

1
00:00:01,280 --> 00:00:08,759
good morning so we've heard over a

2
00:00:05,250 --> 00:00:10,710
number of years at the SSE and elsewhere

3
00:00:08,759 --> 00:00:14,279
about zero-point energy

4
00:00:10,710 --> 00:00:16,320
vacuum technology and that this is the

5
00:00:14,279 --> 00:00:18,539
the ambient zero-point energy

6
00:00:16,320 --> 00:00:21,689
background is going to provide energy

7
00:00:18,539 --> 00:00:25,199
that will meet all of our needs and yet

8
00:00:21,689 --> 00:00:27,210
it hasn't happened and today what I want

9
00:00:25,199 --> 00:00:31,260
to do is ask the question from a

10
00:00:27,210 --> 00:00:34,380
fundamental level why is there in fact

11
00:00:31,260 --> 00:00:36,929
the possibility of obtaining continuous

12
00:00:34,380 --> 00:00:40,170
power from the vacuum or are we diluting

13
00:00:36,929 --> 00:00:44,488
ourselves so let's take a look at some

14
00:00:40,170 --> 00:00:47,489
basic principles behind obtaining energy

15
00:00:44,488 --> 00:00:52,229
from the vacuum so the first question is

16
00:00:47,488 --> 00:00:53,909
what is vacuum energy and we can see oh

17
00:00:52,229 --> 00:00:56,099
I'm sorry that's not the right type of

18
00:00:53,909 --> 00:00:59,250
vacuum energy let me try again so the

19
00:00:56,100 --> 00:01:04,820
question is what is vacuum energy and it

20
00:00:59,250 --> 00:01:04,819
is zero-point energy that fills almost

21
00:01:05,650 --> 00:01:17,180
just okay thanks yeah please I'll talk

22
00:01:13,519 --> 00:01:21,170
louder thank you so the question is what

23
00:01:17,180 --> 00:01:22,880
is this this energy we know from quantum

24
00:01:21,170 --> 00:01:25,280
mechanics and elsewhere from the

25
00:01:22,879 --> 00:01:30,500
uncertainty principle that there is

26
00:01:25,280 --> 00:01:33,200
energy in every mechanical system and

27
00:01:30,500 --> 00:01:34,939
that this energy never goes to zero and

28
00:01:33,200 --> 00:01:37,250
that's why it's called zero-point energy

29

00:01:34,939 --> 00:01:39,649
because even at zero temperature there

30
00:01:37,250 --> 00:01:42,469
still is some energy in the system not

31
00:01:39,649 --> 00:01:44,689
only is there energy in every physical

32
00:01:42,469 --> 00:01:47,090
system but there is energy in free space

33
00:01:44,689 --> 00:01:50,179
itself in the vacuum and this takes

34
00:01:47,090 --> 00:01:52,100
multiple different forms the form that

35
00:01:50,179 --> 00:01:54,289
we're considering right now is

36
00:01:52,099 --> 00:01:56,569
electromagnetic fluctuations and so you

37
00:01:54,289 --> 00:01:59,359
can visualize this as being a vacuum

38
00:01:56,569 --> 00:02:02,029
where those blip-blip look little bursts

39
00:01:59,359 --> 00:02:05,259
of energy here and there and these

40
00:02:02,030 --> 00:02:09,199
bursts of electromagnetic energy cover

41
00:02:05,259 --> 00:02:12,280
the entire spectrum of frequencies and

42
00:02:09,199 --> 00:02:15,859
wavelengths if you take a look at this

43
00:02:12,280 --> 00:02:19,099

analytically we can see that there are

44

00:02:15,860 --> 00:02:21,950

two parts to the radiation in the vacuum

45

00:02:19,099 --> 00:02:25,069

the first part is the thermal radiation

46

00:02:21,949 --> 00:02:27,889

this is the planck distribution and if

47

00:02:25,069 --> 00:02:30,919

source is temperature somewhere of

48

00:02:27,889 --> 00:02:34,399

something the second part the H bar

49

00:02:30,919 --> 00:02:37,280

Omega over 2 occurs even without any

50

00:02:34,400 --> 00:02:38,900

sort of source in free space and it's

51

00:02:37,280 --> 00:02:40,849

been known for a long time it's the

52

00:02:38,900 --> 00:02:44,000

zero-point energy and it's this energy

53

00:02:40,849 --> 00:02:47,620

that we're talking about and we want to

54

00:02:44,000 --> 00:02:47,620

see now Kent

55

00:02:51,860 --> 00:02:59,150

construct it comes out of quantitative

56

00:02:56,150 --> 00:02:59,150

length

57

00:03:06,449 --> 00:03:17,318

I want to talk only about I'm going to

58
00:03:14,500 --> 00:03:19,919
talk only about two different physical

59
00:03:17,318 --> 00:03:24,280
manifestations to this zero-point energy

60
00:03:19,919 --> 00:03:27,789
one of them is the Casimir force as a

61
00:03:24,280 --> 00:03:33,340
mayor in 1948 should show it

62
00:03:27,789 --> 00:03:37,000
theoretically but if you have two plates

63
00:03:33,340 --> 00:03:39,670
that are reflective plates that in

64
00:03:37,000 --> 00:03:41,860
between those reflective plates because

65
00:03:39,669 --> 00:03:44,199
of the boundary conditions and

66
00:03:41,860 --> 00:03:46,900
interference you have only a limited

67
00:03:44,199 --> 00:03:50,379
number of electromagnetic modes that can

68
00:03:46,900 --> 00:03:52,830
exist whereas outside of those caddis

69
00:03:50,379 --> 00:03:55,810
Casimir cavity you can have all

70
00:03:52,830 --> 00:03:59,890
electromagnetic modes and so we can see

71
00:03:55,810 --> 00:04:01,030
that whoops that within the Casimir

72
00:03:59,889 --> 00:04:05,399
cavity

73
00:04:01,030 --> 00:04:07,449
we've got only modes corresponding to

74
00:04:05,400 --> 00:04:09,789
wavelengths that are shorter than twice

75
00:04:07,449 --> 00:04:13,149
the gap spacing for the Casimir cavity

76
00:04:09,789 --> 00:04:15,909
and outside all and the result is that

77
00:04:13,150 --> 00:04:18,579
there is more radiation pressure outside

78
00:04:15,909 --> 00:04:19,738
than inside and so these two plates are

79
00:04:18,579 --> 00:04:24,310
attracted together

80
00:04:19,738 --> 00:04:26,409
Casimir predicted this in 1948 and over

81
00:04:24,310 --> 00:04:28,149
the years people have been measuring it

82
00:04:26,410 --> 00:04:30,250
and most recently have been measuring it

83
00:04:28,149 --> 00:04:33,009
to better than one percent accuracy and

84
00:04:30,250 --> 00:04:34,990
shown that in fact Casimir is right so

85
00:04:33,009 --> 00:04:36,819
there is this Casimir force it's real

86

00:04:34,990 --> 00:04:39,220
vacuum energy is palpable

87
00:04:36,819 --> 00:04:42,430
the second example that I'll give right

88
00:04:39,220 --> 00:04:45,550
now has to do with vacuum fluctuations

89
00:04:42,430 --> 00:04:48,459
and noise and we know that in electronic

90
00:04:45,550 --> 00:04:49,900
devices resistors diodes and so on that

91
00:04:48,459 --> 00:04:52,060
after you get rid of all the other

92
00:04:49,899 --> 00:04:55,120
sources of noise there still is some

93
00:04:52,060 --> 00:04:57,399
basic noise and these fluctuations are

94
00:04:55,120 --> 00:05:00,069
due to zero-point energy so this is well

95
00:04:57,399 --> 00:05:06,519
known the stuff is real now the question

96
00:05:00,069 --> 00:05:08,180
is can we use it and the answer is we

97
00:05:06,519 --> 00:05:11,079
haven't done so yet

98
00:05:08,180 --> 00:05:13,550
there are a number of different

99
00:05:11,079 --> 00:05:15,948
proposals for getting energy from the

100
00:05:13,550 --> 00:05:19,850

vacuum but as far as I know none of them

101

00:05:15,949 --> 00:05:23,270

has been reliably carried out and is

102

00:05:19,850 --> 00:05:25,639

reproducible so is this because we

103

00:05:23,269 --> 00:05:27,978

haven't found the right way or is there

104

00:05:25,639 --> 00:05:31,310

an underlying principle that limits us

105

00:05:27,978 --> 00:05:33,258

here and let's take a look at this in

106

00:05:31,310 --> 00:05:36,740

order to do this what I'm going to do is

107

00:05:33,259 --> 00:05:40,038

look at three different classes of

108

00:05:36,740 --> 00:05:42,680

inventions on extracting energy from the

109

00:05:40,038 --> 00:05:45,589

vacuum and see what the underlying

110

00:05:42,680 --> 00:05:46,668

principles are for each of these classes

111

00:05:45,589 --> 00:05:49,758

the first

112

00:05:46,668 --> 00:05:52,370

I'm calling nonlinear extraction and it

113

00:05:49,759 --> 00:05:54,560

involves getting using these random

114

00:05:52,370 --> 00:05:57,379

fluctuations that we have somehow and

115
00:05:54,560 --> 00:05:59,598
extracting energy from them the second

116
00:05:57,379 --> 00:06:01,728
is mechanical extraction uses the force

117
00:05:59,598 --> 00:06:03,079
and Casimir cavities and the third one

118
00:06:01,728 --> 00:06:07,728
is something different and that's

119
00:06:03,079 --> 00:06:09,740
passing material atoms gas through

120
00:06:07,728 --> 00:06:12,769
Casimir cavities let's take a look at

121
00:06:09,740 --> 00:06:14,240
the first one so the first one has been

122
00:06:12,769 --> 00:06:17,959
described in a number of different

123
00:06:14,240 --> 00:06:21,590
places most completely recently by a

124
00:06:17,959 --> 00:06:24,859
Thomas Malone this year he wrote a paper

125
00:06:21,589 --> 00:06:26,869
called proposed use of zero bias diode

126
00:06:24,860 --> 00:06:29,840
arrays as thermal electric noise

127
00:06:26,870 --> 00:06:33,348
rectifiers and non thermal energy

128
00:06:29,839 --> 00:06:36,619
harvesters and the basic idea is making

129
00:06:33,348 --> 00:06:39,079
use of a diode and I show from his paper

130
00:06:36,620 --> 00:06:41,689
a band diagram for a diode where

131
00:06:39,079 --> 00:06:45,019
electrons can move more easily downhill

132
00:06:41,689 --> 00:06:47,000
than they can move uphill and that means

133
00:06:45,019 --> 00:06:51,109
that if we've got random fluctuations

134
00:06:47,000 --> 00:06:52,819
they're rectified meaning that we'll get

135
00:06:51,110 --> 00:06:56,598
more in one direction than the other we

136
00:06:52,819 --> 00:06:58,939
all ultimately end up with DC power so

137
00:06:56,598 --> 00:07:04,629
let's take a look at the underlying

138
00:06:58,939 --> 00:07:07,639
principle here in nineteen in 1871

139
00:07:04,629 --> 00:07:09,860
Maxwell was looking at the second law of

140
00:07:07,639 --> 00:07:13,699
thermodynamics and proposed the demon

141
00:07:09,860 --> 00:07:17,230
and his demon was a little fellow who

142
00:07:13,699 --> 00:07:21,430
would go through and selectively alter

143

00:07:17,230 --> 00:07:23,200
a process so as to make entropy decrease

144
00:07:21,430 --> 00:07:25,240
and break down the second law of

145
00:07:23,199 --> 00:07:28,089
thermodynamics the particular picture

146
00:07:25,240 --> 00:07:32,170
that I have here shows the demon

147
00:07:28,089 --> 00:07:34,689
allowing dark particles of gas to go to

148
00:07:32,170 --> 00:07:36,280
the right but not light particles to go

149
00:07:34,689 --> 00:07:38,620
to the right so he opens this little

150
00:07:36,279 --> 00:07:40,269
door and lets gas through only one way

151
00:07:38,620 --> 00:07:42,730
than other than the other way the same

152
00:07:40,269 --> 00:07:47,079
process can be carried out for heat and

153
00:07:42,730 --> 00:07:49,930
various other phenomena and in that way

154
00:07:47,079 --> 00:07:51,099
one should be able to reduce the entropy

155
00:07:49,930 --> 00:07:55,530
and break the second law of

156
00:07:51,100 --> 00:07:58,420
thermodynamics it doesn't work many

157
00:07:55,529 --> 00:08:00,879

different Maxwell's demons have been

158

00:07:58,420 --> 00:08:03,550

proposed over the years some of them

159

00:08:00,879 --> 00:08:04,990

very ingenious and one by one they've

160

00:08:03,550 --> 00:08:07,300

been picked apart and we find out that

161

00:08:04,990 --> 00:08:09,100

it doesn't work and actually the

162

00:08:07,300 --> 00:08:10,870

fundamental reason has to do with

163

00:08:09,100 --> 00:08:16,120

information theory but that's for

164

00:08:10,870 --> 00:08:20,399

another talk so that means that if we

165

00:08:16,120 --> 00:08:24,189

are talking about a thermal distribution

166

00:08:20,399 --> 00:08:27,659

in equilibrium we cannot obtain energy

167

00:08:24,189 --> 00:08:32,379

from it we cannot contain power from it

168

00:08:27,660 --> 00:08:36,330

why not you can look at it in a kinetic

169

00:08:32,379 --> 00:08:40,090

way using einstein's detailed balance in

170

00:08:36,330 --> 00:08:43,180

1917 Einstein discussed the fact that

171

00:08:40,090 --> 00:08:46,899

detailed balance exists if we have a

172
00:08:43,179 --> 00:08:50,469
multi state system in equilibrium that

173
00:08:46,899 --> 00:08:52,419
in that system every process every

174
00:08:50,470 --> 00:08:54,399
transition rate in one direction is

175
00:08:52,419 --> 00:08:56,169
matched by an equal and opposite

176
00:08:54,399 --> 00:09:02,019
transition rate in the other direction

177
00:08:56,169 --> 00:09:04,809
and so by detail balance the the there

178
00:09:02,019 --> 00:09:08,500
can be no net flow between any two

179
00:09:04,809 --> 00:09:13,029
states this always occurs when we are in

180
00:09:08,500 --> 00:09:16,000
equilibrium again this was looked at

181
00:09:13,029 --> 00:09:19,389
initially for thermal equilibrium and

182
00:09:16,000 --> 00:09:22,750
the question is does this also apply to

183
00:09:19,389 --> 00:09:25,480
zero-point energy well it turns out that

184
00:09:22,750 --> 00:09:28,240
zero-point energy is a true equilibrium

185
00:09:25,480 --> 00:09:29,100
State this has been discussed in the

186
00:09:28,240 --> 00:09:31,340
literature for

187
00:09:29,100 --> 00:09:35,550
number of years and shown very

188
00:09:31,340 --> 00:09:39,780
rigorously by Danone in 2005 so that

189
00:09:35,549 --> 00:09:42,449
means that in a zero point energy as

190
00:09:39,779 --> 00:09:46,649
with thermal energy and every other sort

191
00:09:42,450 --> 00:09:50,280
of energy you cannot create a nonlinear

192
00:09:46,649 --> 00:09:53,789
extraction from fluctuations even though

193
00:09:50,279 --> 00:09:56,039
the diode allows electrons to go one way

194
00:09:53,789 --> 00:09:57,870
more easily than the other way in

195
00:09:56,039 --> 00:10:01,730
thermal equilibrium there's detailed

196
00:09:57,870 --> 00:10:01,730
balance and the electrons go