

1614

00:58:38,069 --> 00:58:36,400

this makes sense because you know length

1615

00:58:39,670 --> 00:58:38,079

is inverse energy

1616

00:58:41,190 --> 00:58:39,680

now you're starting to get a handle on

1617

00:58:43,910 --> 00:58:41,200

all of this let's take a look at another

1618

00:58:45,670 --> 00:58:43,920

paper which i'll link in the description

1619

00:58:48,150 --> 00:58:45,680

this is actually a section from a book i

1620

00:58:49,670 --> 00:58:48,160

believe and you can take a look well

1621

00:58:51,829 --> 00:58:49,680

here what this is saying is that if we

1622

00:58:53,589 --> 00:58:51,839

have extra dimension c here is four plus

1623

00:58:55,589 --> 00:58:53,599

the extra spatial dimensions right there

1624

00:58:58,549 --> 00:58:55,599

that's delta you have the einstein

1625

00:59:02,230 --> 00:58:58,559

hilbert action this we know if we remove

1626
00:59:03,430 --> 00:59:02,240
this δy this is just the standard

1627
00:59:05,670 --> 00:59:03,440
action that leads to the einstein

1628
00:59:07,349 --> 00:59:05,680
equations and we trivially add some more

1629
00:59:08,549 --> 00:59:07,359
spatial dimensions right here and then

1630
00:59:10,150 --> 00:59:08,559
here's some matter fields you want to

1631
00:59:11,750 --> 00:59:10,160
couple some matter to it and notice that

1632
00:59:14,150 --> 00:59:11,760
it's four dimensional here whereas this

1633
00:59:16,390 --> 00:59:14,160
one is four plus δ and that's saying

1634
00:59:18,470 --> 00:59:16,400
hey let's restrict our standard model

1635
00:59:20,470 --> 00:59:18,480
matter field to this four dimensional

1636
00:59:22,309 --> 00:59:20,480
manifold and that explains why we see

1637
00:59:23,589 --> 00:59:22,319
them as fairly strong but then gravity

1638
00:59:25,829 --> 00:59:23,599

is allowed to

1639

00:59:27,190 --> 00:59:25,839

leak out into the extra delta dimensions

1640

00:59:28,870 --> 00:59:27,200

if we take a look at this this also

1641

00:59:30,549 --> 00:59:28,880

gives us some bounds on the extra

1642

00:59:32,470 --> 00:59:30,559

dimensions now there are large extra

1643

00:59:33,670 --> 00:59:32,480

dimensions as well the add model i

1644

00:59:35,990 --> 00:59:33,680

mentioned before

1645

00:59:37,510 --> 00:59:36,000

isn't a compactification and you can

1646

00:59:39,270 --> 00:59:37,520

similarly find bounds on them which are

1647

00:59:41,750 --> 00:59:39,280

found here now that you're becoming more

1648

00:59:44,069 --> 00:59:41,760

and more familiar with tevs and gevs and

1649

00:59:46,069 --> 00:59:44,079

so on you can at least skim this paper

1650

00:59:47,510 --> 00:59:46,079

and get an idea of what's being said

1651
00:59:49,829 --> 00:59:47,520
notice here another number you should

1652
00:59:52,230 --> 00:59:49,839
recognize is the planck scale which is

1653
00:59:54,150 --> 00:59:52,240
10 to the 16 tev we have it written down

1654
00:59:55,510 --> 00:59:54,160
as 10 to the 19 gev but those are the

1655
00:59:57,430 --> 00:59:55,520
same numbers

1656
00:59:59,750 --> 00:59:57,440
now let's have a quick aside on knots if

1657
01:00:01,750 --> 00:59:59,760
i have enough room here what is a knot a

1658
01:00:06,549 --> 01:00:01,760
knot is an embedding of

1659
01:00:08,309 --> 01:00:06,559
a circle into \mathbb{R}^3 let's take an example

1660
01:00:09,750 --> 01:00:08,319
right there is a knot and this what

1661
01:00:11,430 --> 01:00:09,760
we're actually seeing this is not a knot

1662
01:00:13,510 --> 01:00:11,440
this is an embedding of a knot

1663
01:00:16,230 --> 01:00:13,520

technically these should be modded out

1664

01:00:18,630 --> 01:00:16,240

by isotopic equivalents i'll include a

1665

01:00:20,789 --> 01:00:18,640

link to a podcast where we go into more

1666

01:00:22,630 --> 01:00:20,799

about knots and quantum field theory

1667

01:00:26,549 --> 01:00:22,640

each one of these guys can directly

1668

01:00:26,559 --> 01:00:30,630

in two plus one dimensions

1669

01:00:33,510 --> 01:00:31,910

now you may ask well why is it that

1670

01:00:36,470 --> 01:00:33,520

we're going from

1671

01:00:40,069 --> 01:00:36,480

a circle to r^3 but not to r^d well there

1672

01:00:43,750 --> 01:00:40,079

are extensions except you can't have s^1

1673

01:00:45,589 --> 01:00:43,760

you cannot have s^1 into r^4 you can

1674

01:00:48,069 --> 01:00:45,599

except that every single knot can be

1675

01:00:49,990 --> 01:00:48,079

trivially unknotted so it can be morphed

1676

01:00:51,990 --> 01:00:50,000

into a circle

1677

01:00:54,470 --> 01:00:52,000

so that's why you'll have to have s2 if

1678

01:00:57,670 --> 01:00:54,480

you're going into r4 and then

1679

01:00:59,349 --> 01:00:57,680

s3 into r5 etc if you want to have

1680

01:01:01,109 --> 01:00:59,359

higher dimensional generalization of

1681

01:01:03,589 --> 01:01:01,119

knots but then their connection to

1682

01:01:05,190 --> 01:01:03,599

findment diagrams are

1683

01:01:06,549 --> 01:01:05,200

more complicated and i believe it's

1684

01:01:11,270 --> 01:01:06,559

current research

1685

01:01:14,710 --> 01:01:12,630

additionally whenever you hear about the

1686

01:01:17,510 --> 01:01:14,720

plank length that will come up the plank

1687

01:01:19,270 --> 01:01:17,520

length it can't be that space is quote

1688

01:01:21,030 --> 01:01:19,280

unquote trivially

1689

01:01:23,349 --> 01:01:21,040

made up into some lattice of discrete

1690

01:01:24,950 --> 01:01:23,359

lattice of plank lengths plank cubed and

1691

01:01:27,030 --> 01:01:24,960

so on and the reason is that that

1692

01:01:28,390 --> 01:01:27,040

concept is not lawrence and variant

1693

01:01:29,589 --> 01:01:28,400

because what if you're zooming past it

1694

01:01:31,589 --> 01:01:29,599

then do you get smaller than the planck

1695

01:01:32,950 --> 01:01:31,599

length what if you make this room into

1696

01:01:34,870 --> 01:01:32,960

the plank length and should this room

1697

01:01:36,950 --> 01:01:34,880

exist from another perspective you get

1698

01:01:38,309 --> 01:01:36,960

into plenty of paradoxes and that's

1699

01:01:39,910 --> 01:01:38,319

because we don't have

1700

01:01:41,990 --> 01:01:39,920

an understanding as to what happens

1701
01:01:43,670 --> 01:01:42,000
around that scale another way that extra

1702
01:01:45,910 --> 01:01:43,680
dimensions can be tested is if you

1703
01:01:48,549 --> 01:01:45,920
collide particles so let's say they look

1704
01:01:51,670 --> 01:01:49,910
and then

1705
01:01:53,190 --> 01:01:51,680
what who knows what happens here no one

1706
01:01:54,470 --> 01:01:53,200
actually knows their finemen diagrams

1707
01:01:55,990 --> 01:01:54,480
and so on but whether or not that

1708
01:01:58,549 --> 01:01:56,000
corresponds to something physical who

1709
01:02:00,069 --> 01:01:58,559
knows imagine they come out like this

1710
01:02:01,750 --> 01:02:00,079
well

1711
01:02:03,349 --> 01:02:01,760
what happened here

1712
01:02:05,030 --> 01:02:03,359
this is the same as this but then this

1713
01:02:06,710 --> 01:02:05,040

is less than this which means we have a

1714

01:02:08,549 --> 01:02:06,720

if they're the same particles we don't

1715

01:02:09,990 --> 01:02:08,559

have a conservation of momentum and then

1716

01:02:11,750 --> 01:02:10,000

we can say that perhaps what happened

1717

01:02:13,589 --> 01:02:11,760

was some of the momentum leaked into

1718

01:02:14,549 --> 01:02:13,599

another dimension so this is also being

1719

01:02:16,150 --> 01:02:14,559

looked for

1720

01:02:24,630 --> 01:02:16,160

this is called discrepancies and

1721

01:02:28,870 --> 01:02:26,470

now let's take a dive into penrose's

1722

01:02:30,630 --> 01:02:28,880

theory the microtubules of consciousness

1723

01:02:32,470 --> 01:02:30,640

because this is meant to be an overview

1724

01:02:33,910 --> 01:02:32,480

and each one of these is could be its

1725

01:02:36,470 --> 01:02:33,920

own two hour three hour four hour

1726

01:02:38,950 --> 01:02:36,480

podcast on its own at least let's simply

1727

01:02:40,630 --> 01:02:38,960

go to wikipedia and get familiar with

1728

01:02:42,870 --> 01:02:40,640

using these

1729

01:02:44,390 --> 01:02:42,880

conversion equations and natural units

1730

01:02:46,630 --> 01:02:44,400

the whole point of this video the

1731

01:02:48,789 --> 01:02:46,640

founders of this theory are penrose and

1732

01:02:50,230 --> 01:02:48,799

stuart hamerov

1733

01:02:51,829 --> 01:02:50,240

so if we take a look we're just looking

1734

01:02:53,589 --> 01:02:51,839

for equations right now we're scrolling

1735

01:02:56,309 --> 01:02:53,599

through i'm not concerned too much with

1736

01:02:58,150 --> 01:02:56,319

the background notice this this looks

1737

01:02:59,190 --> 01:02:58,160

extremely similar to

1738

01:03:01,349 --> 01:02:59,200

this

1739

01:03:03,270 --> 01:03:01,359

and it is it's called penrose's

1740

01:03:05,510 --> 01:03:03,280

indeterminacy principle much like

1741

01:03:07,589 --> 01:03:05,520

heisenberg's uncertainty principle what

1742

01:03:09,190 --> 01:03:07,599

penrose is saying is that imagine we

1743

01:03:11,270 --> 01:03:09,200

have one particle and then it's in a

1744

01:03:13,190 --> 01:03:11,280

superposition so let's imagine it's

1745

01:03:16,230 --> 01:03:13,200

a superposition of just two states which

1746

01:03:18,549 --> 01:03:16,240

can be left or right let's call this

1747

01:03:20,870 --> 01:03:18,559

option a and let's call this option b

1748

01:03:22,549 --> 01:03:20,880

along with option a and option b they

1749

01:03:24,150 --> 01:03:22,559

have their own warping of space time so

1750

01:03:25,910 --> 01:03:24,160

gravity anytime you hear about a

1751

01:03:28,549 --> 01:03:25,920

gravitational field usually when you

1752

01:03:30,789 --> 01:03:28,559

hear the term gravitational field it's

1753

01:03:33,029 --> 01:03:30,799

the metric the space-time metric in

1754

01:03:34,870 --> 01:03:33,039

general relativity however

1755

01:03:36,710 --> 01:03:34,880

technically speaking the gravitational

1756

01:03:39,190 --> 01:03:36,720

field tensor is the romanian tensor and

1757

01:03:41,109 --> 01:03:39,200

the gravitational potential is the

1758

01:03:42,710 --> 01:03:41,119

metric regardless we take a look here

1759

01:03:44,549 --> 01:03:42,720

and we say that there are different

1760

01:03:46,549 --> 01:03:44,559

warpings of space time associated with

1761

01:03:48,630 --> 01:03:46,559

each of the options so a may have some

1762

01:03:50,950 --> 01:03:48,640

warping that looks like this as you go

1763

01:03:53,190 --> 01:03:50,960

outward and then b may look like let's

1764

01:03:54,870 --> 01:03:53,200

say this and then you wonder well is

1765

01:03:56,950 --> 01:03:54,880

this the superpositions that ordinarily

1766

01:03:58,870 --> 01:03:56,960

be denoted this plus this

1767

01:04:01,029 --> 01:03:58,880

well are we to have a superposition of

1768

01:04:02,789 --> 01:04:01,039

space times what penrose is saying is

1769

01:04:04,870 --> 01:04:02,799

that once the particles are of a

1770

01:04:07,670 --> 01:04:04,880

sufficient distance from one another in

1771

01:04:09,109 --> 01:04:07,680

metric space so over here it says eg is

1772

01:04:10,950 --> 01:04:09,119

the gravitational self energy and the

1773

01:04:12,710 --> 01:04:10,960

degree of space time separation so the

1774

01:04:14,789 --> 01:04:12,720

degree of space-time separation is a bit

1775

01:04:16,390 --> 01:04:14,799

of a misnomer here what's meant is that

1776

01:04:18,549 --> 01:04:16,400

there's a symplectic measure on the

1777

01:04:20,710 --> 01:04:18,559

metric of space times and then from that

1778

01:04:22,150 --> 01:04:20,720

you assign a number to the metric of a

1779

01:04:24,230 --> 01:04:22,160

and then to the metric of b and you see

1780

01:04:26,870 --> 01:04:24,240

the difference once that difference is

1781

01:04:29,589 --> 01:04:26,880

large enough then there's a collapse so

1782

01:04:31,510 --> 01:04:29,599

this is a mechanism that merges gravity

1783

01:04:33,990 --> 01:04:31,520

as well as the quantum collapse as well

1784

01:04:36,309 --> 01:04:34,000

as consciousness so like three

1785

01:04:37,910 --> 01:04:36,319

mysteries in one there's an episode with

1786

01:04:39,430 --> 01:04:37,920

stewart hamrov if you want to see more

1787

01:04:41,829 --> 01:04:39,440

about that over here it says one

1788

01:04:44,230 --> 01:04:41,839

kilogram of an object will reach its

1789

01:04:46,150 --> 01:04:44,240

objective reduction within 10 to the

1790

01:04:47,829 --> 01:04:46,160

minus 37 seconds i believe this is

1791

01:04:49,750 --> 01:04:47,839

incorrect on wikipedia because when you

1792

01:04:51,109 --> 01:04:49,760

take a look at the reference here

1793

01:04:54,230 --> 01:04:51,119

it

1794

01:04:56,150 --> 01:04:54,240

actually doesn't make a

1795

01:04:58,069 --> 01:04:56,160

it only has one reference to kilograms

1796

01:04:59,829 --> 01:04:58,079

and it's 10 kilograms not one and then

1797

01:05:01,510 --> 01:04:59,839

it says 10 to the minus 43. so i'm

1798

01:05:04,150 --> 01:05:01,520

unsure where wikipedia gets their number

1799

01:05:05,910 --> 01:05:04,160

from and here is the better diagram that

1800

01:05:08,390 --> 01:05:05,920

i was trying to draw before of the

1801

01:05:10,150 --> 01:05:08,400

different space times and you can see

1802

01:05:11,589 --> 01:05:10,160

let's see yes that's correct there is

1803

01:05:13,589 --> 01:05:11,599

technically a sympathetic measure on the

1804

01:05:14,950 --> 01:05:13,599

space of four metrics that's right and

1805

01:05:16,789 --> 01:05:14,960

penrose is not going into extra

1806

01:05:18,870 --> 01:05:16,799

dimensions here okay so let's write down

1807

01:05:20,069 --> 01:05:18,880

that equation it's the gravitational

1808

01:05:21,430 --> 01:05:20,079

self energy

1809

01:05:25,190 --> 01:05:21,440

one over

1810

01:05:27,750 --> 01:05:25,200

\hbar is one in our context and τ

1811

01:05:30,150 --> 01:05:27,760

which is the time

1812

01:05:32,630 --> 01:05:30,160

so let me as well just write that as t

1813

01:05:36,309 --> 01:05:32,640

what is the gravitational self energy

1814

01:05:38,630 --> 01:05:36,319

one may guess naively that it is $m_1 m_2$

1815

01:05:39,670 --> 01:05:38,640

and then g over r and that would be

1816

01:05:41,589 --> 01:05:39,680

correct

1817

01:05:42,950 --> 01:05:41,599

because of this however if you look it

1818

01:05:45,430 --> 01:05:42,960

up online there's about a there's a

1819

01:05:46,870 --> 01:05:45,440

correction of about five thirds or so

1820

01:05:47,829 --> 01:05:46,880

that doesn't matter because we're using

1821

01:05:49,190 --> 01:05:47,839

this

1822

01:05:50,950 --> 01:05:49,200

then what i'm unclear about is that

1823

01:05:53,109 --> 01:05:50,960

there's still an r here so we have an

1824

01:05:54,549 --> 01:05:53,119

extra factor and i'm unsure of how he's

1825

01:05:56,230 --> 01:05:54,559

deriving

1826
01:05:58,309 --> 01:05:56,240
this number when there should be one

1827
01:06:00,309 --> 01:05:58,319
more factor to me this r should be a

1828
01:06:03,029 --> 01:06:00,319
function of t and this should be related

1829
01:06:04,630 --> 01:06:03,039
to the measure that we had here

1830
01:06:07,349 --> 01:06:04,640
i mean the measure that's generated from

1831
01:06:09,589 --> 01:06:07,359
the metrics however i'm unsure of this

1832
01:06:11,589 --> 01:06:09,599
and i'm going to be speaking to stuart

1833
01:06:13,910 --> 01:06:11,599
hameroff at the end of the summer in

1834
01:06:16,549 --> 01:06:13,920
order to verify all of this an essential

1835
01:06:18,789 --> 01:06:16,559
feature of penrose's theory is that when

1836
01:06:21,510 --> 01:06:18,799
there's a wave function collapse where

1837
01:06:24,309 --> 01:06:21,520
it collapses to is chosen neither

1838
01:06:26,309 --> 01:06:24,319

randomly nor algorithmically this is

1839

01:06:28,870 --> 01:06:26,319

outlined in his book called the

1840

01:06:30,710 --> 01:06:28,880

emperor's new mind where penrose makes

1841

01:06:33,990 --> 01:06:30,720

an analogy between something called

1842

01:06:35,829 --> 01:06:34,000

non-recursively innumerable sets and

1843

01:06:38,069 --> 01:06:35,839

truths in mathematics that can't be

1844

01:06:40,789 --> 01:06:38,079

proven yet we as

1845

01:06:42,950 --> 01:06:40,799

people as humans with minds are able to

1846

01:06:44,630 --> 01:06:42,960

see this as being true by the way if you

1847

01:06:46,630 --> 01:06:44,640

have questions about any of this you can

1848

01:06:48,069 --> 01:06:46,640

go to the discord or to the subreddit

1849

01:06:49,510 --> 01:06:48,079

people will help you there and people

1850

01:06:51,349 --> 01:06:49,520

will also be just as confused as

1851

01:06:53,029 --> 01:06:51,359

yourself and as myself and we help one

1852

01:06:54,470 --> 01:06:53,039

another out links to all of those the

1853

01:06:55,670 --> 01:06:54,480

subreddit and the discord will be in the

1854

01:06:57,029 --> 01:06:55,680

description

1855

01:07:01,670 --> 01:06:57,039

you may wonder why is it that we're

1856

01:07:03,750 --> 01:07:01,680

using one gev instead of one mev because

1857

01:07:05,670 --> 01:07:03,760

this one's the proton and this one is

1858

01:07:07,990 --> 01:07:05,680

the electron why are you prioritizing

1859

01:07:09,029 --> 01:07:08,000

the proton over the electron well it

1860

01:07:11,029 --> 01:07:09,039

just makes some of the napkin

1861

01:07:13,270 --> 01:07:11,039

calculations easier so this is all about

1862

01:07:15,109 --> 01:07:13,280

nc's napkin calculations as well as it

1863

01:07:17,109 --> 01:07:15,119

gives you a much more concrete physical

1864

01:07:18,710 --> 01:07:17,119

intuition later we'll derive the radius

1865

01:07:20,710 --> 01:07:18,720

of an atom but for now you can see that

1866

01:07:22,309 --> 01:07:20,720

this is the radius of a proton it's also

1867

01:07:24,150 --> 01:07:22,319

the energy of a proton the mass of a

1868

01:07:26,309 --> 01:07:24,160

proton which as we mentioned earlier

1869

01:07:28,789 --> 01:07:26,319

this means my desk is 10 to the 16

1870

01:07:30,309 --> 01:07:28,799

protons long if you take 10 to the 16

1871

01:07:33,510 --> 01:07:30,319

protons and stack them you get the

1872

01:07:35,829 --> 01:07:33,520

length of my desk and i said

1873

01:07:37,750 --> 01:07:35,839

desk so don't get excited okay now let's

1874

01:07:39,109 --> 01:07:37,760

get to vacuum energy

1875

01:07:41,270 --> 01:07:39,119

okay you've heard the story that the

1876

01:07:43,270 --> 01:07:41,280

universe is expanding and because it's

1877

01:07:46,069 --> 01:07:43,280

expanding it has a positive cosmological

1878

01:07:48,150 --> 01:07:46,079

constant and much fervor is expressed to

1879

01:07:49,750 --> 01:07:48,160

the disdain of the word prediction the

1880

01:07:51,910 --> 01:07:49,760

worst prediction of physics i'm sure

1881

01:07:55,109 --> 01:07:51,920

you've heard worst

1882

01:07:58,309 --> 01:07:56,630

and many people dislike this word

1883

01:08:00,470 --> 01:07:58,319

prediction because it's not as if a

1884

01:08:02,230 --> 01:08:00,480

specific theory was said to be false

1885

01:08:03,829 --> 01:08:02,240

because of this prediction however that

1886

01:08:05,910 --> 01:08:03,839

gives the impression of discounting the

1887

01:08:08,390 --> 01:08:05,920

calculation completely it wasn't a

1888

01:08:12,390 --> 01:08:08,400

prediction per se it was a compartment

1889

01:08:15,109 --> 01:08:12,400

namely if λ was to

1890

01:08:18,789 --> 01:08:16,229

with

1891

01:08:20,630 --> 01:08:18,799

the standard model

1892

01:08:22,149 --> 01:08:20,640

that is if it was to be a consequence of

1893

01:08:23,829 --> 01:08:22,159

absolute energy from the vacuum

1894

01:08:25,590 --> 01:08:23,839

fluctuations from the planck scale

1895

01:08:27,430 --> 01:08:25,600

upward then it should be of order let's

1896

01:08:29,269 --> 01:08:27,440

say x we're going to calculate that it

1897

01:08:31,189 --> 01:08:29,279

was a compartment test rather than a

1898

01:08:33,910 --> 01:08:31,199

prediction the mechanism could have been

1899

01:08:35,669 --> 01:08:33,920

the vacuum fluctuations of qed i believe

1900

01:08:37,910 --> 01:08:35,679

weinberg calculated this but it turns

1901

01:08:39,829 --> 01:08:37,920

out to be vastly vastly incorrect so

1902

01:08:43,030 --> 01:08:39,839

let's take a look there are three main

1903

01:08:43,040 --> 01:08:46,390

of vacuum energy

1904

01:08:49,829 --> 01:08:47,990

and this is just from the standard model

1905

01:08:52,470 --> 01:08:49,839

forget about general relativity so

1906

01:08:55,430 --> 01:08:52,480

number one qcd and these are these

1907

01:08:58,870 --> 01:08:55,440

little cork bilinears number two

1908

01:09:01,030 --> 01:08:58,880

it's the higgs field

1909

01:09:03,189 --> 01:09:01,040

and number three it would be the zero

1910

01:09:09,510 --> 01:09:03,199

point

1911

01:09:13,590 --> 01:09:12,709

and this one is of order 10 to the minus

1912

01:09:15,910 --> 01:09:13,600

one

1913

01:09:18,149 --> 01:09:15,920

g e v

1914

01:09:20,630 --> 01:09:18,159

and what power goes here

1915

01:09:24,070 --> 01:09:20,640

it's a pressure it's dark energy it's a

1916

01:09:25,510 --> 01:09:24,080

property of space time itself so four

1917

01:09:26,870 --> 01:09:25,520

simple

1918

01:09:30,309 --> 01:09:26,880

then what is the higgs fields

1919

01:09:32,309 --> 01:09:30,319

contribution ten squared gev

1920

01:09:34,630 --> 01:09:32,319

and what power goes here well what else

1921

01:09:36,149 --> 01:09:34,640

could it be number four

1922

01:09:38,309 --> 01:09:36,159

let's get to the calculation of the zero

1923

01:09:40,149 --> 01:09:38,319

point fluctuations what this means is

1924

01:09:41,910 --> 01:09:40,159

that at each space-time volume

1925

01:09:43,990 --> 01:09:41,920

space-time so now we're dealing with

1926

01:09:47,030 --> 01:09:44,000

four not just three volumes but i'll

1927

01:09:48,470 --> 01:09:47,040

draw it as a cube at each space-time

1928

01:09:50,550 --> 01:09:48,480

volume

1929

01:09:52,070 --> 01:09:50,560

of length let's say l

1930

01:09:54,550 --> 01:09:52,080

so l

1931

01:09:57,510 --> 01:09:54,560

cubed in this case but actually it's

1932

01:09:59,110 --> 01:09:57,520

truly l4 so let's just place

1933

01:10:01,350 --> 01:09:59,120

l4 here

1934

01:10:04,470 --> 01:10:01,360

that corresponding to this length is

1935

01:10:06,470 --> 01:10:04,480

some frequency omega the reason why is

1936

01:10:07,910 --> 01:10:06,480

that we have this relation that energy

1937

01:10:09,750 --> 01:10:07,920

is related to

1938

01:10:11,669 --> 01:10:09,760

frequency which means there's a tight

1939

01:10:13,350 --> 01:10:11,679

relationship between frequency and

1940

01:10:14,550 --> 01:10:13,360

energy you can convert between the two

1941

01:10:17,270 --> 01:10:14,560

we're going to do that later once we

1942

01:10:19,430 --> 01:10:17,280

analyze the sun from each space time

1943

01:10:22,390 --> 01:10:19,440

volume of length l there's a

1944

01:10:24,229 --> 01:10:22,400

contribution of a certain mode that

1945

01:10:26,470 --> 01:10:24,239

happens within here so let's call that

1946

01:10:28,470 --> 01:10:26,480

frequency well whatever it's omega in

1947

01:10:31,669 --> 01:10:28,480

this case so we constantly get these

1948

01:10:33,510 --> 01:10:31,679

omegas associated with length one plus

1949

01:10:34,550 --> 01:10:33,520

an omega associated with length length

1950

01:10:36,630 --> 01:10:34,560

two

1951

01:10:39,590 --> 01:10:36,640

so on and so on and because of this

1952

01:10:42,390 --> 01:10:39,600

relation here the shorter the length

1953

01:10:44,390 --> 01:10:42,400

the larger the energy firstly that means

1954

01:10:46,709 --> 01:10:44,400

that it's infinite technically the zero

1955

01:10:48,950 --> 01:10:46,719

point fluctuation yields an infinite

1956

01:10:51,270 --> 01:10:48,960

energy but that doesn't mean that it's

1957

01:10:53,030 --> 01:10:51,280

literally true it means technically it's

1958

01:10:54,070 --> 01:10:53,040

true with our theories which already

1959

01:10:57,110 --> 01:10:54,080

break down

1960

01:10:59,590 --> 01:10:57,120

planck scale this is what you've heard

1961

01:11:01,910 --> 01:10:59,600

so how about we simply cut it off at the

1962

01:11:04,470 --> 01:11:01,920

length scale so we let this be the

1963

01:11:07,830 --> 01:11:04,480

planck length which by the way is what

1964

01:11:09,510 --> 01:11:07,840

well it's the inverse of the planck mass

1965

01:11:11,590 --> 01:11:09,520

because we're taking an inverse of an

1966

01:11:15,990 --> 01:11:11,600

inverse we simply get that the energy

1967

01:11:18,709 --> 01:11:17,750

from

1968

01:11:43,430 --> 01:11:18,719

the

1969

01:11:45,910 --> 01:11:43,440

contributes this is why this nc or this

1970

01:11:48,229 --> 01:11:45,920

napkin calculation which is contingent

1971

01:11:50,709 --> 01:11:48,239

on this on the order of symbol this

1972

01:11:53,030 --> 01:11:50,719

tilde here is so vital this is what

1973

01:11:55,669 --> 01:11:53,040

allows you to do this quickly without

1974

01:11:58,630 --> 01:11:55,679

thinking eventually

1975

01:12:01,910 --> 01:11:58,640

this gives an nc of what a napkin

1976

01:12:03,750 --> 01:12:01,920

calculation of 10 to the 18

1977

01:12:05,030 --> 01:12:03,760

g e v

1978

01:12:07,350 --> 01:12:05,040

to the fourth

1979

01:12:10,470 --> 01:12:07,360

well this should be that and then that

1980

01:12:18,790 --> 01:12:10,480

means that this is 10 to the 72

1981

01:12:22,390 --> 01:12:20,149

what's observed is what you can get

1982

01:12:24,630 --> 01:12:22,400

online because this is what's calculated

1983

01:12:26,390 --> 01:12:24,640

by data

1984

01:12:27,910 --> 01:12:26,400

you'll see these strange units and then

1985

01:12:30,149 --> 01:12:27,920

you'll have to look up on some other

1986

01:12:31,669 --> 01:12:30,159

conversion site so for example let's

1987

01:12:34,229 --> 01:12:31,679

take a look here

1988

01:12:35,590 --> 01:12:34,239

here's some conversion table

1989

01:12:38,310 --> 01:12:35,600

you can find online they've set the

1990

01:12:40,229 --> 01:12:38,320

boltzmann constant to one as well

1991

01:12:41,350 --> 01:12:40,239

and here's another one

1992

01:12:43,030 --> 01:12:41,360

i'll leave these links in the

1993

01:12:45,030 --> 01:12:43,040

description because these can be helpful

1994

01:12:47,510 --> 01:12:45,040

you'll notice that some of them differ

1995

01:12:49,350 --> 01:12:47,520

at the last digits and the reason is

1996

01:12:51,189 --> 01:12:49,360

again i mentioned this some places round

1997

01:12:52,790 --> 01:12:51,199

up some places round down

1998

01:12:58,470 --> 01:12:52,800

this then becomes

1999

01:13:02,709 --> 01:13:00,630

to the 4. you may wonder why am i not

2000

01:13:04,790 --> 01:13:02,719

placing square brackets here well you

2001

01:13:06,950 --> 01:13:04,800

can it doesn't matter because you know

2002

01:13:08,550 --> 01:13:06,960

that this is the only unit anyway

2003

01:13:10,550 --> 01:13:08,560

you may wonder well where does this

2004

01:13:11,990 --> 01:13:10,560

observation come from like i mentioned

2005

01:13:15,030 --> 01:13:12,000

people look at data and then they have

2006

01:13:16,709 --> 01:13:15,040

some assumptions like homogeneity and an

2007

01:13:18,550 --> 01:13:16,719

isotropic universe and then you get the

2008

01:13:20,470 --> 01:13:18,560

friedman equations which you can look up

2009

01:13:22,470 --> 01:13:20,480

which relates the acceleration to the

2010

01:13:25,110 --> 01:13:22,480

cosmological constant and thus the

2011

01:13:28,149 --> 01:13:25,120

pressure and density

2012

01:13:31,350 --> 01:13:28,159

the above then yields slash implies that

2013

01:13:34,070 --> 01:13:31,360

our napkin calculation is the same as

2014

01:13:37,910 --> 01:13:34,080

the observed

2015

01:13:40,149 --> 01:13:37,920

times 10 to the 120

2016

01:13:43,270 --> 01:13:40,159

and now you know about the vacuum energy

2017

01:13:46,709 --> 01:13:44,870

now let's get on to calculating with the

2018

01:13:48,870 --> 01:13:46,719

swinger limit if you watched the

2019

01:13:51,110 --> 01:13:48,880

salvator pius interview you'll notice

2020

01:13:53,350 --> 01:13:51,120

that one coulomb of charge was brought

2021

01:13:55,270 --> 01:13:53,360

up so firstly let's talk about what is

2022

01:13:58,630 --> 01:13:55,280

one coulomb of charge let's get a handle

2023

01:13:59,990 --> 01:13:58,640

on it let's go to wikipedia our friend

2024

01:14:02,229 --> 01:14:00,000

we take a look and we see that the

2025

01:14:04,870 --> 01:14:02,239

elementary charge was assigned to this

2026

01:14:08,390 --> 01:14:04,880

exact value in 2019. so this is the

2027

01:14:10,070 --> 01:14:08,400

exact value of one elementary charge it

2028

01:14:12,470 --> 01:14:10,080

turns out that elementary charge is a

2029

01:14:15,430 --> 01:14:12,480

dimensionless quantity let's write this

2030

01:14:17,350 --> 01:14:15,440

down here

2031

01:14:20,229 --> 01:14:17,360

elementary charge

2032

01:14:24,310 --> 01:14:20,239

is on the order of 10 to the minus 19

2033

01:14:28,470 --> 01:14:26,149

this means that one coulomb which i'm

2034

01:14:32,310 --> 01:14:28,480

going to denote as c

2035

01:14:34,550 --> 01:14:32,320

1 coulomb is the same as 10 to the 19

2036

01:14:38,070 --> 01:14:34,560

charges

2037

01:14:40,070 --> 01:14:38,080

they're the same they're just the

2038

01:14:42,870 --> 01:14:40,080

reverse of one another plus or minus

2039

01:14:47,830 --> 01:14:42,880

let's deal with protons 10 to the 19

2040

01:14:49,750 --> 01:14:47,840

protons that's 10 to the 19 g e v

2041

01:14:52,550 --> 01:14:49,760

let's get a handle on that number if we

2042

01:14:55,189 --> 01:14:52,560

were to stack protons one after the

2043

01:15:02,709 --> 01:14:58,709

10 to the 19 times

2044

01:15:04,149 --> 01:15:02,719

then going up to our conversion chart

2045

01:15:10,630 --> 01:15:04,159

that is

2046

01:15:14,630 --> 01:15:12,870

that's the definition of one kilometer

2047

01:15:16,229 --> 01:15:14,640

that means if you were to take protons

2048

01:15:18,709 --> 01:15:16,239

and stack them stack them stack them

2049

01:15:21,110 --> 01:15:18,719

without any gap in between it would be a

2050

01:15:22,950 --> 01:15:21,120

strip of one proton wide and then one

2051

01:15:25,110 --> 01:15:22,960

kilometer high

2052

01:15:26,550 --> 01:15:25,120

that's an extreme amount of charge great

2053

01:15:28,390 --> 01:15:26,560

now we've gotten out of the way what is

2054

01:15:29,750 --> 01:15:28,400

one coulomb let's get to the schwinger

2055

01:15:33,189 --> 01:15:29,760

limit

2056

01:15:35,590 --> 01:15:33,199

scale above which the electromagnetic

2057

01:15:37,270 --> 01:15:35,600

field is expected to become non-linear

2058

01:15:38,470 --> 01:15:37,280

so we haven't observed this because this

2059

01:15:39,910 --> 01:15:38,480

is an extreme amount we're going to

2060

01:15:42,470 --> 01:15:39,920

actually deal with what the heck does

2061

01:15:44,470 --> 01:15:42,480

this mean in our manageable units

2062

01:15:46,709 --> 01:15:44,480

the limit is typically reported as some

2063

01:15:49,270 --> 01:15:46,719

maximum electric field or magnetic field

2064

01:15:50,630 --> 01:15:49,280

before some non-linear effects kick in

2065

01:15:53,430 --> 01:15:50,640

if we take a look here we see this

2066

01:15:55,030 --> 01:15:53,440

firstly let's just analyze this

2067

01:15:57,430 --> 01:15:55,040

we notice there's a c we notice there's

2068

01:15:59,350 --> 01:15:57,440

an \hbar we set those to one that means

2069

01:16:01,030 --> 01:15:59,360

that all that's left over is mass over

2070

01:16:03,270 --> 01:16:01,040

charge charge is dimensionless mass

2071

01:16:05,510 --> 01:16:03,280

squared that means energy squared that

2072

01:16:06,950 --> 01:16:05,520

means that this is energy squared this

2073

01:16:08,790 --> 01:16:06,960

is a force

2074

01:16:11,350 --> 01:16:08,800

and then this has the same units this is

2075

01:16:13,830 --> 01:16:11,360

also a force so tesla has the units of

2076

01:16:15,830 --> 01:16:13,840

force energy squared e has this volts

2077

01:16:17,510 --> 01:16:15,840

over meter has the unit's energy squared

2078

01:16:19,430 --> 01:16:17,520

you can get that right now just by

2079

01:16:23,350 --> 01:16:19,440

looking at this for three seconds

2080

01:16:27,990 --> 01:16:24,709

so e is

2081

01:16:30,950 --> 01:16:28,000

on the order of 10 to the 18 volts per

2082

01:16:32,229 --> 01:16:30,960

meter this is also as defined here m e

2083

01:16:35,510 --> 01:16:32,239

squared c

2084

01:16:39,189 --> 01:16:35,520

to the 3 over h bar the charge of the

2085

01:16:41,270 --> 01:16:39,199

electron that is in our units m e so the

2086

01:16:43,910 --> 01:16:41,280

mass of the electron those become one

2087

01:16:45,669 --> 01:16:43,920

this becomes one and then we get this

2088

01:16:48,149 --> 01:16:45,679

now the charge of the electron is just

2089

01:16:50,149 --> 01:16:48,159

one let's get a handle on this number so

2090

01:16:53,270 --> 01:16:50,159

firstly what is a volt we don't have to

2091

01:16:55,030 --> 01:16:53,280

do much work because a volt

2092

01:16:58,470 --> 01:16:55,040

well a gev

2093

01:17:00,390 --> 01:16:58,480

is 10 to the 9 volts and that means so

2094

01:17:02,550 --> 01:17:00,400

we can just take 9 from inside there and

2095

01:17:06,149 --> 01:17:02,560

it becomes ten to the nine so nine plus

2096

01:17:07,510 --> 01:17:06,159

nine g e v over meters and then we can

2097

01:17:08,470 --> 01:17:07,520

go up

2098

01:17:09,669 --> 01:17:08,480

stairs

2099

01:17:13,189 --> 01:17:09,679

to

2100

01:17:16,310 --> 01:17:13,199

16.

2101

01:17:18,950 --> 01:17:16,320

using our formula from above we get that

2102

01:17:20,870 --> 01:17:18,960

a meter is this and i will just put some

2103

01:17:22,950 --> 01:17:20,880

clouds around this

2104

01:17:25,110 --> 01:17:22,960

as well

2105

01:17:27,430 --> 01:17:25,120

because we have an inverse meter here we

2106

01:17:30,070 --> 01:17:27,440

take the inverses of this so we take one

2107

01:17:31,910 --> 01:17:30,080

here minus and plus that becomes a plus

2108

01:17:34,709 --> 01:17:31,920

one this then implies that we take the

2109

01:17:38,630 --> 01:17:34,719

nine we plus 16 to it so we get 10 to

2110

01:17:40,470 --> 01:17:38,640

the 25 gev

2111

01:17:42,470 --> 01:17:40,480

squared this is by the way a unit of

2112

01:17:44,470 --> 01:17:42,480

force like we mentioned before

2113

01:17:46,790 --> 01:17:44,480

ah and those again who have watched the

2114

01:17:49,110 --> 01:17:46,800

salvator pius interview you know that he

2115

01:17:50,550 --> 01:17:49,120

mentions the super force and what the

2116

01:17:51,270 --> 01:17:50,560

super force is

2117

01:17:55,270 --> 01:17:51,280

is

2118

01:17:57,030 --> 01:17:55,280

it's simply the planck force

2119

01:17:58,870 --> 01:17:57,040

now you should have more of an intuition

2120

01:17:59,510 --> 01:17:58,880

as to what this actually means so this

2121

01:18:04,630 --> 01:17:59,520

is

2122

01:18:08,229 --> 01:18:04,640

we've calculated before the square of

2123

01:18:11,590 --> 01:18:09,669

and you can see that makes sense in

2124

01:18:13,030 --> 01:18:11,600

terms of units because mass squared is

2125

01:18:15,510 --> 01:18:13,040

the same as energy squared is the same

2126

01:18:17,189 --> 01:18:15,520

as force now as i've mentioned before i

2127

01:18:19,510 --> 01:18:17,199

don't think force is a particularly

2128

01:18:21,750 --> 01:18:19,520

useful concept in fundamental physics i

2129

01:18:23,270 --> 01:18:21,760

think pressure is so there should be a

2130

01:18:23,990 --> 01:18:23,280

planck pressure

2131

01:18:27,110 --> 01:18:24,000

and

2132

01:18:28,310 --> 01:18:27,120

plank density i call it the plank

2133

01:18:30,229 --> 01:18:28,320

pressure it doesn't seem like anyone

2134

01:18:32,070 --> 01:18:30,239

else calls it that but anyway how do you

2135

01:18:34,310 --> 01:18:32,080

get the plank pressure well you take

2136

01:18:35,750 --> 01:18:34,320

some energy and you divide it by volume

2137

01:18:37,910 --> 01:18:35,760

what's the energy that we have we have

2138

01:18:40,149 --> 01:18:37,920

the mass the plank mass and we divide it

2139

01:18:42,709 --> 01:18:40,159

by some volume what's the volume that we

2140

01:18:44,550 --> 01:18:42,719

have we have the plank length and we

2141

01:18:45,910 --> 01:18:44,560

just cube that

2142

01:18:47,350 --> 01:18:45,920

and that's how you derive the plank

2143

01:18:48,870 --> 01:18:47,360

pressure at least that's what i think it

2144

01:18:51,189 --> 01:18:48,880

should be called now at first i was

2145

01:18:53,110 --> 01:18:51,199

going to draw some picture to give some

2146

01:18:55,350 --> 01:18:53,120

interesting ideas to what the schwinger

2147

01:18:57,189 --> 01:18:55,360

limit is in some fundamental manner but

2148

01:18:59,270 --> 01:18:57,199

actually force isn't

2149

01:19:01,189 --> 01:18:59,280

a particularly interesting

2150

01:19:03,669 --> 01:19:01,199

concept because it requires extra

2151
01:19:05,510 --> 01:19:03,679
structure so for example we know that we

2152
01:19:07,669 --> 01:19:05,520
have these inverse squared laws that

2153
01:19:10,709 --> 01:19:07,679
characterize the coulomb force and

2154
01:19:12,709 --> 01:19:10,719
gravity which technically means that you

2155
01:19:14,709 --> 01:19:12,719
can get however

2156
01:19:17,350 --> 01:19:14,719
large of a force you'd like depending on

2157
01:19:18,790 --> 01:19:17,360
how close you are to the original source

2158
01:19:22,870 --> 01:19:18,800
to the point source if it's a point

2159
01:19:25,990 --> 01:19:22,880
source this to me demonstrates a flaw

2160
01:19:28,950 --> 01:19:26,000
in newtonian mechanics from the get-go

2161
01:19:31,270 --> 01:19:28,960
and yet it works so well thus if a

2162
01:19:33,270 --> 01:19:31,280
particular theory has a major flaw

2163
01:19:37,189 --> 01:19:33,280

perhaps give it a chance to breathe

2164

01:19:40,550 --> 01:19:37,199

before dismissing it as patently broken

2165

01:19:42,630 --> 01:19:40,560

see all of this is decidedly simple and

2166

01:19:44,790 --> 01:19:42,640

often you'll be confused but not know

2167

01:19:46,790 --> 01:19:44,800

where your confusion is often what will

2168

01:19:48,470 --> 01:19:46,800

happen is you'll ask someone to explain

2169

01:19:50,390 --> 01:19:48,480

or re-explain some phenomenon or some

2170

01:19:51,669 --> 01:19:50,400

mathematical trick and then they'll say

2171

01:19:53,270 --> 01:19:51,679

well what part of it did you not

2172

01:19:55,270 --> 01:19:53,280

understand and you won't be able to give

2173

01:19:57,030 --> 01:19:55,280

an account because your confusion is

2174

01:19:59,189 --> 01:19:57,040

such that you're unable to see where

2175

01:20:00,950 --> 01:19:59,199

your confusion is that is to say you

2176
01:20:02,870 --> 01:20:00,960
don't know the aspects of the technique

2177
01:20:05,430 --> 01:20:02,880
or the mathematical trick or formula or

2178
01:20:06,870 --> 01:20:05,440
structure etc that you don't understand

2179
01:20:08,709 --> 01:20:06,880
so asking someone to explain a

2180
01:20:09,669 --> 01:20:08,719
particular part because you just chose

2181
01:20:11,350 --> 01:20:09,679
in some part and you say i don't

2182
01:20:12,470 --> 01:20:11,360
understand this somewhat fruitless

2183
01:20:14,550 --> 01:20:12,480
because that was

2184
01:20:16,149 --> 01:20:14,560
arbitrarily chosen by you this is one of

2185
01:20:18,310 --> 01:20:16,159
the reasons why it's great to read from

2186
01:20:20,149 --> 01:20:18,320
multiple sources so watch multiple

2187
01:20:22,070 --> 01:20:20,159
videos on the same phenomenon the same

2188
01:20:23,110 --> 01:20:22,080

trick the same formula you'll see

2189

01:20:24,229 --> 01:20:23,120

professors when they're being

2190

01:20:25,990 --> 01:20:24,239

interviewed or when you go to their

2191

01:20:27,830 --> 01:20:26,000

office they'll often have

2192

01:20:29,270 --> 01:20:27,840

a plethora of books and then you think

2193

01:20:30,470 --> 01:20:29,280

well they're extremely bright and they

2194

01:20:32,550 --> 01:20:30,480

are they're extremely extremely

2195

01:20:33,669 --> 01:20:32,560

extremely bright hardworking people but

2196

01:20:35,590 --> 01:20:33,679

then you wonder why do you have five

2197

01:20:37,590 --> 01:20:35,600

books on linear algebra and it's because

2198

01:20:39,350 --> 01:20:37,600

even ed whitson needs to read from

2199

01:20:41,430 --> 01:20:39,360

multiple sources on the same topic in

2200

01:20:43,189 --> 01:20:41,440

order to truly understand it you need to

2201

01:20:44,870 --> 01:20:43,199

see it from multiple perspectives

2202

01:20:46,550 --> 01:20:44,880

actually i spoke to jordan peterson

2203

01:20:48,470 --> 01:20:46,560

about this exact topic i'll leave the

2204

01:20:50,550 --> 01:20:48,480

podcast in the description so if you

2205

01:20:52,149 --> 01:20:50,560

feel like some concept is far beyond you

2206

01:20:53,750 --> 01:20:52,159

perhaps it's not perhaps you need to

2207

01:20:55,750 --> 01:20:53,760

re-watch the video so you can re-watch

2208

01:20:57,669 --> 01:20:55,760

this one if you like or you can watch

2209

01:20:59,430 --> 01:20:57,679

from multiple sources and then it will

2210

01:21:01,830 --> 01:20:59,440

slowly start to make sense you'll start

2211

01:21:03,590 --> 01:21:01,840

to see this baroque intricate complex

2212

01:21:05,510 --> 01:21:03,600

object from multiple perspectives you

2213

01:21:07,350 --> 01:21:05,520

can only see a projection of it and then

2214

01:21:08,790 --> 01:21:07,360

you start to build a shape of it seeing

2215

01:21:10,950 --> 01:21:08,800

it from one source generally doesn't

2216

01:21:12,709 --> 01:21:10,960

help to sum up learn from multiple

2217

01:21:14,550 --> 01:21:12,719

sources read multiple sources watch

2218

01:21:15,990 --> 01:21:14,560

multiple sources sometimes you don't

2219

01:21:17,669 --> 01:21:16,000

need to know where your confusion is

2220

01:21:18,870 --> 01:21:17,679

because at least you don't consciously

2221

01:21:20,870 --> 01:21:18,880

need to know because it will

2222

01:21:23,590 --> 01:21:20,880

unconsciously resolve itself after

2223

01:21:25,990 --> 01:21:23,600

learning from different perspectives

2224

01:21:28,709 --> 01:21:26,000

okay now let's get to number eight which

2225

01:21:30,310 --> 01:21:28,719

is annihilating positron electron pairs

2226

01:21:31,430 --> 01:21:30,320

and quantum gravity we got to get

2227

01:21:33,030 --> 01:21:31,440

through this quick i'm likely going to

2228

01:21:34,790 --> 01:21:33,040

turn this screen off i'm making way too

2229

01:21:36,470 --> 01:21:34,800

many mistakes i'm recording this over

2230

01:21:37,830 --> 01:21:36,480

and over and different parts aren't

2231

01:21:39,750 --> 01:21:37,840

working so

2232

01:21:41,270 --> 01:21:39,760

if there are any errors here obviously

2233

01:21:43,110 --> 01:21:41,280

leave them in the comments it's great if

2234

01:21:45,110 --> 01:21:43,120

you unceremoniously point them out i

2235

01:21:47,030 --> 01:21:45,120

don't mind i'll highlight them

2236

01:21:49,110 --> 01:21:47,040

annihilating pairs of positron electrons

2237

01:21:51,030 --> 01:21:49,120

and quantum gravity so firstly what

2238

01:21:52,390 --> 01:21:51,040

happens when you look at the vacuum

2239

01:21:55,189 --> 01:21:52,400

simply look

2240

01:21:57,430 --> 01:21:55,199

well we know this relation which is e is

2241

01:21:58,870 --> 01:21:57,440

the inverse of time

2242

01:22:01,189 --> 01:21:58,880

and let's imagine that we wanted to

2243

01:22:03,590 --> 01:22:01,199

create particles that were

2244

01:22:05,990 --> 01:22:03,600

on the order of an electron so electron

2245

01:22:08,070 --> 01:22:06,000

positron then we just replace this e

2246

01:22:09,910 --> 01:22:08,080

with the mass of an electron technically

2247

01:22:15,189 --> 01:22:09,920

it's two but it doesn't matter because

2248

01:22:18,950 --> 01:22:17,750

this means that for a small amount of

2249

01:22:21,510 --> 01:22:18,960

time

2250

01:22:23,669 --> 01:22:21,520

an electron positron pair can be created

2251

01:22:25,990 --> 01:22:23,679

and then you can also ask this is a unit

2252

01:22:28,310 --> 01:22:26,000

of length which means that if you were

2253

01:22:30,390 --> 01:22:28,320

to probe the vacuum if you were to look

2254

01:22:32,629 --> 01:22:30,400

close enough and exactly how close

2255

01:22:36,629 --> 01:22:32,639

enough well what is m e m e remember

2256

01:22:39,750 --> 01:22:36,639

it's akin to 1 mev which is the same as

2257

01:22:42,070 --> 01:22:39,760

10 to the minus 3 g e v

2258

01:22:44,550 --> 01:22:42,080

this means looking at empty space itself

2259

01:22:47,350 --> 01:22:44,560

if you look close enough just the act of

2260

01:22:49,430 --> 01:22:47,360

looking close enough will create the

2261

01:22:50,870 --> 01:22:49,440

electron positron pairs now this is

2262

01:22:52,310 --> 01:22:50,880

something you know from quantum field

2263

01:22:54,550 --> 01:22:52,320

theory and by the way when people say

2264

01:22:56,229 --> 01:22:54,560

quantum field theory there's not the

2265

01:22:58,070 --> 01:22:56,239

quantum field theory there are multiple

2266

01:22:59,590 --> 01:22:58,080

it's it's more like a framework so

2267

01:23:01,830 --> 01:22:59,600

there's five four and then there are

2268

01:23:03,590 --> 01:23:01,840

different well string theory itself can

2269

01:23:05,990 --> 01:23:03,600

be thought of as a generalization of

2270

01:23:07,590 --> 01:23:06,000

quantum field theory so when people say

2271

01:23:09,110 --> 01:23:07,600

quantum field theory you should ask them

2272

01:23:10,629 --> 01:23:09,120

well which quantum field theory are you

2273

01:23:12,470 --> 01:23:10,639

referring to now let's talk about

2274

01:23:14,229 --> 01:23:12,480

quantum gravity forget about field

2275

01:23:16,070 --> 01:23:14,239

theory when it comes to quantum gravity

2276

01:23:25,430 --> 01:23:16,080

there are several conceptual infinities

2277

01:23:28,310 --> 01:23:26,790

so firstly if you're going to be

2278

01:23:30,470 --> 01:23:28,320

infinitely accurate about let's say

2279

01:23:32,550 --> 01:23:30,480

where an electron is you have to measure

2280

01:23:33,990 --> 01:23:32,560

it an infinite amount of time or prepare

2281

01:23:35,510 --> 01:23:34,000

something and then measure that in

2282

01:23:37,750 --> 01:23:35,520

infinite amount of time because there's

2283

01:23:39,430 --> 01:23:37,760

an error an uncertainty associated with

2284

01:23:41,110 --> 01:23:39,440

the measurement and then another

2285

01:23:43,430 --> 01:23:41,120

infinity comes in when you're having to

2286

01:23:44,709 --> 01:23:43,440

store all of those bits somewhere and

2287

01:23:47,189 --> 01:23:44,719

then you also need to make your

2288

01:23:48,390 --> 01:23:47,199

apparatus size infinitely large because

2289

01:23:50,790 --> 01:23:48,400

you want to make sure that there's no

2290

01:23:52,550 --> 01:23:50,800

quantum fluctuations that make an error

2291

01:23:54,550 --> 01:23:52,560

in one of your bits as well as well

2292

01:23:56,870 --> 01:23:54,560

decoherence etc so there are many

2293

01:23:59,189 --> 01:23:56,880

antinomies that crop up which imply that

2294

01:24:01,910 --> 01:23:59,199

however we're ordinarily viewing our

2295

01:24:03,669 --> 01:24:01,920

laws or viewing space time it must be

2296

01:24:05,590 --> 01:24:03,679

some approximation

2297

01:24:07,830 --> 01:24:05,600

also interestingly enough when it comes

2298

01:24:09,430 --> 01:24:07,840

to higher energies it doesn't mean lower

2299

01:24:11,590 --> 01:24:09,440

distances when it comes to quantum

2300

01:24:13,750 --> 01:24:11,600

gravity ordinarily we think well you

2301
01:24:15,990 --> 01:24:13,760
just place in plenty of energy to probe

2302
01:24:17,910 --> 01:24:16,000
a smaller and smaller distance well

2303
01:24:25,189 --> 01:24:17,920
that's true except at some point you

2304
01:24:28,470 --> 01:24:26,950
that is to say if you want to measure a

2305
01:24:30,070 --> 01:24:28,480
small distance while you put in more

2306
01:24:31,350 --> 01:24:30,080
energy but if you want to measure an

2307
01:24:33,430 --> 01:24:31,360
even smaller distance you put in more

2308
01:24:34,950 --> 01:24:33,440
energy at some point you just create a

2309
01:24:37,110 --> 01:24:34,960
black hole and then the more energy you

2310
01:24:39,750 --> 01:24:37,120
put in the larger the radius of the

2311
01:24:42,070 --> 01:24:39,760
black hole so at some point larger

2312
01:24:44,149 --> 01:24:42,080
energy actually means larger distance

2313
01:24:46,310 --> 01:24:44,159

and then even more fundamental than that

2314

01:24:48,870 --> 01:24:46,320

the black hole will start to evaporate

2315

01:24:51,030 --> 01:24:48,880

and let out hawking radiation which is

2316

01:24:53,350 --> 01:24:51,040

low energy particles even though what

2317

01:24:55,510 --> 01:24:53,360

you inputted was high energy particles

2318

01:24:57,669 --> 01:24:55,520

so you get a strange intermingling of

2319

01:24:59,430 --> 01:24:57,679

high and low and the reversal of it from

2320

01:25:01,590 --> 01:24:59,440

what you'd expect from our ordinary

2321

01:25:04,229 --> 01:25:01,600

calculations okay now let's talk about

2322

01:25:07,189 --> 01:25:04,239

black holes so how much density is

2323

01:25:08,550 --> 01:25:07,199

required to create a black hole turns

2324

01:25:10,709 --> 01:25:08,560

out that's an ill-defined question

2325

01:25:12,310 --> 01:25:10,719

because we need to pick a test mass much

2326

01:25:14,709 --> 01:25:12,320

like with gravity and the coupling

2327

01:25:16,229 --> 01:25:14,719

constant it's dependent upon mass same

2328

01:25:18,629 --> 01:25:16,239

with black holes you can get whatever

2329

01:25:21,030 --> 01:25:18,639

density you like so let's just choose a

2330

01:25:23,990 --> 01:25:21,040

mass and then ask a different question

2331

01:25:25,830 --> 01:25:24,000

how small of a region what is the radius

2332

01:25:27,830 --> 01:25:25,840

called the schwarzschild radius what is

2333

01:25:29,750 --> 01:25:27,840

the radius that we can take this mass

2334

01:25:31,750 --> 01:25:29,760

and squeeze it into such that it will

2335

01:25:33,990 --> 01:25:31,760

produce a black hole i'm going to call

2336

01:25:35,910 --> 01:25:34,000

this schwarzschild radius capital r

2337

01:25:38,070 --> 01:25:35,920

and first we need to choose a mass so

2338

01:25:40,470 --> 01:25:38,080

let's choose a copacetic one perhaps the

2339

01:25:42,390 --> 01:25:40,480

plank mass and then think well what

2340

01:25:44,470 --> 01:25:42,400

region of space how small do we have to

2341

01:25:46,390 --> 01:25:44,480

squeeze the plank mass to create a black

2342

01:25:48,870 --> 01:25:46,400

hole we'll do this in a variety of ways

2343

01:25:51,350 --> 01:25:48,880

number one naively it's simple the

2344

01:25:53,750 --> 01:25:51,360

standard physics folklore says what we

2345

01:25:55,510 --> 01:25:53,760

do is we take a plank mass and we stuff

2346

01:25:57,750 --> 01:25:55,520

it into a plank length and that creates

2347

01:25:59,750 --> 01:25:57,760

a black hole then we wonder well what is

2348

01:26:03,830 --> 01:25:59,760

a plank length what's a plank length but

2349

01:26:06,470 --> 01:26:05,030

so let's say

2350

01:26:07,430 --> 01:26:06,480

plank length

2351

01:26:09,750 --> 01:26:07,440

is

2352

01:26:11,510 --> 01:26:09,760

inverse planck mass

2353

01:26:14,229 --> 01:26:11,520

we've used this answer many times and

2354

01:26:16,149 --> 01:26:14,239

we're done that's the answer in one line

2355

01:26:18,709 --> 01:26:16,159

we've derived the schwarzschild radius

2356

01:26:20,470 --> 01:26:18,719

of a mass flank of a planck mass another

2357

01:26:22,709 --> 01:26:20,480

way of calculating this again this is

2358

01:26:24,950 --> 01:26:22,719

also naive is to think okay what does it

2359

01:26:27,270 --> 01:26:24,960

involve it involves gravity so newton's

2360

01:26:29,750 --> 01:26:27,280

constant and it involves some mass let's

2361

01:26:32,870 --> 01:26:29,760

give it a variable name for now mu so it

2362

01:26:34,390 --> 01:26:32,880

involves g and it involves mu

2363

01:26:36,629 --> 01:26:34,400

which is a mass

2364

01:26:39,110 --> 01:26:36,639

we then use these quantities to come up

2365

01:26:41,430 --> 01:26:39,120

with a radius which is length now how do

2366

01:26:43,990 --> 01:26:41,440

we combine g and μ so

2367

01:26:48,310 --> 01:26:44,000

newton and a mass to make the units

2368

01:26:50,310 --> 01:26:48,320

match up well it's as simple as

2369

01:26:52,550 --> 01:26:50,320

combining it in this manner because

2370

01:26:54,470 --> 01:26:52,560

recall this is of units inverse mass

2371

01:26:56,790 --> 01:26:54,480

squared and this is of unit's mass and

2372

01:26:58,870 --> 01:26:56,800

so we have an inverse mass in total and

2373

01:27:01,030 --> 01:26:58,880

this is an inverse mass unit as well

2374

01:27:02,550 --> 01:27:01,040

keep in mind that there are no alphas

2375

01:27:05,030 --> 01:27:02,560

here and the reason is that we're not

2376

01:27:06,790 --> 01:27:05,040
referencing electric charge at all

2377

01:27:09,430 --> 01:27:06,800
now we know that g

2378

01:27:14,229 --> 01:27:11,669
mass planck squared inverse

2379

01:27:17,030 --> 01:27:14,239
and we know that we can set μ in this

2380

01:27:20,070 --> 01:27:17,040
case to be mass planck and then we

2381

01:27:22,390 --> 01:27:20,080
recover the same formula let's do

2382

01:27:24,629 --> 01:27:22,400
another naive calculation what would the

2383

01:27:27,110 --> 01:27:24,639
density of such a black hole be we know

2384

01:27:29,270 --> 01:27:27,120
that it only involves the planck mass

2385

01:27:31,189 --> 01:27:29,280
and we know the units of density and so

2386

01:27:33,750 --> 01:27:31,199
we would imagine that the density would

2387

01:27:35,350 --> 01:27:33,760
be mass length to the fourth and that's

2388

01:27:37,189 --> 01:27:35,360

actually correct

2389

01:27:39,430 --> 01:27:37,199

and then for a final way of calculating

2390

01:27:41,430 --> 01:27:39,440

this we go to wikipedia

2391

01:27:43,189 --> 01:27:41,440

what is the schwarzschild radius and we

2392

01:27:44,149 --> 01:27:43,199

see that it is

2393

01:28:00,229 --> 01:27:44,159

r

2394

01:28:02,709 --> 01:28:00,239

which you'll notice is the exact same as

2395

01:28:04,390 --> 01:28:02,719

this formula that we have here except we

2396

01:28:05,830 --> 01:28:04,400

just called it mu and they called it

2397

01:28:08,229 --> 01:28:05,840

capital m

2398

01:28:11,030 --> 01:28:08,239

note one needs to be a bit prudent here

2399

01:28:12,790 --> 01:28:11,040

because the volume inside a horizon is

2400

01:28:14,709 --> 01:28:12,800

dependent on the coordinate system and

2401

01:28:16,310 --> 01:28:14,719

so the densities are also dependent on

2402

01:28:17,990 --> 01:28:16,320

the observer

2403

01:28:20,950 --> 01:28:18,000

if you don't have a lesson on this then

2404

01:28:22,390 --> 01:28:20,960

it will appear as if this is magic or

2405

01:28:24,550 --> 01:28:22,400

that it requires years and years of

2406

01:28:27,189 --> 01:28:24,560

training but it's not either of those

2407

01:28:29,910 --> 01:28:27,199

two the popularizers of science have an

2408

01:28:33,189 --> 01:28:29,920

incentive to mystify these subjects for

2409

01:28:35,350 --> 01:28:33,199

you unless you're in the universities

2410

01:28:36,470 --> 01:28:35,360

however it's fairly effortless if it's

2411

01:28:38,870 --> 01:28:36,480

explained

2412

01:28:41,189 --> 01:28:38,880

by belaboring these technical details

2413

01:28:42,950 --> 01:28:41,199

and being extremely precise now you may

2414

01:28:45,830 --> 01:28:42,960

also say hey kurt well i could have come

2415

01:28:49,030 --> 01:28:45,840

up with any first attempt at a formula g

2416

01:28:51,350 --> 01:28:49,040

to the power of 5 and m to the power of

2417

01:28:53,430 --> 01:28:51,360

2 and so on and so on

2418

01:28:55,430 --> 01:28:53,440

or square root of so on and so on and

2419

01:28:57,270 --> 01:28:55,440

yes that's correct which is why it

2420

01:29:00,149 --> 01:28:57,280

requires a certain amount of physical

2421

01:29:01,990 --> 01:29:00,159

intuition as well however in this case

2422

01:29:04,229 --> 01:29:02,000

the dimensional analysis would make all

2423

01:29:05,910 --> 01:29:04,239

of this trivial because you have to have

2424

01:29:07,669 --> 01:29:05,920

inverse square mass as the left and the

2425

01:29:09,350 --> 01:29:07,679

right side dimension anyway the left

2426

01:29:11,110 --> 01:29:09,360

hand side of the radius the short style

2427

01:29:12,550 --> 01:29:11,120

radius which is a length has to match

2428

01:29:14,470 --> 01:29:12,560

with whatever the units are on the right

2429

01:29:16,550 --> 01:29:14,480

hand side which severely limits the

2430

01:29:18,149 --> 01:29:16,560

amount of formulas you can generate

2431

01:29:20,629 --> 01:29:18,159

also keep in mind that some of these

2432

01:29:23,430 --> 01:29:20,639

formula depend on the fact that we're in

2433

01:29:26,790 --> 01:29:23,440

fairly low dimensions where in

2434

01:29:28,149 --> 01:29:26,800

let's say dim of our manifold is four

2435

01:29:30,390 --> 01:29:28,159

well it's

2436

01:29:32,470 --> 01:29:30,400

three plus one so that's space

2437

01:29:34,790 --> 01:29:32,480

that's when we're calculating the

2438

01:29:36,950 --> 01:29:34,800

density of a neutron star and we said

2439

01:29:38,950 --> 01:29:36,960

hey what we do is we look to our left

2440

01:29:40,950 --> 01:29:38,960

look up look down look look toward and

2441

01:29:42,470 --> 01:29:40,960

backward and all we see are neutrons and

2442

01:29:44,149 --> 01:29:42,480

thus we get

2443

01:29:46,550 --> 01:29:44,159

gev

2444

01:29:49,350 --> 01:29:46,560

to the fourth this actually depends on

2445

01:29:51,030 --> 01:29:49,360

sphere packing because the atoms act

2446

01:29:52,950 --> 01:29:51,040

like spheres and in higher dimensions

2447

01:29:54,629 --> 01:29:52,960

this doesn't work because

2448

01:29:56,149 --> 01:29:54,639

spheres don't act like cubes in higher

2449

01:29:57,910 --> 01:29:56,159

dimensions they become less and less of

2450

01:29:59,830 --> 01:29:57,920

the space and thus over here we're

2451

01:30:02,149 --> 01:29:59,840

drastically overestimating or

2452

01:30:04,310 --> 01:30:02,159

underestimating our quantity and this by

2453

01:30:06,709 --> 01:30:04,320

the way is assuming flat space if we're

2454

01:30:08,470 --> 01:30:06,719

in hyperbolic space well then it becomes

2455

01:30:10,149 --> 01:30:08,480

even different there's no limit to the

2456

01:30:12,790 --> 01:30:10,159

amount of spheres that can surround

2457

01:30:15,030 --> 01:30:12,800

another sphere and the concept of

2458

01:30:17,750 --> 01:30:15,040

average quote-unquote density becomes

2459

01:30:19,750 --> 01:30:17,760

more difficult to define accurately

2460

01:30:21,350 --> 01:30:19,760

now one of the reasons for being this

2461

01:30:23,510 --> 01:30:21,360

captious or

2462

01:30:26,070 --> 01:30:23,520

let's say scrupulous let's say over

2463

01:30:27,590 --> 01:30:26,080

scrupulous is because

2464

01:30:29,669 --> 01:30:27,600

there are enthymemes what are called

2465

01:30:31,430 --> 01:30:29,679

enthemes which are unstated data

2466

01:30:33,430 --> 01:30:31,440

unstated assumptions that go into an

2467

01:30:35,350 --> 01:30:33,440

argument and the reason they're unstated

2468

01:30:37,669 --> 01:30:35,360

is because they're so simple they're so

2469

01:30:39,430 --> 01:30:37,679

familiar many people like even nima

2470

01:30:40,870 --> 01:30:39,440

arkani hamed don't go through each of

2471

01:30:42,629 --> 01:30:40,880

these assumptions one it would just take

2472

01:30:44,790 --> 01:30:42,639

too long but two is that they're so

2473

01:30:46,390 --> 01:30:44,800

familiar they are generally glossed over

2474

01:30:48,950 --> 01:30:46,400

but i like to make as much of what's

2475

01:30:50,790 --> 01:30:48,960

ordinarily below the earth i'd like to

2476

01:30:52,790 --> 01:30:50,800

unearth it because then perhaps you

2477

01:30:54,390 --> 01:30:52,800

won't be as confused as myself when i

2478

01:30:55,669 --> 01:30:54,400

was learning these subjects if you'd

2479

01:30:57,669 --> 01:30:55,679

like to learn a little bit more about

2480

01:30:59,669 --> 01:30:57,679

enthymemes some example of them in

2481

01:31:01,750 --> 01:30:59,679

physics then you can check out this clip

2482

01:31:03,510 --> 01:31:01,760

with luis elisondo linked in the

2483

01:31:05,669 --> 01:31:03,520

description okay so that was a quick

2484

01:31:07,350 --> 01:31:05,679

detour into quantum gravity if you want

2485

01:31:09,430 --> 01:31:07,360

to learn more like i mentioned there's

2486

01:31:11,830 --> 01:31:09,440

an extremely detailed episode on quantum

2487

01:31:13,430 --> 01:31:11,840

gravity with salvator pious and that's

2488

01:31:15,590 --> 01:31:13,440

linked in the description now we should

2489

01:31:17,189 --> 01:31:15,600

get onto the sponsor message just so you

2490

01:31:19,510 --> 01:31:17,199

know anytime there's a sponsor message

2491

01:31:21,110 --> 01:31:19,520

on the toe channel there's usually a

2492

01:31:22,950 --> 01:31:21,120

timestamp here that says click on this

2493

01:31:24,550 --> 01:31:22,960

timestamp which somewhere here as well

2494

01:31:26,149 --> 01:31:24,560

as in the description because i don't

2495

01:31:28,550 --> 01:31:26,159

want to manipulate anyone into watching

2496

01:31:30,390 --> 01:31:28,560

a sponsor message that generally means

2497

01:31:32,390 --> 01:31:30,400

because this channel depends on the

2498

01:31:34,390 --> 01:31:32,400

patrons which we'll talk about and the

2499

01:31:36,149 --> 01:31:34,400

sponsors that's the only reason i'm able

2500

01:31:38,229 --> 01:31:36,159

to do this full time it usually means

2501

01:31:40,390 --> 01:31:38,239

that the sponsors pay less because

2502

01:31:42,709 --> 01:31:40,400

people will just click on the time stamp

2503

01:31:44,709 --> 01:31:42,719

however i'm hoping and i well i hope

2504

01:31:47,189 --> 01:31:44,719

this is the case that in the long run

2505

01:31:48,950 --> 01:31:47,199

the trust that's built between myself

2506

01:31:50,470 --> 01:31:48,960

and you by seeing you're not being

2507

01:31:52,629 --> 01:31:50,480

manipulated into a sponsor message you

2508

01:31:53,750 --> 01:31:52,639

can always click out of them and the

2509

01:31:55,350 --> 01:31:53,760

sponsors hopefully it's better for

2510

01:31:57,669 --> 01:31:55,360

everyone the sponsors myself and the

2511

01:32:00,229 --> 01:31:57,679

audience in the long run now the sponsor

2512

01:32:01,750 --> 01:32:00,239

for today is brilliant brilliant.org

2513

01:32:04,149 --> 01:32:01,760

toe is where you can visit if you want

2514

01:32:06,070 --> 01:32:04,159

to get 20 off an annual subscription

2515

01:32:07,350 --> 01:32:06,080

what brilliant is that it's a website

2516

01:32:09,270 --> 01:32:07,360

where you can go and you can take

2517

01:32:11,030 --> 01:32:09,280

courses and they don't feel like courses

2518

01:32:13,830 --> 01:32:11,040

it makes learning math and science and

2519

01:32:15,910 --> 01:32:13,840

engineering an extremely practical fun

2520

01:32:17,830 --> 01:32:15,920

enterprise where it's interactive rather

2521

01:32:19,910 --> 01:32:17,840

than you being told information you can

2522

01:32:21,990 --> 01:32:19,920

play with the information and speaking

2523

01:32:23,910 --> 01:32:22,000

of information in a little while from

2524

01:32:26,950 --> 01:32:23,920

now i hope to speak to chiara marletto

2525

01:32:29,350 --> 01:32:26,960

or david deutsch on constructor theory

2526

01:32:31,590 --> 01:32:29,360

and that's heavily based in information

2527

01:32:33,590 --> 01:32:31,600

theory so i decided to take a course on

2528

01:32:35,830 --> 01:32:33,600

information theory and

2529

01:32:41,430 --> 01:32:35,840

from that you find that this formula

2530

01:32:45,189 --> 01:32:43,350

this formula is an extremely natural

2531

01:32:47,510 --> 01:32:45,199

formula for entropy and it would be

2532

01:32:50,470 --> 01:32:47,520

strange to define it in any other manner

2533

01:32:52,470 --> 01:32:50,480

again visit brilliant.org to get 20

2534

01:32:54,390 --> 01:32:52,480

off your annual subscription the second

2535

01:32:56,149 --> 01:32:54,400

sponsor is algo and algo is an

2536

01:32:57,830 --> 01:32:56,159

end-to-end supply chain optimization

2537

01:32:59,669 --> 01:32:57,840

software company with software that

2538

01:33:01,750 --> 01:32:59,679

helps business users optimize sales and

2539

01:33:03,669 --> 01:33:01,760

operations planning to avoid stockouts

2540

01:33:05,750 --> 01:33:03,679

reduce returns and inventory write downs

2541

01:33:08,470 --> 01:33:05,760

while reducing inventory investment it's

2542

01:33:11,430 --> 01:33:08,480

a supply chain ai that drives smart roi

2543

01:33:12,950 --> 01:33:11,440

headed by amjad hussein you can support

2544

01:33:15,750 --> 01:33:12,960

the tow podcast as well as your own

2545

01:33:18,790 --> 01:33:15,760

learning by visiting brilliant.org toe

2546

01:33:20,629 --> 01:33:18,800

and also by visiting [amjad algo.com](http://amjad.algo.com) all

2547

01:33:22,470 --> 01:33:20,639

the links are in the description you

2548

01:33:24,550 --> 01:33:22,480

should also know that it's the patrons

2549

01:33:26,310 --> 01:33:24,560

as well that allow this to happen i was

2550

01:33:28,310 --> 01:33:26,320

supposed to spend about

2551
01:33:29,910 --> 01:33:28,320
two hours on a video like this it's been

2552
01:33:31,910 --> 01:33:29,920
almost two weeks at this point because

2553
01:33:34,149 --> 01:33:31,920
of different errors and so on but i'm

2554
01:33:36,229 --> 01:33:34,159
able to do this because of the patrons

2555
01:33:37,910 --> 01:33:36,239
so if you want to support content like

2556
01:33:40,790 --> 01:33:37,920
this then please do consider going to

2557
01:33:42,950 --> 01:33:40,800
patreon.com

2558
01:33:44,950 --> 01:33:42,960
my wife is also extremely thankful too

2559
01:33:46,470 --> 01:33:44,960
as now she's full time with me

2560
01:33:49,030 --> 01:33:46,480
responding to the community and helping

2561
01:33:50,629 --> 01:33:49,040
me plan the direction of toe and she's

2562
01:33:52,550 --> 01:33:50,639
extremely extremely

2563
01:33:55,510 --> 01:33:52,560

grateful every time we get a new patron

2564

01:33:57,910 --> 01:33:55,520

she's like oh my gosh that's so sweet

2565

01:34:00,550 --> 01:33:57,920

so both my wife and myself thank you so

2566

01:34:02,790 --> 01:34:00,560

much okay let's get back to these nc's

2567

01:34:04,470 --> 01:34:02,800

these napkin calculations with one about

2568

01:34:06,390 --> 01:34:04,480

the length of an atom the radius of an

2569

01:34:07,350 --> 01:34:06,400

atom we'll start to move quick from this

2570

01:34:11,510 --> 01:34:07,360

point

2571

01:34:16,709 --> 01:34:14,870

we have a model here with the electron

2572

01:34:19,110 --> 01:34:16,719

on the outside and then the proton in

2573

01:34:20,950 --> 01:34:19,120

the center so how do we determine the

2574

01:34:26,550 --> 01:34:20,960

radius of an atom

2575

01:34:31,030 --> 01:34:29,110

firstly what do we know the energy

2576

01:34:36,390 --> 01:34:31,040

has a contribution that looks like this

2577

01:34:41,110 --> 01:34:38,790

and we have another contribution

2578

01:34:44,470 --> 01:34:41,120

which comes from the kinetic term

2579

01:34:46,550 --> 01:34:44,480

and this we can use equation number two

2580

01:34:50,310 --> 01:34:46,560

the bolded number tube

2581

01:34:50,320 --> 01:34:56,870

into an r squared

2582

01:35:01,030 --> 01:34:58,629

which mass is this this is the mass of

2583

01:35:03,430 --> 01:35:01,040

an electron

2584

01:35:04,229 --> 01:35:03,440

and for our purposes we can get rid of

2585

01:35:05,510 --> 01:35:04,239

these

2586

01:35:08,629 --> 01:35:05,520

factors here

2587

01:35:13,110 --> 01:35:08,639

and just say well what minimizes this

2588

01:35:16,950 --> 01:35:15,110

this and then there's a minimum point

2589

01:35:19,270 --> 01:35:16,960

and then it starts to look like

2590

01:35:21,270 --> 01:35:19,280

1 over r

2591

01:35:22,629 --> 01:35:21,280

in the long run yes it looks like 1 over

2592

01:35:24,950 --> 01:35:22,639

r and then in the short run it looks

2593

01:35:27,110 --> 01:35:24,960

like this guy over here

2594

01:35:30,390 --> 01:35:27,120

we want to know what is the minimum

2595

01:35:34,229 --> 01:35:31,830

you can differentiate this to get the

2596

01:35:36,149 --> 01:35:34,239

answer or you can guess and then you get

2597

01:35:41,990 --> 01:35:36,159

that

2598

01:35:45,350 --> 01:35:43,669

this is the bohr radius and we were able

2599

01:35:47,669 --> 01:35:45,360

to derive that in maybe two or three

2600

01:35:50,149 --> 01:35:47,679

lines with napkin calculations we can go

2601

01:35:54,550 --> 01:35:50,159

back over here where i should have said

2602

01:36:01,030 --> 01:35:56,709

and now we get that from equation number

2603

01:36:03,590 --> 01:36:02,149

and by the way because this is the

2604

01:36:05,030 --> 01:36:03,600

average speed of the electron of the

2605

01:36:07,030 --> 01:36:05,040

atom this is the reason why

2606

01:36:08,310 --> 01:36:07,040

schrodinger's equation works because

2607

01:36:10,470 --> 01:36:08,320

schrodinger's equation is

2608

01:36:12,390 --> 01:36:10,480

non-relativistic and you can see that

2609

01:36:16,229 --> 01:36:12,400

just from the factor alpha which means

2610

01:36:19,189 --> 01:36:17,830

let's skip forward because we're going

2611

01:36:21,590 --> 01:36:19,199

to need this for our next napkin

2612

01:36:23,750 --> 01:36:21,600

calculation i realized that the size of

2613

01:36:25,270 --> 01:36:23,760

the earth comes first how would we go

2614

01:36:26,950 --> 01:36:25,280

about calculating the size of the earth

2615

01:36:27,990 --> 01:36:26,960

well that occurs when the gravitational

2616

01:36:30,310 --> 01:36:28,000

pressure

2617

01:36:32,229 --> 01:36:30,320

is counterbalanced by the atomic

2618

01:36:34,070 --> 01:36:32,239

pressure so this is unlike the neutron

2619

01:36:36,390 --> 01:36:34,080

star it requires a bit more work so what

2620

01:36:38,790 --> 01:36:36,400

is the gravitational pressure let's call

2621

01:36:41,430 --> 01:36:38,800

it capital p and it's going to be some

2622

01:36:43,590 --> 01:36:41,440

energy over some volume what energy well

2623

01:36:45,510 --> 01:36:43,600

the gravitational energy sum m we don't

2624

01:36:49,030 --> 01:36:45,520

know what m yet we'll figure this out

2625

01:36:50,709 --> 01:36:49,040

over r and then over some volume so

2626
01:36:51,669 --> 01:36:50,719
r cubed

2627
01:36:53,030 --> 01:36:51,679
however

2628
01:36:55,910 --> 01:36:53,040
recall

2629
01:36:57,669 --> 01:36:55,920
that g g newton so the gravitational

2630
01:37:00,310 --> 01:36:57,679
constant

2631
01:37:02,310 --> 01:37:00,320
is the planck mass squared inverse and

2632
01:37:04,629 --> 01:37:02,320
also let's make a density so a density

2633
01:37:07,990 --> 01:37:04,639
is what it's some mass over some volume

2634
01:37:09,669 --> 01:37:08,000
which is let's say mass over r cubed

2635
01:37:11,510 --> 01:37:09,679
then these two

2636
01:37:14,390 --> 01:37:11,520
combine to help make

2637
01:37:19,109 --> 01:37:15,189
and

2638
01:37:20,310 --> 01:37:19,119

this

2639

01:37:22,870 --> 01:37:20,320

now we would like to know what the

2640

01:37:24,950 --> 01:37:22,880

atomic pressure is so this atomic

2641

01:37:26,550 --> 01:37:24,960

pressure which i should denote these

2642

01:37:27,910 --> 01:37:26,560

differently let's say

2643

01:37:30,310 --> 01:37:27,920

the pressure due to gravity and the

2644

01:37:31,590 --> 01:37:30,320

pressure due to the atoms this atomic

2645

01:37:34,149 --> 01:37:31,600

pressure is going to be again some

2646

01:37:35,750 --> 01:37:34,159

energy over some volume so what is the

2647

01:37:37,510 --> 01:37:35,760

energy well it's going to be the energy

2648

01:37:41,189 --> 01:37:37,520

associated with the atom which we have

2649

01:37:44,070 --> 01:37:41,199

over here so let's call this ea

2650

01:37:45,510 --> 01:37:44,080

ea and this is going to be over r a to

2651
01:37:50,229 --> 01:37:45,520
the third

2652
01:37:54,709 --> 01:37:51,990
then we want to know well what is this

2653
01:37:56,310 --> 01:37:54,719
density here this row this row is going

2654
01:37:57,510 --> 01:37:56,320
to be some mass

2655
01:37:59,669 --> 01:37:57,520
over some

2656
01:38:03,669 --> 01:37:59,679
volume because that's what a density is

2657
01:38:06,390 --> 01:38:03,679
and what mass well a proton mass

2658
01:38:09,189 --> 01:38:06,400
over what volume

2659
01:38:12,070 --> 01:38:09,199
making in substitutions we get one over

2660
01:38:13,270 --> 01:38:12,080
the planck mass this is different i

2661
01:38:14,629 --> 01:38:13,280
should have used different notation but

2662
01:38:16,390 --> 01:38:14,639
this is the proton mass this is the

2663
01:38:17,750 --> 01:38:16,400

planck mass

2664

01:38:20,070 --> 01:38:17,760

squared

2665

01:38:23,109 --> 01:38:20,080

alpha sixth

2666

01:38:25,669 --> 01:38:23,119

m proton

2667

01:38:33,430 --> 01:38:27,510

of the electron

2668

01:38:47,750 --> 01:38:36,149

and this implies that the radius of the

2669

01:38:50,790 --> 01:38:49,189

this implies that the radius of the

2670

01:38:53,030 --> 01:38:50,800

earth is this

2671

01:38:55,109 --> 01:38:53,040

so this is in general for rocky planets

2672

01:38:57,189 --> 01:38:55,119

now this means that alpha factors in the

2673

01:38:59,109 --> 01:38:57,199

mass of the electron the planck mass fat

2674

01:39:01,830 --> 01:38:59,119

while g factors in the mass of the

2675

01:39:03,750 --> 01:39:01,840

proton all of this comes into play to

2676

01:39:05,590 --> 01:39:03,760

derive the size of the earth or the size

2677

01:39:07,030 --> 01:39:05,600

of rocky planets in general like mars

2678

01:39:09,030 --> 01:39:07,040

and venus and so on this is what's

2679

01:39:11,109 --> 01:39:09,040

extremely powerful about this napkin

2680

01:39:13,510 --> 01:39:11,119

calculation technique and natural units

2681

01:39:16,149 --> 01:39:13,520

etc this was perhaps six or seven lines

2682

01:39:18,629 --> 01:39:16,159

of derivation that you do in a closet to

2683

01:39:20,390 --> 01:39:18,639

figure out the radius of the earth

2684

01:39:22,310 --> 01:39:20,400

by the way for fun if you want to

2685

01:39:24,629 --> 01:39:22,320

calculate what is the weight of the

2686

01:39:26,870 --> 01:39:24,639

world you can do so in a second so we

2687

01:39:29,669 --> 01:39:26,880

have some guy here

2688

01:39:33,990 --> 01:39:29,679

and he is some angry

2689

01:39:42,950 --> 01:39:37,030

and let's just make the rest of his body

2690

01:39:42,960 --> 01:39:47,430

and he's holding the world

2691

01:39:50,950 --> 01:39:49,590

well what is the weight of the world the

2692

01:39:52,229 --> 01:39:50,960

weight of the world not the mass of the

2693

01:39:53,590 --> 01:39:52,239

world well you can get the mass from

2694

01:39:55,270 --> 01:39:53,600

this but the weight of the world is

2695

01:39:56,629 --> 01:39:55,280

actually zero so when you hear that and

2696

01:39:58,310 --> 01:39:56,639

the reason is because it's all pointing

2697

01:39:59,750 --> 01:39:58,320

toward the center you're experiencing

2698

01:40:01,590 --> 01:39:59,760

the weight of the world actually the

2699

01:40:03,750 --> 01:40:01,600

weight of the world if you want to be

2700

01:40:05,350 --> 01:40:03,760

atlas you just do a handstand because

2701

01:40:06,870 --> 01:40:05,360

the weight of the world is well it's

2702

01:40:08,709 --> 01:40:06,880

technically zero because it's pointing

2703

01:40:10,470 --> 01:40:08,719

from every single direction zero now the

2704

01:40:12,470 --> 01:40:10,480

reason why i say technically zero is

2705

01:40:14,149 --> 01:40:12,480

because then you may say well okay let's

2706

01:40:15,830 --> 01:40:14,159

imagine that we're here on earth so we

2707

01:40:17,910 --> 01:40:15,840

want the gravitational force of the

2708

01:40:19,590 --> 01:40:17,920

earth to hold up another gravitational

2709

01:40:21,189 --> 01:40:19,600

force well let's say you place some mass

2710

01:40:22,629 --> 01:40:21,199

here yes it's heavy let's say you

2711

01:40:24,470 --> 01:40:22,639

increase it you increase it you increase

2712

01:40:25,750 --> 01:40:24,480

it to the size of another earth then

2713

01:40:27,750 --> 01:40:25,760

actually the weight is zero because

2714

01:40:29,830 --> 01:40:27,760

you're in the in between points of the

2715

01:40:31,109 --> 01:40:29,840

same masses so in some sense the weight

2716

01:40:32,629 --> 01:40:31,119

of the world is

2717

01:40:35,189 --> 01:40:32,639

fairly manageable

2718

01:40:37,350 --> 01:40:35,199

all right now let's get to cutting a

2719

01:40:39,030 --> 01:40:37,360

solid now by the way i left out some

2720

01:40:40,470 --> 01:40:39,040

factors here which i've corrected here

2721

01:40:42,149 --> 01:40:40,480

and the reason it's written in this

2722

01:40:43,669 --> 01:40:42,159

manner is because you can then relate

2723

01:40:45,669 --> 01:40:43,679

the size of the earth to the size of an

2724

01:40:47,990 --> 01:40:45,679

atom and the fact that gravity is

2725

01:40:49,590 --> 01:40:48,000

quote-unquote weak is what plays into

2726

01:40:51,910 --> 01:40:49,600

the largeness of a planet or the

2727

01:40:56,229 --> 01:40:51,920

smallness of a planet as for cutting a

2728

01:40:57,590 --> 01:40:56,239

solid what we want is just this equation

2729

01:40:59,750 --> 01:40:57,600

all we have to do

2730

01:41:02,390 --> 01:40:59,760

is exceed the atomic pressure all we

2731

01:41:04,629 --> 01:41:02,400

have to do is just place what is greater

2732

01:41:07,189 --> 01:41:04,639

than this equation there we go extremely

2733

01:41:09,430 --> 01:41:07,199

extremely simple notice this this is the

2734

01:41:11,270 --> 01:41:09,440

most important aspect of this video is

2735

01:41:13,030 --> 01:41:11,280

that there's a perspective shift you can

2736

01:41:14,950 --> 01:41:13,040

now carry this around with you and do

2737

01:41:16,470 --> 01:41:14,960

napkin calculations nc's you can even

2738

01:41:17,669 --> 01:41:16,480

leave them in the comments and derive

2739

01:41:18,470 --> 01:41:17,679

what ordinarily you would think you

2740

01:41:20,790 --> 01:41:18,480

would need

2741

01:41:22,870 --> 01:41:20,800

nuclear physics or special relativity by

2742

01:41:24,629 --> 01:41:22,880

the way about special relativity many

2743

01:41:26,550 --> 01:41:24,639

people talk about time dilation and so

2744

01:41:29,109 --> 01:41:26,560

on but to me what's most interesting

2745

01:41:31,350 --> 01:41:29,119

about special relativity is that it

2746

01:41:33,990 --> 01:41:31,360

messes with what you think existence is

2747

01:41:35,430 --> 01:41:34,000

it places you in an unhinged manner so

2748

01:41:36,310 --> 01:41:35,440

let's take a look over here if there's

2749

01:41:37,830 --> 01:41:36,320

some

2750

01:41:40,790 --> 01:41:37,840

event that occurs outside your light

2751

01:41:42,950 --> 01:41:40,800

cone then what's considered simultaneous

2752

01:41:45,590 --> 01:41:42,960

is a dubious concept the reason being

2753

01:41:47,430 --> 01:41:45,600

that if you were to say for example the

2754

01:41:49,669 --> 01:41:47,440

corner store the store on your corner

2755

01:41:52,310 --> 01:41:49,679

doesn't exist anymore well why are you

2756

01:41:54,550 --> 01:41:52,320

saying that it's because now it is no

2757

01:41:56,070 --> 01:41:54,560

longer there it is now

2758

01:41:57,510 --> 01:41:56,080

bought by someone else or it is now

2759

01:41:59,990 --> 01:41:57,520

demolished

2760

01:42:02,550 --> 01:42:00,000

well there exists another perspective

2761

01:42:04,790 --> 01:42:02,560

where it does exist this is explored in

2762

01:42:06,709 --> 01:42:04,800

the carlo ravelli interview and this is

2763

01:42:09,430 --> 01:42:06,719

because the notion of simultaneity is

2764

01:42:11,350 --> 01:42:09,440

placed on an unassured grounding

2765

01:42:13,669 --> 01:42:11,360

let's get to a laconic derivation of the

2766

01:42:15,669 --> 01:42:13,679

casimir falloff so all you need to know

2767

01:42:17,430 --> 01:42:15,679

about it is what you've heard from

2768

01:42:19,510 --> 01:42:17,440

popular science which is that it's a

2769

01:42:21,030 --> 01:42:19,520

demonstration of the vacuum fluctuations

2770

01:42:23,189 --> 01:42:21,040

because there's certain modes that are

2771

01:42:25,189 --> 01:42:23,199

allowed and not allowed in between the

2772

01:42:27,669 --> 01:42:25,199

plates there are more outside than

2773

01:42:30,229 --> 01:42:27,679

inside and thus they come together

2774

01:42:32,550 --> 01:42:30,239

you know that it's a pressure and we

2775

01:42:34,790 --> 01:42:32,560

have that it falls off as some r to the

2776

01:42:36,870 --> 01:42:34,800

n what is the n what could it be but

2777

01:42:39,590 --> 01:42:36,880

pressure so it's r to the fourth there

2778

01:42:41,669 --> 01:42:39,600

we go we get that the casimir pressure

2779

01:42:43,590 --> 01:42:41,679

falls off and it's a minus because it's

2780

01:42:45,910 --> 01:42:43,600

an attractive force

2781

01:42:47,990 --> 01:42:45,920

as one over r to the fourth ordinarily

2782

01:42:49,750 --> 01:42:48,000

this is an extremely tedious calculation

2783

01:42:50,709 --> 01:42:49,760

we can go to wikipedia right now just to

2784

01:42:52,149 --> 01:42:50,719

check

2785

01:42:54,310 --> 01:42:52,159

you can see from wikipedia that it

2786

01:42:56,390 --> 01:42:54,320

requires quantum field theory and you go

2787

01:42:58,149 --> 01:42:56,400

through plenty and plenty of rigmarole

2788

01:42:59,590 --> 01:42:58,159

just to arrive at this which is the a to

2789

01:43:01,750 --> 01:42:59,600

the fourth minus that we were referring

2790

01:43:03,189 --> 01:43:01,760

to these factors are what we firstly

2791

01:43:04,870 --> 01:43:03,199

these are set to one this is what we

2792

01:43:07,109 --> 01:43:04,880

didn't derive but you were able to get

2793

01:43:09,030 --> 01:43:07,119

an estimate now you may wonder why is it

2794

01:43:11,510 --> 01:43:09,040

that we go through so much pedantic

2795

01:43:12,870 --> 01:43:11,520

palaver just to arrive at a small

2796

01:43:14,950 --> 01:43:12,880

correction when we could have done this

2797

01:43:16,950 --> 01:43:14,960

in one laconic line

2798

01:43:18,870 --> 01:43:16,960

the reason is that sometimes often you

2799

01:43:20,870 --> 01:43:18,880

want to be precise for example you don't

2800

01:43:22,470 --> 01:43:20,880

want a surgeon that approximately

2801

01:43:24,310 --> 01:43:22,480

operates on you

2802

01:43:27,270 --> 01:43:24,320

thus in mathematics one goes through

2803

01:43:28,870 --> 01:43:27,280

great pains to make explicit each axiom

2804

01:43:30,470 --> 01:43:28,880

and line of reasoning now there are

2805

01:43:32,390 --> 01:43:30,480

other reasons for being axiomatic and

2806

01:43:34,870 --> 01:43:32,400

specific for example you may wonder why

2807

01:43:37,109 --> 01:43:34,880

does it take 100 pages to arrive at one

2808

01:43:38,790 --> 01:43:37,119

plus one equals two so there are a

2809

01:43:41,109 --> 01:43:38,800

couple of reasons so one of the reasons

2810

01:43:44,149 --> 01:43:41,119

is that we don't derive that one plus

2811

01:43:46,310 --> 01:43:44,159

one equals two we validate the axiomatic

2812

01:43:48,390 --> 01:43:46,320

system by seeing one plus one equals two

2813

01:43:50,229 --> 01:43:48,400

as a valid target and knowing we need to

2814

01:43:52,310 --> 01:43:50,239

hit it seeing we hit it validates the

2815

01:43:54,709 --> 01:43:52,320

axiomatic system that produced it number

2816

01:43:56,229 --> 01:43:54,719

two is because now that we have axioms

2817

01:43:57,910 --> 01:43:56,239

and then we show that something is

2818

01:44:00,070 --> 01:43:57,920

constructed in this manner because we've

2819

01:44:01,590 --> 01:44:00,080

set it to be then that means that we can

2820

01:44:03,430 --> 01:44:01,600

set it differently we could have

2821

01:44:05,510 --> 01:44:03,440

constructed it differently so for

2822

01:44:07,750 --> 01:44:05,520

example setting the curvature to zero

2823

01:44:09,590 --> 01:44:07,760

gives euclidean geometry and then we

2824

01:44:11,510 --> 01:44:09,600

wonder well what happens if we don't set

2825

01:44:13,910 --> 01:44:11,520

it to zero then we get more general

2826

01:44:15,669 --> 01:44:13,920

spaces like non-euclidean geometry which

2827

01:44:19,510 --> 01:44:15,679

as you know has a crucial role to play

2828

01:44:23,750 --> 01:44:21,030

all right now let's get to analyzing the

2829

01:44:25,030 --> 01:44:23,760

sun this one is a simple one we firstly

2830

01:44:27,189 --> 01:44:25,040

go to

2831

01:44:28,709 --> 01:44:27,199

our friend google and we search for the

2832

01:44:31,109 --> 01:44:28,719

sunlight spectrum and we see it looks

2833

01:44:33,430 --> 01:44:31,119

something like this

2834

01:44:37,750 --> 01:44:33,440

and we see okay this peaks approximately

2835

01:44:41,189 --> 01:44:37,760

at let's say 500 so it's 500

2836

01:44:43,350 --> 01:44:41,199

nanometers is the wavelength we then go

2837

01:44:44,950 --> 01:44:43,360

to our conversion charts

2838

01:44:47,270 --> 01:44:44,960

and we see okay we can use equation

2839

01:44:56,229 --> 01:44:47,280

number three

2840

01:45:06,470 --> 01:44:56,239

use this and we're going to use this

2841

01:45:12,709 --> 01:45:09,669

this gives a temperature on the order of

2842

01:45:14,790 --> 01:45:12,719

5000 or so well let's say on the order

2843

01:45:16,709 --> 01:45:14,800

of

2844

01:45:18,310 --> 01:45:16,719

it's about 5000 kelvin if you want to

2845

01:45:19,430 --> 01:45:18,320

work it out specifically or you can

2846

01:45:21,030 --> 01:45:19,440

simply say it's on the order of

2847

01:45:22,149 --> 01:45:21,040

so-and-so

2848

01:45:23,669 --> 01:45:22,159

and we can search what is the

2849

01:45:25,910 --> 01:45:23,679

temperature of the sun and we see that

2850

01:45:27,350 --> 01:45:25,920

it's approximately correct

2851

01:45:29,350 --> 01:45:27,360

where i just round it up here so it

2852

01:45:30,950 --> 01:45:29,360

could be between 10 to the 3 ten to the

2853

01:45:32,870 --> 01:45:30,960

four that's actually

2854

01:45:35,830 --> 01:45:32,880

halfway in between

2855

01:45:37,669 --> 01:45:35,840

by the way it's from this fact that you

2856

01:45:39,510 --> 01:45:37,679

can look at leds that come from your

2857

01:45:41,430 --> 01:45:39,520

lights or your cell phone screen and

2858

01:45:43,669 --> 01:45:41,440

determine what temperature it would have

2859

01:45:45,270 --> 01:45:43,679

if it were a black body radiator and

2860

01:45:47,030 --> 01:45:45,280

note that your cell phone isn't

2861

01:45:49,270 --> 01:45:47,040

thousands of degrees hot

2862

01:45:52,149 --> 01:45:49,280

thus allowing you to infer just from a

2863

01:45:54,149 --> 01:45:52,159

napkin calculation that leads that

2864

01:45:57,030 --> 01:45:54,159

characterize your phone screen don't

2865

01:45:58,550 --> 01:45:57,040

produce light as black body radiators in

2866

01:46:01,430 --> 01:45:58,560

the same way that for example

2867

01:46:03,430 --> 01:46:01,440

incandescents do

2868

01:46:05,109 --> 01:46:03,440

now let's intuit the radius of the

2869

01:46:07,350 --> 01:46:05,119

electron as you know the radius of the

2870

01:46:09,270 --> 01:46:07,360

electron is well it's a point particle

2871

01:46:10,950 --> 01:46:09,280

however let's think about it classically

2872

01:46:12,709 --> 01:46:10,960

so here's how Lorentz and others thought

2873

01:46:14,950 --> 01:46:12,719

about it classically we have this

2874

01:46:16,709 --> 01:46:14,960

electron here let's call it e

2875

01:46:17,590 --> 01:46:16,719

and it's emitting some electric field

2876

01:46:19,830 --> 01:46:17,600

here

2877

01:46:21,590 --> 01:46:19,840

what we want is that the energy of the

2878

01:46:24,629 --> 01:46:21,600

electron so

2879

01:46:26,390 --> 01:46:24,639

alpha over r e which we have before so

2880

01:46:28,629 --> 01:46:26,400

the energy of the electron

2881

01:46:31,750 --> 01:46:28,639

we don't want that to be much greater

2882

01:46:33,910 --> 01:46:31,760

than $m c^2$ of the electron so in

2883

01:46:35,350 --> 01:46:33,920

our units $m c^2$ is just m

2884

01:46:38,629 --> 01:46:35,360

which implies

2885

01:46:43,350 --> 01:46:41,109

is simply this and there we go we have a

2886

01:46:46,070 --> 01:46:43,360

classical derivation of the radius of

2887

01:46:47,510 --> 01:46:46,080

the electron turns out that

2888

01:46:49,750 --> 01:46:47,520

and by the way lawrence and others

2889

01:46:50,950 --> 01:46:49,760

thought that okay the classical laws

2890

01:46:53,030 --> 01:46:50,960

have to break down somewhat here

2891

01:46:54,629 --> 01:46:53,040

something strange has to occur at that

2892

01:46:55,990 --> 01:46:54,639

radius it and they were trying to

2893

01:46:57,270 --> 01:46:56,000

analyze it and they didn't get the right

2894

01:46:58,950 --> 01:46:57,280

answers and that's because quantum

2895

01:47:01,030 --> 01:46:58,960

mechanics comes in and they had no idea

2896

01:47:03,990 --> 01:47:01,040

about quantum mechanics which says

2897

01:47:05,990 --> 01:47:04,000

actually around the electron is positron

2898

01:47:08,870 --> 01:47:06,000

electron pairs and so on and so it's

2899

01:47:11,510 --> 01:47:08,880

cloudy and the radius of this if we go

2900

01:47:13,430 --> 01:47:11,520

in here the radius of one of these what

2901
01:47:15,910 --> 01:47:13,440
is it what do you think it may be well

2902
01:47:17,750 --> 01:47:15,920
it's an electron positron pair so it's

2903
01:47:18,870 --> 01:47:17,760
this much well it's two of that but it

2904
01:47:20,229 --> 01:47:18,880
doesn't matter

2905
01:47:23,109 --> 01:47:20,239
the point is that the law started

2906
01:47:24,709 --> 01:47:23,119
breaking down at a distance 137 times

2907
01:47:26,870 --> 01:47:24,719
greater than where they thought it would

2908
01:47:28,709 --> 01:47:26,880
have broken down if we extrapolate this

2909
01:47:30,870 --> 01:47:28,719
line of reasoning to our current models

2910
01:47:32,790 --> 01:47:30,880
that is the standard model and general

2911
01:47:34,390 --> 01:47:32,800
relativity while they suggest that

2912
01:47:36,629 --> 01:47:34,400
there's some breakdown that occurs at

2913
01:47:39,350 --> 01:47:36,639

the planck scale my money would be that

2914

01:47:42,550 --> 01:47:39,360

new laws would be required far before we

2915

01:47:44,950 --> 01:47:42,560

get to the planck scale maybe not 130

2916

01:47:47,350 --> 01:47:44,960

times before the planck scale but many

2917

01:47:49,590 --> 01:47:47,360

many more orders of magnitude prior to

2918

01:47:51,270 --> 01:47:49,600

that energy

2919

01:47:53,270 --> 01:47:51,280

all right now we're on to solids and

2920

01:47:55,109 --> 01:47:53,280

x-rays if we want to find out the number

2921

01:47:57,430 --> 01:47:55,119

density that is the number of atoms in a

2922

01:48:00,550 --> 01:47:57,440

solid per unit volume what does it look

2923

01:48:02,950 --> 01:48:00,560

like well number

2924

01:48:05,030 --> 01:48:02,960

density

2925

01:48:09,189 --> 01:48:05,040

firstly let's think about the units

2926

01:48:11,590 --> 01:48:09,199

it's gev to sum n what is n is it minus

2927

01:48:13,109 --> 01:48:11,600

three it's plus three

2928

01:48:15,910 --> 01:48:13,119

and what information do we have we have

2929

01:48:17,910 --> 01:48:15,920

the radius of the atom and so it's that

2930

01:48:19,189 --> 01:48:17,920

cubed and we can use this equation from

2931

01:48:21,590 --> 01:48:19,199

before

2932

01:48:28,149 --> 01:48:21,600

alpha times the mass of the electron is

2933

01:48:31,990 --> 01:48:30,629

which is kev to the third and this is

2934

01:48:34,070 --> 01:48:32,000

one of the reasons why it's much better

2935

01:48:35,590 --> 01:48:34,080

to work with gevs and so on because this

2936

01:48:37,189 --> 01:48:35,600

gives you an actual

2937

01:48:40,149 --> 01:48:37,199

tangible amount you understand what a

2938

01:48:41,910 --> 01:48:40,159

kev is and by the way kev what is its

2939

01:48:44,870 --> 01:48:41,920

relationship to light

2940

01:48:46,629 --> 01:48:44,880

that is to say if we're on the order of

2941

01:48:48,950 --> 01:48:46,639

a length that is

2942

01:48:50,390 --> 01:48:48,960

let's say just one kev then we'll need

2943

01:48:53,910 --> 01:48:50,400

to shine a light

2944

01:48:55,669 --> 01:48:53,920

whose wavelength is at least one kev in

2945

01:48:56,870 --> 01:48:55,679

order to resolve this distance i'll

2946

01:48:58,470 --> 01:48:56,880

explain exactly what that means to

2947

01:49:00,870 --> 01:48:58,480

resolve it and then you can wonder well

2948

01:49:02,950 --> 01:49:00,880

what is one kev of light you can look

2949

01:49:05,189 --> 01:49:02,960

that up online let's do that right now

2950

01:49:07,830 --> 01:49:05,199

so you can see from this napkin

2951

01:49:10,229 --> 01:49:07,840

calculation that an x-ray is what allows

2952

01:49:12,629 --> 01:49:10,239

you to probe solids that's why we use

2953

01:49:14,550 --> 01:49:12,639

x-rays because their wavelength is just

2954

01:49:16,470 --> 01:49:14,560

short enough to resolve the distance of

2955

01:49:18,229 --> 01:49:16,480

the atoms within a solid and when we

2956

01:49:19,430 --> 01:49:18,239

talk about a certain wavelength is

2957

01:49:21,189 --> 01:49:19,440

what's needed to resolve a certain

2958

01:49:23,669 --> 01:49:21,199

distance that was never explained at

2959

01:49:25,590 --> 01:49:23,679

least not to me properly i always heard

2960

01:49:27,109 --> 01:49:25,600

of it in terms of balls you take some

2961

01:49:28,870 --> 01:49:27,119

large ball and you try and throw it and

2962

01:49:30,390 --> 01:49:28,880

you try and resolve you need smaller and

2963

01:49:32,229 --> 01:49:30,400

smaller balls in order to get higher

2964

01:49:33,750 --> 01:49:32,239

resolution but i think a better way of

2965

01:49:36,709 --> 01:49:33,760

understanding this understanding why we

2966

01:49:38,709 --> 01:49:36,719

need x-rays or whatever uv rays whatever

2967

01:49:40,229 --> 01:49:38,719

the light is to resolve a certain

2968

01:49:41,590 --> 01:49:40,239

distance i think it's better explained

2969

01:49:44,470 --> 01:49:41,600

like this

2970

01:49:45,270 --> 01:49:44,480

if we zoom in here so let's zoom in this

2971

01:49:47,030 --> 01:49:45,280

is

2972

01:49:49,830 --> 01:49:47,040

let's see how many pixels wide maybe

2973

01:49:54,390 --> 01:49:51,669

one two three maybe this is on the order

2974

01:50:00,790 --> 01:49:54,400

of 50. who knows but then if i say let's

2975

01:50:05,350 --> 01:50:03,189

see if we make this cell size the cell

2976

01:50:07,270 --> 01:50:05,360

size by the way is equivalent to a

2977

01:50:10,149 --> 01:50:07,280

wavelength so we want the wavelength

2978

01:50:12,950 --> 01:50:10,159

small in order to resolve

2979

01:50:15,270 --> 01:50:12,960

shorter and shorter distances

2980

01:50:18,310 --> 01:50:15,280

if we make the cell size fairly large

2981

01:50:20,550 --> 01:50:18,320

like 200 then we can just make out that

2982

01:50:21,830 --> 01:50:20,560

there exists some substructure here we

2983

01:50:24,149 --> 01:50:21,840

cannot make out that there was any

2984

01:50:26,310 --> 01:50:24,159

structure above and as soon as we start

2985

01:50:27,910 --> 01:50:26,320

reducing it we're resolving with higher

2986

01:50:29,910 --> 01:50:27,920

and higher frequencies you can think of

2987

01:50:33,669 --> 01:50:29,920

it like that so if

2988

01:50:35,270 --> 01:50:33,679

this is let's say on the order of a

2989

01:50:37,910 --> 01:50:35,280

cell and then we want to get to the

2990

01:50:40,149 --> 01:50:37,920

order of an atom well we need to shoot

2991

01:50:42,070 --> 01:50:40,159

smaller and smaller wavelengths of light

2992

01:50:43,510 --> 01:50:42,080

this corresponds to the wavelength and

2993

01:50:44,870 --> 01:50:43,520

all of a sudden now you can resolve that

2994

01:50:46,390 --> 01:50:44,880

distance

2995

01:50:47,910 --> 01:50:46,400

i'm placing that as an aside here

2996

01:50:50,870 --> 01:50:47,920

because the way that it's ordinarily

2997

01:50:53,030 --> 01:50:50,880

explained is a bit confusing by the way

2998

01:50:55,510 --> 01:50:53,040

based on this number density you can now

2999

01:50:57,430 --> 01:50:55,520

get a actual density so what do you do

3000

01:50:59,350 --> 01:50:57,440

is you times it by the proton mass

3001
01:51:01,590 --> 01:50:59,360
because the proton slash the neutron are

3002
01:51:03,910 --> 01:51:01,600
what hold the most well the largest

3003
01:51:06,470 --> 01:51:03,920
contribution to the mass

3004
01:51:08,149 --> 01:51:06,480
and then you get the density of solids

3005
01:51:10,390 --> 01:51:08,159
which is the approximate density of the

3006
01:51:13,030 --> 01:51:10,400
earth too see all of this which is

3007
01:51:15,510 --> 01:51:13,040
ordinarily seen as tremendously advanced

3008
01:51:17,350 --> 01:51:15,520
can be calculated extremely easily with

3009
01:51:18,870 --> 01:51:17,360
napkin calculations

3010
01:51:20,870 --> 01:51:18,880
okay now we're on the last one the

3011
01:51:23,830 --> 01:51:20,880
scales of the universe in particular the

3012
01:51:25,189 --> 01:51:23,840
higgs boson which is extremely easy now

3013
01:51:27,109 --> 01:51:25,199

that we've gone through

3014

01:51:29,430 --> 01:51:27,119

plenty of these exercises and you're so

3015

01:51:32,310 --> 01:51:29,440

familiar with natural units and gevs and

3016

01:51:34,390 --> 01:51:32,320

so on what is the scale that you should

3017

01:51:36,470 --> 01:51:34,400

find the higgs boson how far should you

3018

01:51:38,390 --> 01:51:36,480

zoom in to find it well firstly let's go

3019

01:51:40,950 --> 01:51:38,400

on google

3020

01:51:43,830 --> 01:51:40,960

and we see look they give you the mass

3021

01:51:46,830 --> 01:51:43,840

in terms of gev now this c we set to one

3022

01:51:48,550 --> 01:51:46,840

so this gev it's 125 gev

3023

01:51:52,070 --> 01:51:48,560

125

3024

01:51:54,790 --> 01:51:52,080

g e v higgs

3025

01:51:58,229 --> 01:51:56,470

from the above conversion chart or we

3026
01:52:00,310 --> 01:51:58,239
can go to a website and see what does

3027
01:52:02,629 --> 01:52:00,320
that correspond to in terms of length

3028
01:52:05,270 --> 01:52:02,639
now you can see how far do you have to

3029
01:52:07,990 --> 01:52:05,280
zoom in in order for you to find the

3030
01:52:09,109 --> 01:52:08,000
higgs boson you can convert that or you

3031
01:52:11,189 --> 01:52:09,119
can use another chart they're all

3032
01:52:13,189 --> 01:52:11,199
approximately the same remember we only

3033
01:52:14,950 --> 01:52:13,199
care about the order we can also type in

3034
01:52:16,550 --> 01:52:14,960
well what is the lhc

3035
01:52:17,830 --> 01:52:16,560
what is the highest energy of the

3036
01:52:21,189 --> 01:52:17,840
particles that have been collided and

3037
01:52:24,470 --> 01:52:21,199
it's 13 tev we covered this earlier that

3038
01:52:26,790 --> 01:52:24,480

tells you something concrete about how

3039

01:52:28,790 --> 01:52:26,800

small the distances are now these

3040

01:52:30,070 --> 01:52:28,800

numbers are no longer foreign to you

3041

01:52:31,830 --> 01:52:30,080

you're extremely familiar with

3042

01:52:33,910 --> 01:52:31,840

manipulating them you can get a handle

3043

01:52:35,510 --> 01:52:33,920

on them by the way another reason why

3044

01:52:37,189 --> 01:52:35,520

they're afraid that black holes could be

3045

01:52:39,109 --> 01:52:37,199

created well i didn't mention this in

3046

01:52:41,350 --> 01:52:39,119

the extra dimensions part but it's

3047

01:52:43,430 --> 01:52:41,360

because if gravity is leaking in to some

3048

01:52:45,350 --> 01:52:43,440

other dimension then that means that

3049

01:52:47,270 --> 01:52:45,360

gravity is in fact stronger than we

3050

01:52:49,030 --> 01:52:47,280

think somewhere else so it's weaker here

3051
01:52:50,950 --> 01:52:49,040
but it's stronger somewhere else and so

3052
01:52:52,709 --> 01:52:50,960
what we think of what would ordinarily

3053
01:52:54,470 --> 01:52:52,719
create a black hole the conditions may

3054
01:52:55,990 --> 01:52:54,480
be much smaller because gravity is much

3055
01:52:58,070 --> 01:52:56,000
stronger than we think though luckily

3056
01:53:03,910 --> 01:52:58,080
the earth hasn't been enveloped by a

3057
01:53:08,870 --> 01:53:06,310
okay great you should congratulate

3058
01:53:10,310 --> 01:53:08,880
yourself because in about two hours or

3059
01:53:12,790 --> 01:53:10,320
an hour and a half however long this

3060
01:53:15,589 --> 01:53:12,800
video is you've now covered quite a

3061
01:53:17,910 --> 01:53:15,599
significant amount of work we've gone

3062
01:53:19,589 --> 01:53:17,920
through newton's constant and seeing

3063
01:53:22,390 --> 01:53:19,599

that it's actually mass dependent or

3064

01:53:25,189 --> 01:53:22,400

energy it's proportional to the

3065

01:53:27,750 --> 01:53:25,199

mass to the inverse square of a mass and

3066

01:53:29,589 --> 01:53:27,760

pressure and speed is dimensionless

3067

01:53:31,910 --> 01:53:29,599

this pressure in a neutron star the

3068

01:53:33,589 --> 01:53:31,920

proportionate strength of forces knots

3069

01:53:35,270 --> 01:53:33,599

and extra dimensions calculating the

3070

01:53:37,510 --> 01:53:35,280

swinger limit just getting a handle on

3071

01:53:39,830 --> 01:53:37,520

it the size of the earth analyzing the

3072

01:53:41,750 --> 01:53:39,840

sun the casimir effect how it falls off

3073

01:53:43,030 --> 01:53:41,760

a vacuum expectation energy the length

3074

01:53:44,629 --> 01:53:43,040

of an atom

3075

01:53:47,189 --> 01:53:44,639

microtubules

3076

01:53:48,629 --> 01:53:47,199

sk the higgs boson the god particle you

3077

01:53:51,350 --> 01:53:48,639

even learned about deriving the

3078

01:53:53,990 --> 01:53:51,360

schwarzschild radius and black holes and

3079

01:53:57,430 --> 01:53:54,000

by the way for fun these acrostically

3080

01:53:59,350 --> 01:53:57,440

spell out napkin calculations

3081

01:54:01,270 --> 01:53:59,360

all of this becomes

3082

01:54:03,990 --> 01:54:01,280

virtually child's play

3083

01:54:05,990 --> 01:54:04,000

once you use natural units and then

3084

01:54:07,350 --> 01:54:06,000

some physical intuition

3085

01:54:09,510 --> 01:54:07,360

all right now continue watching for the

3086

01:54:11,430 --> 01:54:09,520

next couple minutes because this will

3087

01:54:14,070 --> 01:54:11,440

help you contextualize what came before

3088

01:54:16,229 --> 01:54:14,080

and so it will stick more readily recall

3089

01:54:18,070 --> 01:54:16,239

unlike giving viewer exercises quote

3090

01:54:21,030 --> 01:54:18,080

unquote which is par for the course in

3091

01:54:23,109 --> 01:54:21,040

most courses and lectures and so on

3092

01:54:24,550 --> 01:54:23,119

people almost never do exercises

3093

01:54:26,870 --> 01:54:24,560

including myself and i'm extremely

3094

01:54:28,390 --> 01:54:26,880

motivated to do so the most nourishing

3095

01:54:30,310 --> 01:54:28,400

approach is to provide a point of view

3096

01:54:31,990 --> 01:54:30,320

shift and that's what you now have there

3097

01:54:34,709 --> 01:54:32,000

are a variety of phenomenon that you can

3098

01:54:36,870 --> 01:54:34,719

now do an nc too so a napkin calculation

3099

01:54:38,390 --> 01:54:36,880

and if you find a particularly inventive

3100

01:54:41,030 --> 01:54:38,400

one then share it in the comments

3101

01:54:43,109 --> 01:54:41,040

section but delineate each step don't

3102

01:54:44,470 --> 01:54:43,119

skip when explaining to people now as

3103

01:54:46,070 --> 01:54:44,480

you go through life and you want to

3104

01:54:48,149 --> 01:54:46,080

develop a bit more of a physical

3105

01:54:49,750 --> 01:54:48,159

intuition then constantly think about

3106

01:54:51,510 --> 01:54:49,760

what you're seeing and the numbers that

3107

01:54:53,990 --> 01:54:51,520

you're hearing and the lengths and the

3108

01:54:56,070 --> 01:54:54,000

times and the quantities etc in terms of

3109

01:54:57,669 --> 01:54:56,080

gev and also think about how you can

3110

01:55:00,149 --> 01:54:57,679

derive them from these somewhat

3111

01:55:01,669 --> 01:55:00,159

fundamental principles a last note on

3112

01:55:03,350 --> 01:55:01,679

learning every time that you hear

3113

01:55:04,550 --> 01:55:03,360

someone describe some object in a

3114

01:55:06,629 --> 01:55:04,560

different way

3115

01:55:09,189 --> 01:55:06,639

so for example you may hear me refer to

3116

01:55:11,189 --> 01:55:09,199

fields in some other video as a

3117

01:55:12,790 --> 01:55:11,199

group twice over and what's meant by

3118

01:55:14,950 --> 01:55:12,800

that what do i mean by that it's that

3119

01:55:16,470 --> 01:55:14,960

you have these field axioms so

3120

01:55:18,709 --> 01:55:16,480

commutative associative neutral elements

3121

01:55:21,109 --> 01:55:18,719

so on so on so on and it's it's two of

3122

01:55:23,350 --> 01:55:21,119

them whereas one of these is like

3123

01:55:25,910 --> 01:55:23,360

a group a commutative group and so it's

3124

01:55:27,510 --> 01:55:25,920

somewhat like a twice over group this is

3125

01:55:29,350 --> 01:55:27,520

this is false because there's an

3126

01:55:31,830 --> 01:55:29,360

interplay between these like you need to

3127

01:55:33,990 --> 01:55:31,840

exclude the neutral element here for the

3128

01:55:36,149 --> 01:55:34,000

multiplicative inverse and so on however

3129

01:55:37,669 --> 01:55:36,159

the point is that when you hear someone

3130

01:55:39,510 --> 01:55:37,679

explain something that you think you

3131

01:55:41,189 --> 01:55:39,520

know but explained in a different way

3132

01:55:42,870 --> 01:55:41,199

it's useful to write that down in some

3133

01:55:44,470 --> 01:55:42,880

reference document and then eventually

3134

01:55:47,109 --> 01:55:44,480

go back and think how are all these

3135

01:55:48,470 --> 01:55:47,119

disparate lessons or views the same

3136

01:55:49,990 --> 01:55:48,480

another one may be how are all the

3137

01:55:52,149 --> 01:55:50,000

exponentials the definitions of

3138

01:55:55,109 --> 01:55:52,159

exponentials the same so we know that an

3139

01:55:58,470 --> 01:55:55,119

exponential map goes from $t \in \mathfrak{g}$ so the

3140

01:56:00,470 --> 01:55:58,480

lead algebra to the group itself well

3141

01:56:02,870 --> 01:56:00,480

how is that related to

3142

01:56:04,790 --> 01:56:02,880

what we know as e to the e squared for

3143

01:56:06,709 --> 01:56:04,800

example equals so and so on

3144

01:56:08,790 --> 01:56:06,719

as a number by the way almost no one

3145

01:56:11,589 --> 01:56:08,800

will do this exercise that is you write

3146

01:56:13,350 --> 01:56:11,599

down the disparate lessons and teachings

3147

01:56:15,910 --> 01:56:13,360

and then you try to relate them there's

3148

01:56:17,350 --> 01:56:15,920

about n choose two of them so how is

3149

01:56:18,550 --> 01:56:17,360

this related to that how is this related

3150

01:56:20,709 --> 01:56:18,560

to that how is this related to that how

3151

01:56:22,149 --> 01:56:20,719

is this related to that and so on

3152

01:56:24,310 --> 01:56:22,159

almost no one will do that because it's

3153

01:56:25,910 --> 01:56:24,320

extremely tedious which means if you do

3154

01:56:28,550 --> 01:56:25,920

this then you'll garner far more insight

3155

01:56:29,510 --> 01:56:28,560

than your peers maybe that

3156

01:56:31,189 --> 01:56:29,520

that

3157

01:56:33,430 --> 01:56:31,199

competitive edge will

3158

01:56:35,430 --> 01:56:33,440

tickle your rivalrous nature if it does

3159

01:56:37,189 --> 01:56:35,440

then you can use it as motivation and

3160

01:56:39,430 --> 01:56:37,199

for myself i may be doing a video at

3161

01:56:41,270 --> 01:56:39,440

some point i'm not don't hold me to this

3162

01:56:43,030 --> 01:56:41,280

on how the various definitions of

3163

01:56:45,189 --> 01:56:43,040

entropy are all related so there's

3164

01:56:48,070 --> 01:56:45,199

shannon there's thermal

3165

01:56:49,109 --> 01:56:48,080

there's neg entropy there's residual

3166

01:56:51,750 --> 01:56:49,119

entropy

3167

01:56:53,589 --> 01:56:51,760

and so on so on as i mentioned before

3168

01:56:55,510 --> 01:56:53,599

this video will be akin to an

3169

01:56:57,589 --> 01:56:55,520

introduction to another video that i

3170

01:56:59,830 --> 01:56:57,599

plan on releasing at some point now this

3171

01:57:01,109 --> 01:56:59,840

one has taken way way way too long so

3172

01:57:03,109 --> 01:57:01,119

perhaps i thought i was going to do it

3173

01:57:04,550 --> 01:57:03,119

in a few months this going through a

3174

01:57:06,070 --> 01:57:04,560

theoretical physics paper you don't

3175

01:57:07,750 --> 01:57:06,080

currently understand

3176

01:57:09,350 --> 01:57:07,760

i was going to go through geometric

3177

01:57:10,550 --> 01:57:09,360

unity perhaps i won't do that in a few

3178

01:57:13,109 --> 01:57:10,560

months perhaps it will be the winter

3179

01:57:14,470 --> 01:57:13,119

time now because this was way way way

3180

01:57:16,070 --> 01:57:14,480

more difficult than i thought it would

3181

01:57:17,990 --> 01:57:16,080

be regardless you can expect that at

3182

01:57:19,510 --> 01:57:18,000

some point so the question is is this

3183

01:57:21,350 --> 01:57:19,520

leading anywhere this

3184

01:57:23,189 --> 01:57:21,360

lecture series and i don't plan on

3185

01:57:24,390 --> 01:57:23,199

releasing more content like this as this

3186

01:57:25,750 --> 01:57:24,400

is not my forte

3187

01:57:27,990 --> 01:57:25,760

i'm interested in what i call

3188

01:57:29,990 --> 01:57:28,000

explicating the landscape of theories of

3189

01:57:32,149 --> 01:57:30,000

everything which means to intensely

3190

01:57:33,750 --> 01:57:32,159

investigate each toe geometric unity

3191

01:57:36,070 --> 01:57:33,760

wolf rooms so there's a thumbnail here

3192

01:57:37,510 --> 01:57:36,080

you can click on or in the description

3193

01:57:39,430 --> 01:57:37,520

thomas campbells there's theories on

3194

01:57:41,510 --> 01:57:39,440

consciousness there's veltan xiaowungs

3195

01:57:43,189 --> 01:57:41,520

like ian ian mcgillcrist and john

3196

01:57:45,030 --> 01:57:43,199

verveicky i mentioned before there's

3197

01:57:46,950 --> 01:57:45,040

interpretations of quantum theory like

3198

01:57:48,629 --> 01:57:46,960

carlo rivelli and nicholas jisson

3199

01:57:51,109 --> 01:57:48,639

there's even how to go about learning

3200

01:57:52,790 --> 01:57:51,119

mathematics with norman weilberger and

3201

01:57:54,629 --> 01:57:52,800

richard borchards

3202

01:57:57,030 --> 01:57:54,639

i highly recommend both of their youtube

3203

01:57:58,950 --> 01:57:57,040

channels by the way norman in particular

3204

01:58:01,990 --> 01:57:58,960

is great at making whatever is complex

3205

01:58:03,589 --> 01:58:02,000

seems so elementary that it's criminally

3206

01:58:05,030 --> 01:58:03,599

humiliating

3207

01:58:06,950 --> 01:58:05,040

now most people have a subscriber

3208

01:58:09,270 --> 01:58:06,960

request but i have a request for you to

3209

01:58:11,510 --> 01:58:09,280

not subscribe unless you're interested

3210

01:58:13,270 --> 01:58:11,520

in podcasts about the above

3211

01:58:15,669 --> 01:58:13,280

as this channel's

3212

01:58:17,350 --> 01:58:15,679

bread and butter are those podcasts you

3213

01:58:19,990 --> 01:58:17,360

will be sorely disappointed if you

3214

01:58:21,430 --> 01:58:20,000

expect more videos like this so check

3215

01:58:23,669 --> 01:58:21,440

out some of the other podcasts on this

3216

01:58:25,350 --> 01:58:23,679

channel here's a playlist for you to get

3217

01:58:26,790 --> 01:58:25,360

started also it's linked in the

3218

01:58:29,510 --> 01:58:26,800

description

3219

01:58:32,870 --> 01:58:29,520

again if you have an interesting nc

3220

01:58:35,189 --> 01:58:32,880

about some napkin calculation about some

3221

01:58:37,109 --> 01:58:35,199

observable that ordinarily is a tedious

3222

01:58:39,430 --> 01:58:37,119

calculation that you can arrive at

3223

01:58:41,270 --> 01:58:39,440

simply from this new natural unit point

3224

01:58:43,589 --> 01:58:41,280

of view then make sure to leave it in

3225

01:58:45,750 --> 01:58:43,599

the comments and make it clear what each

3226

01:58:47,910 --> 01:58:45,760

step is don't skip any steps i'll also

3227

01:58:50,870 --> 01:58:47,920

place a thread in the subreddit

3228

01:58:51,990 --> 01:58:50,880

reddit.com r theories of everything and

3229

01:58:54,070 --> 01:58:52,000

i'll try to comment on the most

3230

01:58:56,310 --> 01:58:54,080

interesting ones if you want to share or

3231

01:58:57,750 --> 01:58:56,320

get feedback on your nc or on your

3232

01:59:00,709 --> 01:58:57,760

theory of everything let's imagine you

3233

01:59:02,550 --> 01:59:00,719

have one then or some ideas to one then

3234

01:59:04,550 --> 01:59:02,560

go to the discord that's also linked in

3235

01:59:06,790 --> 01:59:04,560

the subreddit below again like i

3236

01:59:08,470 --> 01:59:06,800

mentioned there's no one source on this

3237

01:59:10,229 --> 01:59:08,480

it's strewn generally across several

3238

01:59:11,750 --> 01:59:10,239

lectures and you start to intuit it as a

3239

01:59:13,910 --> 01:59:11,760

physics student

3240

01:59:16,629 --> 01:59:13,920

however videos that served as

3241

01:59:19,510 --> 01:59:16,639

inspiration to this one are that of nima

3242

01:59:21,109 --> 01:59:19,520

arkani hamed andrew dotson

3243

01:59:22,870 --> 01:59:21,119

pretty much physics and sabine

3244

01:59:24,870 --> 01:59:22,880

hostenfelder i recommend you check out

3245

01:59:26,709 --> 01:59:24,880

all of those channels the links to their

3246

01:59:31,109 --> 01:59:26,719

work are in the description

3247

01:59:34,790 --> 01:59:33,030

the podcast is now finished if you'd

3248

01:59:37,910 --> 01:59:34,800

like to support conversations like this

3249

01:59:42,070 --> 01:59:37,920

then do consider going to patreon.com

3250

01:59:44,709 --> 01:59:42,080

c-u-r-t j-a-i-m-u-n-g-a-l

3251

01:59:46,470 --> 01:59:44,719

that is kurt jaimungle it's support from

3252

01:59:48,310 --> 01:59:46,480

the patrons and from the sponsors that