

## Is vacuum energy really real?

- Force between Casimir cavities plates



$\lambda < 2 \cdot \text{spacing}$



$\lambda < 2 \cdot \text{spacing}$



$\lambda > 2 \cdot \text{spacing}$

- ZPE: zero fluctuations in electronic components



1  
00:00:06,950 --> 00:00:03,350  
good morning

2  
00:00:09,990 --> 00:00:06,960  
so we've heard over a number of years

3  
00:00:11,030 --> 00:00:10,000  
uh at the sse and elsewhere about zero

4  
00:00:14,150 --> 00:00:11,040  
point energy

5  
00:00:16,630 --> 00:00:14,160  
vacuum technology and that this is

6  
00:00:18,790 --> 00:00:16,640  
the the ambient zero-point energy

7  
00:00:21,429 --> 00:00:18,800  
background is going to provide

8  
00:00:23,590 --> 00:00:21,439  
energy that'll meet all of our needs and

9  
00:00:25,990 --> 00:00:23,600  
yet it hasn't happened

10  
00:00:26,790 --> 00:00:26,000  
and uh today what i want to do is ask

11  
00:00:30,070 --> 00:00:26,800  
the question

12  
00:00:33,190 --> 00:00:30,080  
from a fundamental level why

13  
00:00:34,950 --> 00:00:33,200

is there in fact the possibility of

14

00:00:38,310 --> 00:00:34,960

obtaining continuous power from the

15

00:00:41,270 --> 00:00:38,320

vacuum or are we deluding ourselves

16

00:00:42,389 --> 00:00:41,280

so let's take a look at some basic

17

00:00:46,069 --> 00:00:42,399

principles

18

00:00:49,270 --> 00:00:46,079

behind obtaining energy from the vacuum

19

00:00:50,709 --> 00:00:49,280

so the first question is what is vacuum

20

00:00:53,270 --> 00:00:50,719

energy

21

00:00:54,869 --> 00:00:53,280

and we can see oh i'm sorry that's not

22

00:00:55,670 --> 00:00:54,879

the right type of vacuum energy let me

23

00:00:58,229 --> 00:00:55,680

try again

24

00:00:59,029 --> 00:00:58,239

so the question is what is vacuum energy

25

00:01:02,549 --> 00:00:59,039

uh and

26

00:01:06,950 --> 00:01:02,559

it is zero point energy that fills all

27

00:01:16,230 --> 00:01:13,109

okay thanks yeah please uh

28

00:01:16,950 --> 00:01:16,240

i'll talk louder thank you uh so the

29

00:01:20,789 --> 00:01:16,960

question is

30

00:01:22,550 --> 00:01:20,799

what is uh this this energy we know

31

00:01:24,469 --> 00:01:22,560

from quantum mechanics and elsewhere

32

00:01:27,990 --> 00:01:24,479

from the uncertainty principle

33

00:01:31,270 --> 00:01:28,000

that there is energy uh

34

00:01:31,830 --> 00:01:31,280

in every mechanical system and that this

35

00:01:34,069 --> 00:01:31,840

energy

36

00:01:35,990 --> 00:01:34,079

never goes to zero and that's why it's

37

00:01:37,749 --> 00:01:36,000

called zero point energy because even

38

00:01:39,429 --> 00:01:37,759

at zero temperature there still is some

39

00:01:42,230 --> 00:01:39,439

energy in the system

40

00:01:44,149 --> 00:01:42,240

not only is there energy in every uh

41

00:01:45,350 --> 00:01:44,159

physical system but there is energy in

42

00:01:47,910 --> 00:01:45,360

free space itself

43

00:01:48,389 --> 00:01:47,920

in the vacuum and this takes multiple

44

00:01:51,350 --> 00:01:48,399

different

45

00:01:52,149 --> 00:01:51,360

forms the form that we're considering

46

00:01:54,149 --> 00:01:52,159

right now

47

00:01:55,590 --> 00:01:54,159

is electromagnetic fluctuations and so

48

00:01:57,830 --> 00:01:55,600

you can visualize this

49

00:02:00,069 --> 00:01:57,840

as being a vacuum where those blip blip

50

00:02:02,550 --> 00:02:00,079

blip little bursts of energy

51  
00:02:04,310 --> 00:02:02,560  
here and there and these bursts of

52  
00:02:08,550 --> 00:02:04,320  
electromagnetic energy

53  
00:02:11,350 --> 00:02:08,560  
cover uh the entire spectrum of

54  
00:02:12,470 --> 00:02:11,360  
frequencies and wavelengths if you take

55  
00:02:15,510 --> 00:02:12,480  
a look at this

56  
00:02:18,470 --> 00:02:15,520  
analytically we can see that

57  
00:02:19,830 --> 00:02:18,480  
there are two parts to the radiation in

58  
00:02:22,309 --> 00:02:19,840  
the vacuum

59  
00:02:24,470 --> 00:02:22,319  
the first part is the thermal radiation

60  
00:02:27,830 --> 00:02:24,480  
this is the planck distribution

61  
00:02:30,869 --> 00:02:27,840  
and its source is temperature somewhere

62  
00:02:32,869 --> 00:02:30,879  
of something the second part the  $h$ -bar

63  
00:02:35,589 --> 00:02:32,879

omega over two

64

00:02:36,869 --> 00:02:35,599

occurs even without any sort of source

65

00:02:38,630 --> 00:02:36,879

in free space

66

00:02:39,990 --> 00:02:38,640

and it's been known for a long time it's

67

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

the zero point energy

68

00:02:43,270 --> 00:02:42,000

and it's this energy that we're talking

69

00:03:01,589 --> 00:02:43,280

about

70

00:03:05,589 --> 00:03:03,110

and the answer is that there are a

71

00:03:08,390 --> 00:03:05,599

number of physical manifestations

72

00:03:09,350 --> 00:03:08,400

for a zero point energy i'm going to

73

00:03:12,550 --> 00:03:09,360

talk

74

00:03:15,350 --> 00:03:12,560

only about uh hooks

75

00:03:16,790 --> 00:03:15,360

batteries dead i'm going to talk only

76

00:03:18,790 --> 00:03:16,800

about two different

77

00:03:20,710 --> 00:03:18,800

physical manifestations to this

78

00:03:23,990 --> 00:03:20,720

zero-point energy

79

00:03:27,350 --> 00:03:24,000

one of them is the casimir force uh

80

00:03:32,229 --> 00:03:27,360

casimir in 1948

81

00:03:36,149 --> 00:03:32,239

showed theoretically that if you have

82

00:03:38,550 --> 00:03:36,159

two plates that are reflective plates

83

00:03:39,430 --> 00:03:38,560

that are in between those reflective

84

00:03:41,830 --> 00:03:39,440

plates

85

00:03:42,869 --> 00:03:41,840

because of the boundary conditions and

86

00:03:44,949 --> 00:03:42,879

interference

87

00:03:46,630 --> 00:03:44,959

you have only a limited number of

88

00:03:49,910 --> 00:03:46,640

electromagnetic modes

89

00:03:53,270 --> 00:03:49,920

that can exist whereas outside of those

90

00:03:56,070 --> 00:03:53,280

cat this casimir cavity you can have all

91

00:03:56,390 --> 00:03:56,080

electromagnetic modes and so we can see

92

00:04:03,750 --> 00:03:56,400

that

93

00:04:06,309 --> 00:04:03,760

cavity uh we've got uh only

94

00:04:07,910 --> 00:04:06,319

modes corresponding to uh wavelengths

95

00:04:08,630 --> 00:04:07,920

that are shorter than twice the gap

96

00:04:11,509 --> 00:04:08,640

spacing

97

00:04:13,030 --> 00:04:11,519

for the casimir cavity and outside all

98

00:04:15,429 --> 00:04:13,040

and the result

99

00:04:16,949 --> 00:04:15,439

is that there is more radiation pressure

100

00:04:19,030 --> 00:04:16,959

outside than inside

101  
00:04:20,150 --> 00:04:19,040  
and so these two plates are attracted

102  
00:04:23,990 --> 00:04:20,160  
together

103  
00:04:25,670 --> 00:04:24,000  
casimir predicted this in 1948 and

104  
00:04:27,590 --> 00:04:25,680  
over the years people have been

105  
00:04:27,990 --> 00:04:27,600  
measuring it and most recently have been

106  
00:04:30,550 --> 00:04:28,000  
measuring

107  
00:04:32,790 --> 00:04:30,560  
it to better than one percent accuracy

108  
00:04:35,350 --> 00:04:32,800  
and shown that in fact casimir is right

109  
00:04:37,430 --> 00:04:35,360  
so there is this casimir force it's real

110  
00:04:39,189 --> 00:04:37,440  
vacuum energy is palpable

111  
00:04:41,030 --> 00:04:39,199  
the second example that i'll give right

112  
00:04:44,070 --> 00:04:41,040  
now has to do with

113  
00:04:44,870 --> 00:04:44,080

vacuum fluctuations and noise and we

114

00:04:47,350 --> 00:04:44,880

know that in

115

00:04:48,230 --> 00:04:47,360

electronic devices resistors diodes and

116

00:04:49,909 --> 00:04:48,240

so on

117

00:04:52,070 --> 00:04:49,919

that after you get rid of all the other

118

00:04:54,870 --> 00:04:52,080

sources of noise there still is

119

00:04:55,990 --> 00:04:54,880

some basic noise and these fluctuations

120

00:04:58,390 --> 00:04:56,000

are due to zero point

121

00:04:59,189 --> 00:04:58,400

energy so this is well known the stuff

122

00:05:02,790 --> 00:04:59,199

is real

123

00:05:06,070 --> 00:05:02,800

now the question is uh can we use it

124

00:05:09,909 --> 00:05:06,080

and uh the answer is

125

00:05:12,550 --> 00:05:09,919

uh we haven't done so yet there are

126

00:05:14,150 --> 00:05:12,560

a number of different proposals for

127

00:05:15,350 --> 00:05:14,160

getting energy from the vacuum but as

128

00:05:18,629 --> 00:05:15,360

far as i know

129

00:05:19,189 --> 00:05:18,639

none of them has been reliably carried

130

00:05:22,710 --> 00:05:19,199

out

131

00:05:25,029 --> 00:05:22,720

and is reproducible so is this

132

00:05:27,110 --> 00:05:25,039

because we haven't found the right way

133

00:05:29,909 --> 00:05:27,120

or is there an underlying principle

134

00:05:31,110 --> 00:05:29,919

that limits us here and let's take a

135

00:05:33,110 --> 00:05:31,120

look at this

136

00:05:34,950 --> 00:05:33,120

in order to do this what i'm going to do

137

00:05:38,230 --> 00:05:34,960

is look at

138

00:05:41,590 --> 00:05:38,240

three different classes of inventions

139

00:05:44,550 --> 00:05:41,600

on extracting energy from the vacuum and

140

00:05:46,710 --> 00:05:44,560

see what the underlying principles are

141

00:05:49,830 --> 00:05:46,720

for each of these classes the first

142

00:05:50,629 --> 00:05:49,840

i'm calling non-linear extraction and it

143

00:05:53,270 --> 00:05:50,639

involves

144

00:05:54,629 --> 00:05:53,280

getting using these random fluctuations

145

00:05:56,950 --> 00:05:54,639

that we have somehow

146

00:05:59,270 --> 00:05:56,960

and extracting energy from them the

147

00:06:01,029 --> 00:05:59,280

second is mechanical extraction uses the

148

00:06:02,710 --> 00:06:01,039

force in casimir cavities

149

00:06:05,270 --> 00:06:02,720

and the third one is something different

150

00:06:08,230 --> 00:06:05,280

and that's passing

151

00:06:08,950 --> 00:06:08,240

material atoms gas through casimir

152

00:06:11,110 --> 00:06:08,960

cavities

153

00:06:12,309 --> 00:06:11,120

let's take a look at the first one so

154

00:06:13,830 --> 00:06:12,319

the first one

155

00:06:16,390 --> 00:06:13,840

has been described in a number of

156

00:06:20,070 --> 00:06:16,400

different places most completely

157

00:06:21,990 --> 00:06:20,080

uh recently by thomas vallone

158

00:06:23,270 --> 00:06:22,000

this year he wrote a paper called

159

00:06:26,150 --> 00:06:23,280

proposed use

160

00:06:28,150 --> 00:06:26,160

of zero bias diode arrays as thermal

161

00:06:31,350 --> 00:06:28,160

electric noise rectifiers

162

00:06:34,070 --> 00:06:31,360

and non-thermal energy harvesters

163

00:06:35,270 --> 00:06:34,080

and the basic idea is making use of a

164

00:06:38,390 --> 00:06:35,280

diode and i show

165

00:06:39,350 --> 00:06:38,400

uh from his paper a band diagram for a

166

00:06:41,990 --> 00:06:39,360

diode where

167

00:06:42,870 --> 00:06:42,000

electrons can move more easily downhill

168

00:06:45,749 --> 00:06:42,880

than they can move

169

00:06:48,230 --> 00:06:45,759

uphill and that means that if we've got

170

00:06:51,749 --> 00:06:48,240

random fluctuations they're rectified

171

00:06:53,029 --> 00:06:51,759

meaning that we'll get more in one

172

00:06:56,390 --> 00:06:53,039

direction than the other we

173

00:06:59,029 --> 00:06:56,400

ultimately end up with dc power

174

00:07:01,749 --> 00:06:59,039

so let's take a look at the underlying

175

00:07:05,029 --> 00:07:01,759

principle here

176

00:07:07,670 --> 00:07:05,039

in 19 in 1871

177

00:07:10,629 --> 00:07:07,680

maxwell was looking at the second law of

178

00:07:13,670 --> 00:07:10,639

thermodynamics and proposed a demon

179

00:07:14,230 --> 00:07:13,680

and his demon was a little fellow who

180

00:07:19,110 --> 00:07:14,240

would go

181

00:07:22,070 --> 00:07:19,120

through and selectively alter a process

182

00:07:24,230 --> 00:07:22,080

so as to make entropy decrease and break

183

00:07:26,870 --> 00:07:24,240

down the second law of thermodynamics

184

00:07:27,430 --> 00:07:26,880

the particular picture that i have here

185

00:07:31,670 --> 00:07:27,440

shows

186

00:07:33,830 --> 00:07:31,680

the demon allowing dark particles of gas

187

00:07:35,749 --> 00:07:33,840

to go to the right but not light

188

00:07:36,870 --> 00:07:35,759

particles to go to the right so he opens

189

00:07:39,110 --> 00:07:36,880

this little door

190

00:07:40,469 --> 00:07:39,120

and lets gas through only one way than

191

00:07:41,270 --> 00:07:40,479

rather than the other way the same

192

00:07:43,430 --> 00:07:41,280

process

193

00:07:44,869 --> 00:07:43,440

can be carried out for heat and various

194

00:07:47,909 --> 00:07:44,879

other

195

00:07:48,550 --> 00:07:47,919

phenomena and in that way one should be

196

00:07:50,869 --> 00:07:48,560

able to

197

00:07:53,110 --> 00:07:50,879

reduce the entropy and break the second

198

00:07:56,950 --> 00:07:53,120

law of thermodynamics

199

00:07:59,189 --> 00:07:56,960

it doesn't work many different

200

00:08:00,070 --> 00:07:59,199

maxwell's demons have been proposed over

201  
00:08:02,869 --> 00:08:00,080  
the years

202  
00:08:04,469 --> 00:08:02,879  
uh some of them very ingenious and one

203  
00:08:05,909 --> 00:08:04,479  
by one they've been picked apart and we

204  
00:08:06,629 --> 00:08:05,919  
find out that it doesn't work and

205  
00:08:09,110 --> 00:08:06,639  
actually

206  
00:08:10,629 --> 00:08:09,120  
uh the fundamental reason has to do with

207  
00:08:14,150 --> 00:08:10,639  
information theory but that's

208  
00:08:17,510 --> 00:08:14,160  
for another talk so

209  
00:08:21,189 --> 00:08:17,520  
that means that if we are talking about

210  
00:08:24,390 --> 00:08:21,199  
a thermal uh distribution

211  
00:08:26,869 --> 00:08:24,400  
in equilibrium we cannot obtain

212  
00:08:28,390 --> 00:08:26,879  
energy from it we cannot contain power

213  
00:08:31,589 --> 00:08:28,400

from it

214

00:08:34,790 --> 00:08:31,599

why not you can look at it

215

00:08:37,829 --> 00:08:34,800

in a kinetic way using einstein's

216

00:08:40,389 --> 00:08:37,839

detailed balance in 1917

217

00:08:42,550 --> 00:08:40,399

einstein discussed the fact that

218

00:08:45,190 --> 00:08:42,560

detailed balance exists

219

00:08:46,710 --> 00:08:45,200

if we have a multi-state system in

220

00:08:50,310 --> 00:08:46,720

equilibrium

221

00:08:52,550 --> 00:08:50,320

that in that system every process

222

00:08:53,990 --> 00:08:52,560

every transition rate in one direction

223

00:08:55,910 --> 00:08:54,000

is matched by an equal and

224

00:08:58,790 --> 00:08:55,920

opposite transition rate in the other

225

00:09:03,030 --> 00:08:58,800

direction and so by detailed balance

226

00:09:06,070 --> 00:09:03,040

the uh the there can be no

227

00:09:08,550 --> 00:09:06,080

net flow between any two states

228

00:09:10,070 --> 00:09:08,560

this always occurs when we are in

229

00:09:14,070 --> 00:09:10,080

equilibrium

230

00:09:16,790 --> 00:09:14,080

again this was looked at initially

231

00:09:17,430 --> 00:09:16,800

for thermal equilibrium and the question

232

00:09:21,590 --> 00:09:17,440

is

233

00:09:25,030 --> 00:09:21,600

energy

234

00:09:27,509 --> 00:09:25,040

is a true

235

00:09:29,190 --> 00:09:27,519

equilibrium state uh this has been

236

00:09:30,070 --> 00:09:29,200

discussed in the literature for a number

237

00:09:33,230 --> 00:09:30,080

of years

238

00:09:35,030 --> 00:09:33,240

and shown very rigorously by dannon in

239

00:09:38,150 --> 00:09:35,040

2005.

240

00:09:41,190 --> 00:09:38,160

so that means that in

241

00:09:43,430 --> 00:09:41,200

a zero point energy as with thermal

242

00:09:46,790 --> 00:09:43,440

energy and every other sort of energy

243

00:09:47,829 --> 00:09:46,800

you cannot create a non-linear

244

00:09:51,509 --> 00:09:47,839

extraction

245

00:09:54,310 --> 00:09:51,519

from fluctuations even though the diode

246

00:09:55,910 --> 00:09:54,320

allows electrons to go one way more

247

00:09:57,910 --> 00:09:55,920

easily than the other way