Does Pressure Have Inertia?

- Einstein's classic $E=mc^2$ was basically a demonstration that energy has inertia ($m=E/c^2$).
- It's not immediately obvious whether this proof applies to all terms in $T_{\mu\nu}$ or only to the energy terms.
- If the pressure terms in $T_{\mu\nu}$ don't add to inertia, then we can decouple inertial mass from gravitational mass. Internal pressure will make an object create a stronger gravitational field without changing its inertia.

1
00:00:00,160 --> 00:00:05,829
joke

2
00:00:12,230 --> 00:00:09,110
york is from princeton university he's a

3
00:00:17,670 --> 00:00:12,240
colleague from the pear lab and

4
00:00:20,070 --> 00:00:17,680
a physicist with wide ranging interests

5
00:00:21,590 --> 00:00:20,080
looking forward to seeing what he has to

6
00:00:31,990 --> 00:00:21,600
say about advanced

7
00:00:37,190 --> 00:00:34,950
okay well let me begin by talking about

8
00:00:39,030 --> 00:00:37,200
what this talk is not

9
00:00:40,950 --> 00:00:39,040
i'm not going to be discussing warp

10
00:00:43,430 --> 00:00:40,960
drives or any other

11
00:00:44,150 --> 00:00:43,440
uh technique for moving faster than

12
00:00:46,069 --> 00:00:44,160
light

13
00:00:47,750 --> 00:00:46,079

when i use space propulsion in the title

14
00:00:50,470 --> 00:00:47,760
i simply mean

15
00:00:51,350 --> 00:00:50,480
taking an object preferably a spacecraft

16
00:00:53,430 --> 00:00:51,360
and

17
00:00:55,189 --> 00:00:53,440
getting it to move through the

18
00:00:57,110 --> 00:00:55,199
three-dimensional space that we're

19
00:00:59,430 --> 00:00:57,120
all familiar with at speeds slower than

20
00:01:02,549 --> 00:00:59,440
light

21
00:01:05,189 --> 00:01:02,559
so as an outline

22
00:01:07,109 --> 00:01:05,199
there are a number of systems that we

23
00:01:08,149 --> 00:01:07,119
know for space propulsion that are in

24
00:01:11,030 --> 00:01:08,159
use

25
00:01:12,870 --> 00:01:11,040
and i describe them as having failings

26
00:01:14,390 --> 00:01:12,880
because generally they do less than we'd

27
00:01:16,630 --> 00:01:14,400
like

28
00:01:18,390 --> 00:01:16,640
um i'm going to discuss why some of

29
00:01:19,990 --> 00:01:18,400
these failings seem to be mandated by

30
00:01:21,830 --> 00:01:20,000
physical law

31
00:01:24,310 --> 00:01:21,840
some theoretical alternatives that may

32
00:01:25,910 --> 00:01:24,320
allow better propulsion systems to exist

33
00:01:28,870 --> 00:01:25,920
i'm going to review some specific

34
00:01:31,030 --> 00:01:28,880
proposals for such systems

35
00:01:32,870 --> 00:01:31,040
but i ask the audience to remember that

36
00:01:35,670 --> 00:01:32,880
all of these specific proposals are

37
00:01:43,350 --> 00:01:39,749
so let's start with the basic

38
00:01:45,350 --> 00:01:43,360

um you move something through space by

39
00:01:46,950 --> 00:01:45,360
throwing mass away in one direction to

40
00:01:49,590 --> 00:01:46,960
accelerate in the other direction

41
00:01:50,389 --> 00:01:49,600
this is all in accordance with newton's

42
00:01:53,990 --> 00:01:50,399
third law

43
00:01:55,990 --> 00:01:54,000
and the conservation of momentum now

44
00:01:58,709 --> 00:01:56,000
they're not usually called rockets but i

45
00:01:59,109 --> 00:01:58,719
am classifying ion drives plasma drives

46
00:02:01,910 --> 00:01:59,119
even

47
00:02:03,190 --> 00:02:01,920
exotic speculations like an antimatter

48
00:02:05,510 --> 00:02:03,200
neutrino drive

49
00:02:08,309 --> 00:02:05,520
as basically rockets because they all

50
00:02:10,949 --> 00:02:08,319
work the same way

51
00:02:12,390 --> 00:02:10,959
now if conservation of momentum holds

52
00:02:14,390 --> 00:02:12,400
the rocket is in fact

53
00:02:15,589 --> 00:02:14,400
the only possible completely

54
00:02:18,710 --> 00:02:15,599
self-contained

55
00:02:19,990 --> 00:02:18,720
space propulsion system and somewhat

56
00:02:21,750 --> 00:02:20,000
annoyingly

57
00:02:23,830 --> 00:02:21,760
all rockets suffer from the rocket

58
00:02:27,270 --> 00:02:23,840
paradox

59
00:02:30,470 --> 00:02:27,280
here's an example we've got

60
00:02:32,070 --> 00:02:30,480
uh exhaust velocity the speed at which

61
00:02:34,309 --> 00:02:32,080
you're ejecting matter

62
00:02:35,270 --> 00:02:34,319
express uh plotted across the bottom

63
00:02:37,430 --> 00:02:35,280

here

64
00:02:40,949 --> 00:02:37,440
maxing out at the speed of light because

65
00:02:43,750 --> 00:02:40,959
you can't throw anything away any faster

66
00:02:46,070 --> 00:02:43,760
mass consumption goes down energy

67
00:02:47,830 --> 00:02:46,080
consumption goes up

68
00:02:49,270 --> 00:02:47,840
the more efficient your rocket is in

69
00:02:51,830 --> 00:02:49,280
terms of its

70
00:02:52,710 --> 00:02:51,840
use of mass the less efficient it is in

71
00:02:56,550 --> 00:02:52,720
terms of

72
00:03:02,869 --> 00:02:59,670
in addition there is the

73
00:03:07,670 --> 00:03:05,509
the velocity at which you throw away

74
00:03:10,869 --> 00:03:07,680
your reaction mass

75
00:03:12,550 --> 00:03:10,879
um is pretty much a constraint

76
00:03:14,470 --> 00:03:12,560
on how much you can maneuver on what

77
00:03:18,149 --> 00:03:14,480
total change of velocity

78
00:03:21,350 --> 00:03:18,159
you can accomplish um specifically

79
00:03:21,910 --> 00:03:21,360
the total mass of fuel you need or

80
00:03:23,990 --> 00:03:21,920
rather

81
00:03:26,390 --> 00:03:24,000
the ratio of your fuel mass to the

82
00:03:30,869 --> 00:03:26,400
payload mass you're trying to move

83
00:03:33,589 --> 00:03:30,879
grows exponentially with the ratio of

84
00:03:35,110 --> 00:03:33,599
the delta v the velocity change you want

85
00:03:38,789 --> 00:03:35,120
to accomplish

86
00:03:41,990 --> 00:03:38,799
to the speed at which you're ejecting

87
00:03:45,110 --> 00:03:42,000
the fuel the blue curve

88
00:03:48,869 --> 00:03:45,120

here is a plot of the

89
00:03:49,750 --> 00:03:48,879
rocket equation in uh dimensionless

90
00:03:52,229 --> 00:03:49,760
units uh

91
00:03:53,990 --> 00:03:52,239
just the ratio of of your desired

92
00:03:58,830 --> 00:03:54,000
velocity change to your

93
00:04:01,509 --> 00:03:58,840
exhaust speed uh these other

94
00:04:03,509 --> 00:04:01,519
um uh straight lines

95
00:04:06,070 --> 00:04:03,519
are based on the chemical rockets we're

96
00:04:09,670 --> 00:04:06,080
building these days

97
00:04:11,830 --> 00:04:09,680
uh the green line is uh the minimum

98
00:04:13,589 --> 00:04:11,840
requirements for velocity change for

99
00:04:15,990 --> 00:04:13,599
planetary missions such as nasa is

100
00:04:19,189 --> 00:04:16,000
conducting right now

101
00:04:23,749 --> 00:04:19,199
um and

102
00:04:26,150 --> 00:04:23,759
the red horizontal line is the

103
00:04:28,550 --> 00:04:26,160
our maximum engineering capability in

104
00:04:29,189 --> 00:04:28,560
terms of how much fuel we can cram onto

105
00:04:30,950 --> 00:04:29,199
the thing

106
00:04:32,950 --> 00:04:30,960
in terms relative to the mass of the

107
00:04:36,390 --> 00:04:32,960
structure required to hold it

108
00:04:38,390 --> 00:04:36,400
um the fact that this intersection is

109
00:04:40,469 --> 00:04:38,400
below this intersection is what makes

110
00:04:41,990 --> 00:04:40,479
planetary missions possible

111
00:04:43,590 --> 00:04:42,000
and the fact that they're so close to

112
00:04:46,310 --> 00:04:43,600
each other is what makes them so slow

113
00:04:51,350 --> 00:04:49,590

um so if

114
00:04:53,350 --> 00:04:51,360
conservation of energy and momentum

115
00:04:55,030 --> 00:04:53,360
forces the rocket paradox onto any

116
00:04:56,390 --> 00:04:55,040
self-contained drive

117
00:04:58,710 --> 00:04:56,400
what about systems that aren't

118
00:05:01,110 --> 00:04:58,720
self-contained we've seen allusions to

119
00:05:03,590 --> 00:05:01,120
some of these in previous talks

120
00:05:05,909 --> 00:05:03,600
light sails get thrust by reflecting

121
00:05:08,950 --> 00:05:05,919
radiation from an outside source

122
00:05:11,110 --> 00:05:08,960
the basard ramjet we we saw it discussed

123
00:05:12,390 --> 00:05:11,120
as a fusion ramjet i i like to credit

124
00:05:13,749 --> 00:05:12,400
the guy who seems to have come up with

125
00:05:16,629 --> 00:05:13,759
the original idea

126
00:05:18,790 --> 00:05:16,639
you scoop up the ambient medium as fuel

127
00:05:22,070 --> 00:05:18,800
current carrying tethers get thrust from

128
00:05:23,830 --> 00:05:22,080
exploiting ambient magnetic fields

129
00:05:26,710 --> 00:05:23,840
magnetic sails get thrust from

130
00:05:30,629 --> 00:05:26,720
deflecting ambient plasma

131
00:05:32,870 --> 00:05:30,639
the ramjet may be impossible um

132
00:05:34,310 --> 00:05:32,880
collecting interstellar hydrogen is a

133
00:05:36,710 --> 00:05:34,320
hard problem in itself

134
00:05:38,629 --> 00:05:36,720
and getting it to undergo fusion on the

135
00:05:40,310 --> 00:05:38,639
fly is even harder

136
00:05:42,390 --> 00:05:40,320
all of the other systems are dependent

137
00:05:44,790 --> 00:05:42,400
on special environments or support from

138
00:05:50,710 --> 00:05:47,749

the core problem that makes all of these

139
00:05:52,550 --> 00:05:50,720
drives unsatisfactory

140
00:05:55,510 --> 00:05:52,560
unfortunately happens to be two basic

141
00:05:58,629 --> 00:05:55,520
laws of physics conservation of energy

142
00:06:01,350 --> 00:05:58,639
and conservation of momentum now

143
00:06:02,710 --> 00:06:01,360
in relativity these are the same law

144
00:06:04,790 --> 00:06:02,720
energy and momentum

145
00:06:07,909 --> 00:06:04,800
form a relativistic four vector and all

146
00:06:09,670 --> 00:06:07,919
of its components are conserved

147
00:06:13,270 --> 00:06:09,680
unfortunately you can't escape the

148
00:06:14,629 --> 00:06:13,280
problem just by rejecting relativity

149
00:06:16,870 --> 00:06:14,639
there's something called nether's

150
00:06:19,350 --> 00:06:16,880
theorem in mathematical physics

151
00:06:21,189 --> 00:06:19,360
a very long-standing result it's a

152
00:06:23,430 --> 00:06:21,199
mathematical proof

153
00:06:24,710 --> 00:06:23,440
that any continuous symmetry in a

154
00:06:26,469 --> 00:06:24,720
physical law

155
00:06:28,390 --> 00:06:26,479
leads to the existence of a conserved

156
00:06:30,309 --> 00:06:28,400
quantity

157
00:06:32,070 --> 00:06:30,319
the result of having physical laws that

158
00:06:34,870 --> 00:06:32,080
don't change over time

159
00:06:37,749 --> 00:06:34,880
is the total energy has to be conserved

160
00:06:39,590 --> 00:06:37,759
similarly momentum conservation follows

161
00:06:41,350 --> 00:06:39,600
from the fact that physical laws don't

162
00:06:42,230 --> 00:06:41,360
change when you move from one place to

163
00:06:44,230 --> 00:06:42,240

another

164
00:06:46,150 --> 00:06:44,240
i step from here to here the laws of

165
00:06:48,070 --> 00:06:46,160
physics are the same in both places

166
00:06:51,189 --> 00:06:48,080
therefore momentum is conserved

167
00:06:54,469 --> 00:06:51,199
according to nether's theorem

168
00:06:56,950 --> 00:06:54,479
but there is a loophole

169
00:06:58,230 --> 00:06:56,960
the tensor calculus used in general

170
00:07:00,070 --> 00:06:58,240
relativity

171
00:07:01,670 --> 00:07:00,080
satisfies the defining symmetries of

172
00:07:04,710 --> 00:07:01,680
general relativity

173
00:07:06,870 --> 00:07:04,720
automatically as a matter of notation

174
00:07:08,230 --> 00:07:06,880
the nether construction becomes trivial

175
00:07:11,990 --> 00:07:08,240
it doesn't allow you to

176
00:07:14,550 --> 00:07:12,000
compute a conserved quantity

177
00:07:16,070 --> 00:07:14,560
in fact energy and momentum conservation

178
00:07:19,430 --> 00:07:16,080
in general relativity

179
00:07:19,990 --> 00:07:19,440
have only been proven for simple special

180
00:07:23,110 --> 00:07:20,000
cases

181
00:07:24,309 --> 00:07:23,120
there is no general proof so the

182
00:07:27,270 --> 00:07:24,319
conservation laws

183
00:07:28,629 --> 00:07:27,280
may not hold for the full theory in fact

184
00:07:31,749 --> 00:07:28,639
when you're dealing with an

185
00:07:32,710 --> 00:07:31,759
arbitrarily curved space time such as is

186
00:07:34,790 --> 00:07:32,720
allowed

187
00:07:36,309 --> 00:07:34,800
for the theory it becomes a little bit

188
00:07:38,150 --> 00:07:36,319

difficult to figure out what something

189
00:07:42,390 --> 00:07:38,160
like an energy density even

190
00:07:47,270 --> 00:07:45,510
uh digressing for a moment for most of

191
00:07:50,629 --> 00:07:47,280
this talk i'm assuming that's both

192
00:07:52,469 --> 00:07:50,639
special and general relativity are true

193
00:07:55,189 --> 00:07:52,479
uh now there's a lot of evidence for

194
00:07:58,550 --> 00:07:55,199
this and any alternative theory

195
00:07:59,110 --> 00:07:58,560
if it is to be taken seriously has to

196
00:08:00,950 --> 00:07:59,120
match

197
00:08:02,629 --> 00:08:00,960
a tremendous body of observational

198
00:08:06,230 --> 00:08:02,639
evidence that confirms

199
00:08:07,790 --> 00:08:06,240
both special and general relativity um

200
00:08:09,510 --> 00:08:07,800
however since there are some

201
00:08:12,469 --> 00:08:09,520
anti-relativists around

202
00:08:14,309 --> 00:08:12,479
especially in the sse uh it seems

203
00:08:16,790 --> 00:08:14,319
important to consider alternatives at

204
00:08:19,110 --> 00:08:16,800
least briefly

205
00:08:20,550 --> 00:08:19,120
uh now general relativity is

206
00:08:24,150 --> 00:08:20,560
mathematically unique

207
00:08:27,430 --> 00:08:24,160
it's the only theory that uh

208
00:08:30,070 --> 00:08:27,440
that that satisfies the appropriate

209
00:08:31,589 --> 00:08:30,080
symmetries uh except for little bells

210
00:08:33,909 --> 00:08:31,599
and whistles like whether or not there's

211
00:08:37,269 --> 00:08:33,919
a cosmological constant

212
00:08:38,870 --> 00:08:37,279
if gr is wrong there's no way i should

213
00:08:39,509 --> 00:08:38,880

qualify that there's no way that i know

214
00:08:41,990 --> 00:08:39,519
of

215
00:08:42,709 --> 00:08:42,000
to avoid the nether construction and

216
00:08:44,790 --> 00:08:42,719
we're stuck

217
00:08:47,350 --> 00:08:44,800
with conservation laws that are

218
00:08:50,389 --> 00:08:47,360
technologically inconvenient

219
00:08:52,870 --> 00:08:50,399
however a non-relativistic theory

220
00:08:53,670 --> 00:08:52,880
by definition admits the possibility of

221
00:08:56,790 --> 00:08:53,680
non-local

222
00:08:57,829 --> 00:08:56,800
interactions that propagate faster than

223
00:08:59,910 --> 00:08:57,839
light

224
00:09:02,550 --> 00:08:59,920
which can create the local appearance of

225
00:09:07,190 --> 00:09:02,560
not momentum non-conservation by having

226
00:09:11,030 --> 00:09:08,990
uh in the most extreme case a

227
00:09:13,190 --> 00:09:11,040
non-relativistic theory might allow

228
00:09:15,430 --> 00:09:13,200
instantaneous reaction with the entire

229
00:09:17,350 --> 00:09:15,440
background universe

230
00:09:19,590 --> 00:09:17,360
the local acceleration of the drive

231
00:09:22,070 --> 00:09:19,600
might be obvious

232
00:09:23,670 --> 00:09:22,080
but the reaction of all other matter

233
00:09:25,430 --> 00:09:23,680
everywhere would be impossible to

234
00:09:28,710 --> 00:09:25,440
measure

235
00:09:31,990 --> 00:09:28,720
in fact if mock's principle is valid

236
00:09:33,269 --> 00:09:32,000
it doesn't really have any meaning

237
00:09:35,269 --> 00:09:33,279
mark's principle which has been

238
00:09:36,710 --> 00:09:35,279

mentioned several times

239
00:09:38,949 --> 00:09:36,720
for people who haven't heard of it is

240
00:09:40,949 --> 00:09:38,959
simply the idea that it's the

241
00:09:42,949 --> 00:09:40,959
behavior of the matter in the universe

242
00:09:44,949 --> 00:09:42,959
as a whole that defines

243
00:09:48,870 --> 00:09:44,959
what is an accelerating or

244
00:09:54,550 --> 00:09:52,470
so getting back to relativity

245
00:09:56,550 --> 00:09:54,560
if general relativity is correct the

246
00:09:57,750 --> 00:09:56,560
door may be open to violating momentum

247
00:10:00,389 --> 00:09:57,760
conservation

248
00:10:01,910 --> 00:10:00,399
this would allow non-rocket drives that

249
00:10:03,430 --> 00:10:01,920
don't need to throw mass away to

250
00:10:05,910 --> 00:10:03,440
accelerate

251
00:10:08,069 --> 00:10:05,920
uh candidates worth examining in detail

252
00:10:09,350 --> 00:10:08,079
manipulation of inertia manipulation of

253
00:10:11,110 --> 00:10:09,360
gravity

254
00:10:13,269 --> 00:10:11,120
and then getting someone farther out

255
00:10:15,269 --> 00:10:13,279
manipulating tachyons or violating the

256
00:10:17,590 --> 00:10:15,279
weak energy condition which is a rather

257
00:10:20,069 --> 00:10:17,600
enigmatic statement that i'll discuss in

258
00:10:23,110 --> 00:10:20,079
more detail later

259
00:10:26,230 --> 00:10:23,120
so uh one thing

260
00:10:28,310 --> 00:10:26,240
that um even a lot of physicists

261
00:10:30,790 --> 00:10:28,320
don't notice unless they've researched

262
00:10:33,910 --> 00:10:30,800
the topic there are actually three kinds

263
00:10:37,030 --> 00:10:33,920

three fundamental definitions of mass

264
00:10:39,269 --> 00:10:37,040
inertial mass that's the n in newton's

265
00:10:41,269 --> 00:10:39,279
famous f equals m a equation

266
00:10:42,389 --> 00:10:41,279
it's the resistance of an object to

267
00:10:44,550 --> 00:10:42,399
acceleration

268
00:10:46,710 --> 00:10:44,560
it's the original quantity that got

269
00:10:49,269 --> 00:10:46,720
called mass

270
00:10:51,269 --> 00:10:49,279
gravitational mass also due to newton

271
00:10:54,069 --> 00:10:51,279
about 20 years later

272
00:10:56,069 --> 00:10:54,079
is the the both of the m's that appear

273
00:10:57,829 --> 00:10:56,079
in newton's gravity formula

274
00:11:00,150 --> 00:10:57,839
it's how strongly an object attracts

275
00:11:03,670 --> 00:11:00,160
everything else

276
00:11:06,630 --> 00:11:03,680
energy content mass is the m in

277
00:11:08,710 --> 00:11:06,640
einstein's e equals m c squared it's the

278
00:11:10,949 --> 00:11:08,720
total energy content of a system

279
00:11:14,710 --> 00:11:10,959
divided by the speed of light squared

280
00:11:17,190 --> 00:11:14,720
okay sorry about the typo

281
00:11:17,910 --> 00:11:17,200
now all three of these masses are

282
00:11:21,269 --> 00:11:17,920
exactly

283
00:11:22,550 --> 00:11:21,279
equivalent but nobody really knows why

284
00:11:23,590 --> 00:11:22,560
unless you simply take it as an

285
00:11:24,949 --> 00:11:23,600
assumption

286
00:11:30,230 --> 00:11:24,959
and we certainly don't have any

287
00:11:37,030 --> 00:11:34,710
now for inertia inertial reaction force

288
00:11:38,550 --> 00:11:37,040

is the force that resists any attempt to

289
00:11:40,550 --> 00:11:38,560
accelerate an object the

290
00:11:42,550 --> 00:11:40,560
equal and opposite reaction in newton's

291
00:11:45,590 --> 00:11:42,560
third law

292
00:11:47,990 --> 00:11:45,600
most physicists assume that

293
00:11:49,750 --> 00:11:48,000
inertia and inertial reaction forces are

294
00:11:50,230 --> 00:11:49,760
innate to mass they're just part of what

295
00:11:51,910 --> 00:11:50,240
mass

296
00:11:54,150 --> 00:11:51,920
is it's what it means to say that

297
00:11:56,710 --> 00:11:54,160
something's a massive object

298
00:11:58,230 --> 00:11:56,720
however some physicists wonder why these

299
00:12:00,710 --> 00:11:58,240
reaction forces exist

300
00:12:03,269 --> 00:12:00,720
and speculate that it might be somehow

301
00:12:05,350 --> 00:12:03,279
extrinsic rather than intrinsic

302
00:12:07,350 --> 00:12:05,360
in which case it might be possible to

303
00:12:09,590 --> 00:12:07,360
manipulate whatever external factors

304
00:12:12,870 --> 00:12:09,600
cause it

305
00:12:14,470 --> 00:12:12,880
uh now manipulating inertia

306
00:12:17,350 --> 00:12:14,480
automatically violates momentum

307
00:12:20,069 --> 00:12:17,360
conservation the definition of momentum

308
00:12:21,110 --> 00:12:20,079
uses the inertial mass so if inertial

309
00:12:24,389 --> 00:12:21,120
mass changes

310
00:12:25,030 --> 00:12:24,399
momentum changes however manipulating

311
00:12:26,470 --> 00:12:25,040
inertia

312
00:12:28,790 --> 00:12:26,480
can do more than just mess up the

313
00:12:36,230 --> 00:12:28,800

bookkeeping it allows you to construct

314
00:12:40,389 --> 00:12:38,230
okay now that everybody's had their

315
00:12:44,470 --> 00:12:40,399
giggle why am i calling a wagon wheel

316
00:12:51,350 --> 00:12:48,150
um inertia manipulation lets you turn

317
00:12:52,790 --> 00:12:51,360
a rotating wheel into a space drive now

318
00:12:55,110 --> 00:12:52,800
every spot on the rim

319
00:12:56,230 --> 00:12:55,120
of a rotating wheel is being accelerated

320
00:12:59,350 --> 00:12:56,240
inward

321
00:13:01,269 --> 00:12:59,360
and exerts an outward reaction force

322
00:13:02,550 --> 00:13:01,279
normally all of these forces are in

323
00:13:05,350 --> 00:13:02,560
equilibrium

324
00:13:06,710 --> 00:13:05,360
even an unbalanced wheel just shakes as

325
00:13:09,350 --> 00:13:06,720
it spins

326
00:13:10,310 --> 00:13:09,360
over a full cycle there's no net average

327
00:13:13,829 --> 00:13:10,320
force it just

328
00:13:17,590 --> 00:13:16,470
now suppose you can manipulate inertia

329
00:13:20,470 --> 00:13:17,600
specifically

330
00:13:22,710 --> 00:13:20,480
suppose you can manipulate inertia in

331
00:13:25,430 --> 00:13:22,720
one part of the wheel either by

332
00:13:27,190 --> 00:13:25,440
affecting a volume of space or by doing

333
00:13:28,870 --> 00:13:27,200
something to the wheels components

334
00:13:32,069 --> 00:13:28,880
themselves on the fly

335
00:13:34,389 --> 00:13:32,079
as they pass through the target area

336
00:13:36,389 --> 00:13:34,399
well for this example we're increasing

337
00:13:39,030 --> 00:13:36,399
inertia in this zone

338
00:13:39,509 --> 00:13:39,040

the ratio of acceleration to reaction

339
00:13:45,509 --> 00:13:39,519
force

340
00:13:46,310 --> 00:13:45,519
these are no longer in equilibrium the

341
00:13:49,269 --> 00:13:46,320
whole wheel

342
00:13:49,670 --> 00:13:49,279
is going to accelerate that way it will

343
00:13:51,750 --> 00:13:49,680
be

344
00:13:53,990 --> 00:13:51,760
pulled toward a zone where inertia is

345
00:13:55,990 --> 00:13:54,000
increased and away from a zone where

346
00:13:58,150 --> 00:13:56,000
inertia is decreased

347
00:13:59,670 --> 00:13:58,160
and this is without expelling mass with

348
00:14:05,750 --> 00:13:59,680
without

349
00:14:07,189 --> 00:14:05,760
simply the change in inertia if you can

350
00:14:09,670 --> 00:14:07,199
do it this way will have this

351
00:14:11,269 --> 00:14:09,680
consequence

352
00:14:14,230 --> 00:14:11,279
now one candidate for inertia

353
00:14:15,670 --> 00:14:14,240
manipulation in 1994

354
00:14:18,790 --> 00:14:15,680
bernie heisch who i believe is in the

355
00:14:20,230 --> 00:14:18,800
audience alfonso reider and hal puthoff

356
00:14:22,949 --> 00:14:20,240
published a theory that inertial

357
00:14:24,790 --> 00:14:22,959
reaction forces are a result

358
00:14:27,750 --> 00:14:24,800
of electromagnetic zero point

359
00:14:29,430 --> 00:14:27,760
fluctuations interacting with matter

360
00:14:31,829 --> 00:14:29,440
now in the spirit of full display

361
00:14:33,670 --> 00:14:31,839
disclosure i co-wrote a couple of papers

362
00:14:34,710 --> 00:14:33,680
with some of them a few years later on

363
00:14:38,629 --> 00:14:34,720

this theory so

364
00:14:39,509 --> 00:14:38,639
i'm not entirely unbiased but zpf can be

365
00:14:41,910 --> 00:14:39,519
manipulated

366
00:14:43,350 --> 00:14:41,920
and in principle this could change the

367
00:14:45,430 --> 00:14:43,360
inertia of objects within the

368
00:14:48,310 --> 00:14:45,440
manipulated volume if this theory is

369
00:14:54,949 --> 00:14:51,990
now the one way we know to manipulate

370
00:14:56,310 --> 00:14:54,959
zpf reliably and it's been referenced

371
00:14:56,710 --> 00:14:56,320
before and is going to be referenced

372
00:14:59,910 --> 00:14:56,720
again

373
00:15:01,110 --> 00:14:59,920
is the casmir effect parallel conducting

374
00:15:03,110 --> 00:15:01,120
plates exclude

375
00:15:04,150 --> 00:15:03,120
some of the zpf modes from the space

376
00:15:05,750 --> 00:15:04,160
between them

377
00:15:07,590 --> 00:15:05,760
specifically the modes that are too big

378
00:15:10,790 --> 00:15:07,600
to fit there is a

379
00:15:13,110 --> 00:15:10,800
reduced zpf inside pushes out with less

380
00:15:14,470 --> 00:15:13,120
force than the normal zpf outside pushes

381
00:15:16,470 --> 00:15:14,480
in

382
00:15:18,150 --> 00:15:16,480
so it looks like there's an attractive

383
00:15:18,629 --> 00:15:18,160
force pulling the plates together that

384
00:15:21,030 --> 00:15:18,639
gets

385
00:15:21,670 --> 00:15:21,040
stronger the closer they are because

386
00:15:24,310 --> 00:15:21,680
you're

387
00:15:28,150 --> 00:15:24,320
excluding more modes this has been

388
00:15:31,509 --> 00:15:31,030

so that leads us to what i've labeled

389
00:15:33,990 --> 00:15:31,519
the

390
00:15:35,590 --> 00:15:34,000
high schroeder put off casimir inertial

391
00:15:37,430 --> 00:15:35,600
wheel

392
00:15:39,590 --> 00:15:37,440
if the zpf is the source of inertial

393
00:15:42,150 --> 00:15:39,600
reaction the reduced zpf between

394
00:15:44,230 --> 00:15:42,160
casimir plates should reduce the inertia

395
00:15:45,110 --> 00:15:44,240
so you put plates on one side of the

396
00:15:47,030 --> 00:15:45,120
wheel

397
00:15:49,590 --> 00:15:47,040
you get a reduced inertial reaction

398
00:15:51,189 --> 00:15:49,600
force the wheel accelerates

399
00:15:53,670 --> 00:15:51,199
in the direction away from the side with

400
00:15:56,629 --> 00:15:53,680
the plates

401
00:15:58,389 --> 00:15:56,639
unfortunately the zpf change made by

402
00:16:00,310 --> 00:15:58,399
casimir plates is in the wrong part of

403
00:16:02,069 --> 00:16:00,320
the spectrum to affect inertia very

404
00:16:05,189 --> 00:16:02,079
strongly

405
00:16:06,829 --> 00:16:05,199
um making wildly optimistic estimates

406
00:16:08,150 --> 00:16:06,839
about our precision engineering

407
00:16:10,550 --> 00:16:08,160
capabilities

408
00:16:12,470 --> 00:16:10,560
the best hr pc wheel with current

409
00:16:14,069 --> 00:16:12,480
technology would accelerate at

410
00:16:17,749 --> 00:16:14,079
two times ten to the minus twenty

411
00:16:21,110 --> 00:16:17,759
seventh power meters per second squared

412
00:16:22,949 --> 00:16:21,120
um that would need to operate for a

413
00:16:25,430 --> 00:16:22,959

thousand years to travel a distance

414
00:16:29,189 --> 00:16:25,440
equal to one wavelength of visible light

415
00:16:31,430 --> 00:16:29,199
this is not exactly a practical drive

416
00:16:33,030 --> 00:16:31,440
another candidate for inertial

417
00:16:34,790 --> 00:16:33,040
manipulation

418
00:16:36,790 --> 00:16:34,800
uh for brevity i will just be calling

419
00:16:39,269 --> 00:16:36,800
the woodward effect since the

420
00:16:41,030 --> 00:16:39,279
early 1990s james woodward has been

421
00:16:43,509 --> 00:16:41,040
publishing a theory based on

422
00:16:44,150 --> 00:16:43,519
mock's principle that predicts transient

423
00:16:47,110 --> 00:16:44,160
changes

424
00:16:49,110 --> 00:16:47,120
in the inertia of devices of objects

425
00:16:50,629 --> 00:16:49,120
whose density is changing

426
00:16:53,189 --> 00:16:50,639
some of his papers also contain

427
00:16:55,350 --> 00:16:53,199
experimental tests of the theory

428
00:16:58,069 --> 00:16:55,360
uh his latest at least the latest that i

429
00:16:59,350 --> 00:16:58,079
found in 2010 so i hope it's the most

430
00:17:01,590 --> 00:16:59,360
recent

431
00:17:03,110 --> 00:17:01,600
notes that earlier experiments have been

432
00:17:05,029 --> 00:17:03,120
given conflicting results

433
00:17:07,750 --> 00:17:05,039
but the most recent experiments continue

434
00:17:10,870 --> 00:17:07,760
to support the theory

435
00:17:11,510 --> 00:17:10,880
uh well here's the theory in extremely

436
00:17:14,309 --> 00:17:11,520
brief

437
00:17:15,029 --> 00:17:14,319
form he ultimately ends up deriving this

438
00:17:19,350 --> 00:17:15,039

equation

439
00:17:21,669 --> 00:17:19,360
for transient inertial mass changes

440
00:17:23,669 --> 00:17:21,679
uh it relates the rate of change of

441
00:17:25,510 --> 00:17:23,679
energy density both the first derivative

442
00:17:28,549 --> 00:17:25,520
and the second derivative

443
00:17:31,990 --> 00:17:28,559
to a uh transient change

444
00:17:34,150 --> 00:17:32,000
in the inertia of an object uh the

445
00:17:35,510 --> 00:17:34,160
thing is from his own derivation you

446
00:17:37,909 --> 00:17:35,520
could just as well write this

447
00:17:39,669 --> 00:17:37,919
in terms of a changing mass density this

448
00:17:43,510 --> 00:17:39,679
e naught

449
00:17:46,310 --> 00:17:43,520
is equal to rho naught c squared

450
00:17:48,390 --> 00:17:46,320
so you can take out the c squared

451
00:17:49,750 --> 00:17:48,400
factors write things in terms of mass

452
00:17:52,789 --> 00:17:49,760
density and you get

453
00:17:54,150 --> 00:17:52,799
this equation which is fundamentally the

454
00:17:57,510 --> 00:17:54,160
same equation

455
00:17:59,750 --> 00:17:57,520
um he even uses the equality

456
00:18:00,630 --> 00:17:59,760
well rho naught c squared equals e

457
00:18:04,150 --> 00:18:00,640
naught in

458
00:18:06,470 --> 00:18:04,160
a couple of steps of his derivation

459
00:18:07,350 --> 00:18:06,480
now because woodward writes his equation

460
00:18:10,470 --> 00:18:07,360
informs

461
00:18:13,029 --> 00:18:10,480
in in terms of a changing energy density

462
00:18:15,029 --> 00:18:13,039
all of his experiments have involved

463
00:18:18,150 --> 00:18:15,039

charging and discharging capacitors to

464
00:18:20,630 --> 00:18:18,160
change the energy density

465
00:18:22,950 --> 00:18:20,640
the measurements involve oscillating the

466
00:18:25,750 --> 00:18:22,960
capacitors back and forth

467
00:18:26,789 --> 00:18:25,760
in time with the charge and discharge to

468
00:18:29,590 --> 00:18:26,799
look for a

469
00:18:31,350 --> 00:18:29,600
net static thrust from the changing

470
00:18:34,150 --> 00:18:31,360
inertia

471
00:18:36,710 --> 00:18:34,160
um looking for a net thrust in this kind

472
00:18:39,029 --> 00:18:36,720
of vibrating apparatus is notoriously

473
00:18:42,070 --> 00:18:39,039
prone to experimental confounds

474
00:18:43,830 --> 00:18:42,080
which is probably why the conflicting

475
00:18:45,750 --> 00:18:43,840
results mentioned in his latest paper

476
00:18:49,510 --> 00:18:45,760
have come about

477
00:18:51,510 --> 00:18:49,520
his 2010 report uses a rotating mount

478
00:18:53,110 --> 00:18:51,520
but because he's cycling the capacitors

479
00:18:54,070 --> 00:18:53,120
at a much higher frequency than his

480
00:18:56,070 --> 00:18:54,080
rotation rate

481
00:18:58,310 --> 00:18:56,080
he's still looking for an oscillatory

482
00:19:00,390 --> 00:18:58,320
effect

483
00:19:02,150 --> 00:19:00,400
however it seems like the woodward

484
00:19:05,110 --> 00:19:02,160
effect should be ideal

485
00:19:05,990 --> 00:19:05,120
for the inertial wheel configuration

486
00:19:07,830 --> 00:19:06,000
because

487
00:19:10,470 --> 00:19:07,840
the inertial transient is driven by

488
00:19:12,549 --> 00:19:10,480

changes in mass density all you need to

489
00:19:13,510 --> 00:19:12,559
do to alter one section of a rolling

490
00:19:16,789 --> 00:19:13,520
wheel

491
00:19:20,150 --> 00:19:16,799
is to compress it uh

492
00:19:21,110 --> 00:19:20,160
now funny when when does one section of

493
00:19:26,710 --> 00:19:21,120
a

494
00:19:29,029 --> 00:19:26,720
tires

495
00:19:29,830 --> 00:19:29,039
we've got a natural experiment out there

496
00:19:32,870 --> 00:19:29,840
in the world

497
00:19:34,950 --> 00:19:32,880
for over a century uh

498
00:19:36,310 --> 00:19:34,960
modern pneumatic tires like this one

499
00:19:37,990 --> 00:19:36,320
don't test the effect

500
00:19:39,909 --> 00:19:38,000
the pressure is distributed and there

501
00:19:42,630 --> 00:19:39,919
are no transients

502
00:19:43,909 --> 00:19:42,640
however in the early whoops in the early

503
00:19:46,630 --> 00:19:43,919
1900s

504
00:19:47,830 --> 00:19:46,640
many cars used solid rubber tires well

505
00:19:49,350 --> 00:19:47,840
at least some of them did

506
00:19:51,110 --> 00:19:49,360
there was a lot of experimentation in

507
00:19:53,270 --> 00:19:51,120
that era

508
00:19:54,789 --> 00:19:53,280
those do go through local compression

509
00:19:57,830 --> 00:19:54,799
cycles as the wheels roll

510
00:19:59,510 --> 00:19:57,840
creating rapid changes in density the

511
00:20:00,549 --> 00:19:59,520
woodward transient works out to be

512
00:20:02,789 --> 00:20:00,559
negative

513
00:20:06,470 --> 00:20:02,799

so the reaction force induced against

514
00:20:08,630 --> 00:20:06,480
the tile rotation is directed upward

515
00:20:09,669 --> 00:20:08,640
and so in the reference frame of the car

516
00:20:11,510 --> 00:20:09,679
the wheels spin

517
00:20:13,830 --> 00:20:11,520
they generate an inertial reaction at

518
00:20:15,990 --> 00:20:13,840
every point on their rims

519
00:20:17,750 --> 00:20:16,000
the road rolling by at a speed that

520
00:20:19,510 --> 00:20:17,760
matches the wheel rotation remember

521
00:20:20,950 --> 00:20:19,520
we're still using the car's inertial

522
00:20:22,950 --> 00:20:20,960
frame here

523
00:20:24,630 --> 00:20:22,960
compresses the contact point creating a

524
00:20:26,310 --> 00:20:24,640
woodward inertial transient for each

525
00:20:28,070 --> 00:20:26,320
segment of the wheel as it comes into

526
00:20:30,549 --> 00:20:28,080
contact with the road

527
00:20:32,310 --> 00:20:30,559
this transient is large and negative and

528
00:20:34,390 --> 00:20:32,320
increases as the fourth power of the

529
00:20:35,990 --> 00:20:34,400
car's speed

530
00:20:38,630 --> 00:20:36,000
according to the woodward's equation a

531
00:20:39,270 --> 00:20:38,640
typical 1900s vintage car with solid

532
00:20:41,029 --> 00:20:39,280
tires

533
00:20:42,870 --> 00:20:41,039
should have launched itself into the air

534
00:20:44,710 --> 00:20:42,880
once it hit a speed of four miles per

535
00:20:46,870 --> 00:20:44,720
hour

536
00:20:48,470 --> 00:20:46,880
at best this indicates that the woodward

537
00:20:50,870 --> 00:20:48,480
effect is weaker

538
00:20:53,430 --> 00:20:50,880

than the equation suggests which in

539
00:20:55,510 --> 00:20:53,440
fairness does correspond to some of the

540
00:20:56,630 --> 00:20:55,520
uh results woodward has gotten and

541
00:20:58,549 --> 00:20:56,640
they've noted a

542
00:21:02,070 --> 00:20:58,559
smaller inertial transient than the

543
00:21:05,430 --> 00:21:02,080
equation as written at face value

544
00:21:07,190 --> 00:21:05,440
hello thank you another route to

545
00:21:09,110 --> 00:21:07,200
propellantless propulsion is the

546
00:21:11,430 --> 00:21:09,120
manipulation of gravity

547
00:21:13,270 --> 00:21:11,440
now we've seen einstein's field equation

548
00:21:15,270 --> 00:21:13,280
for gravity before

549
00:21:16,789 --> 00:21:15,280
and i want to concentrate on the source

550
00:21:19,350 --> 00:21:16,799
term which is called t

551
00:21:19,990 --> 00:21:19,360
nu nu it's called the stress energy

552
00:21:22,470 --> 00:21:20,000
tensor

553
00:21:23,270 --> 00:21:22,480
in addition to energy it contains terms

554
00:21:26,070 --> 00:21:23,280
for momentum

555
00:21:29,110 --> 00:21:26,080
energy and momentum flux pressure and

556
00:21:33,590 --> 00:21:30,950
now a question does pressure have

557
00:21:35,510 --> 00:21:33,600
inertia einstein's equals m c

558
00:21:37,350 --> 00:21:35,520
squared was basically a demonstration

559
00:21:38,710 --> 00:21:37,360
that energy has inertia you can write it

560
00:21:41,590 --> 00:21:38,720
as m equals e over z

561
00:21:43,669 --> 00:21:41,600
squared it's not immediately obvious

562
00:21:45,029 --> 00:21:43,679
whether einstein's proof applies to all

563
00:21:48,070 --> 00:21:45,039

terms in team you knew

564
00:21:49,750 --> 00:21:48,080
or only to the energy terms so for the

565
00:21:51,830 --> 00:21:49,760
moment we're going to assume that the

566
00:21:54,950 --> 00:21:51,840
pressure terms in team u-nu

567
00:21:55,830 --> 00:21:54,960
don't add to inertia then we can

568
00:21:58,950 --> 00:21:55,840
decouple

569
00:22:00,870 --> 00:21:58,960
inertial mass from gravitational mass

570
00:22:03,029 --> 00:22:00,880
inert internal pressure will make an

571
00:22:03,590 --> 00:22:03,039
object create a stronger gravitational

572
00:22:06,870 --> 00:22:03,600
field

573
00:22:09,750 --> 00:22:06,880
without changing its inertia

574
00:22:11,510 --> 00:22:09,760
now briefly discussing the nature of

575
00:22:13,990 --> 00:22:11,520
gravity force and acceleration in

576
00:22:16,870 --> 00:22:14,000
relativity in general relativity

577
00:22:18,470 --> 00:22:16,880
gravity is not a force gravity is

578
00:22:20,549 --> 00:22:18,480
space-time curvature

579
00:22:23,350 --> 00:22:20,559
that makes a free trajectory look to a

580
00:22:25,830 --> 00:22:23,360
distant observer as if it's accelerating

581
00:22:27,909 --> 00:22:25,840
right now you're sitting still on earth

582
00:22:28,870 --> 00:22:27,919
the surface is forcing you to accelerate

583
00:22:31,350 --> 00:22:28,880
away

584
00:22:32,870 --> 00:22:31,360
from the curved space-time path that

585
00:22:34,070 --> 00:22:32,880
leads downward toward the center of the

586
00:22:36,310 --> 00:22:34,080
earth

587
00:22:37,590 --> 00:22:36,320
your weight is an inertial reaction

588
00:22:39,750 --> 00:22:37,600

force

589
00:22:41,710 --> 00:22:39,760
there's a natural free-fall trajectory

590
00:22:44,310 --> 00:22:41,720
that leads downward there's a

591
00:22:46,390 --> 00:22:44,320
non-gravitational obstacle forcing

592
00:22:47,270 --> 00:22:46,400
acceleration away from that free-fall

593
00:22:49,510 --> 00:22:47,280
trajectory

594
00:22:53,350 --> 00:22:49,520
this imposed acceleration and there's an

595
00:22:55,909 --> 00:22:53,360
inertial reaction which we call weight

596
00:22:56,390 --> 00:22:55,919
so now let's look at a couple of spears

597
00:22:59,590 --> 00:22:56,400
in

598
00:23:00,470 --> 00:22:59,600
empty space they each have their own

599
00:23:01,590 --> 00:23:00,480
mass

600
00:23:03,669 --> 00:23:01,600
and we're holding them apart

601
00:23:06,870 --> 00:23:03,679
mechanically with a strut

602
00:23:08,870 --> 00:23:06,880
that has negligible mass and we're just

603
00:23:10,549 --> 00:23:08,880
using it to impose a non-gravitational

604
00:23:12,230 --> 00:23:10,559
acceleration on the system

605
00:23:14,070 --> 00:23:12,240
specifically we're using it to hold

606
00:23:16,390 --> 00:23:14,080
these things at rest when they want to

607
00:23:19,669 --> 00:23:16,400
accelerate towards each other

608
00:23:22,390 --> 00:23:19,679
so the imposed accelerations are

609
00:23:24,630 --> 00:23:22,400
different assuming that m1 is not the

610
00:23:26,710 --> 00:23:24,640
same as m2

611
00:23:28,070 --> 00:23:26,720
but the inertial reaction force turns

612
00:23:31,110 --> 00:23:28,080
out to be the same

613
00:23:32,789 --> 00:23:31,120

because this in this acceleration is

614
00:23:36,070 --> 00:23:32,799
proportional to m2

615
00:23:38,310 --> 00:23:36,080
the mass is m1 you get gm1 m2

616
00:23:39,270 --> 00:23:38,320
down here acceleration proportional to

617
00:23:43,269 --> 00:23:39,280
m1

618
00:23:45,510 --> 00:23:43,279
again

619
00:23:47,350 --> 00:23:45,520
the inertial reaction forces exerted on

620
00:23:49,110 --> 00:23:47,360
the strut are identical

621
00:23:51,269 --> 00:23:49,120
everything's in balance nothing's going

622
00:23:54,149 --> 00:23:51,279
anywhere

623
00:23:56,230 --> 00:23:54,159
now let's pressurize m1 keeping its mass

624
00:23:58,390 --> 00:23:56,240
the same

625
00:24:00,549 --> 00:23:58,400
by hypothesis at the moment the pressure

626
00:24:02,470 --> 00:24:00,559
won't increase m1's inertia but will

627
00:24:05,190 --> 00:24:02,480
strengthen its gravity

628
00:24:06,230 --> 00:24:05,200
now this imposed acceleration has become

629
00:24:10,390 --> 00:24:06,240
bigger

630
00:24:12,310 --> 00:24:10,400
this one is still the same because

631
00:24:14,870 --> 00:24:12,320
pressure does not contribute to inertia

632
00:24:15,430 --> 00:24:14,880
we're assuming the forces are out of

633
00:24:16,830 --> 00:24:15,440
balance

634
00:24:19,750 --> 00:24:16,840
and the whole system is going to

635
00:24:21,990 --> 00:24:19,760
accelerate

636
00:24:22,789 --> 00:24:22,000
unfortunately gravity is a weak force to

637
00:24:25,590 --> 00:24:22,799
begin with

638
00:24:28,630 --> 00:24:25,600

and it takes a lot of pressure to rival

639
00:24:30,710 --> 00:24:28,640
the gravitational effect of mass

640
00:24:33,590 --> 00:24:30,720
there's a factor of c squared involved

641
00:24:36,470 --> 00:24:33,600
the strongest materials available

642
00:24:38,149 --> 00:24:36,480
are currently known compressed to just

643
00:24:39,830 --> 00:24:38,159
short of their yield strength

644
00:24:41,669 --> 00:24:39,840
will have a pressure contribution to

645
00:24:44,830 --> 00:24:41,679
their gravity about

646
00:24:47,669 --> 00:24:44,840
10 to the minus 11 that's 10 parts per

647
00:24:48,390 --> 00:24:47,679
trillion the unbalanced gravity drive at

648
00:24:50,470 --> 00:24:48,400
this level

649
00:24:53,269 --> 00:24:50,480
will accelerate at five times ten to the

650
00:24:55,669 --> 00:24:53,279
minus seventeenth meters per second

651
00:24:57,029 --> 00:24:55,679
uh that actually depends on the total

652
00:24:58,870 --> 00:24:57,039
mass of the system

653
00:25:00,149 --> 00:24:58,880
so i'm i'm throwing in an assumption

654
00:25:01,830 --> 00:25:00,159
that you you don't

655
00:25:04,310 --> 00:25:01,840
want to try to build a spacecraft that

656
00:25:07,029 --> 00:25:04,320
weighs more than a few tens of tons

657
00:25:09,029 --> 00:25:07,039
um now that's 10 orders of magnitude

658
00:25:11,350 --> 00:25:09,039
better than the last one we looked at

659
00:25:15,190 --> 00:25:11,360
but it still needs to run 73 days to

660
00:25:17,110 --> 00:25:15,200
travel one millimeter

661
00:25:18,870 --> 00:25:17,120
now we've been supposing for a while

662
00:25:22,149 --> 00:25:18,880
that pressure doesn't have inertia but

663
00:25:26,070 --> 00:25:24,149

then the unbalanced gravity drive

664
00:25:27,750 --> 00:25:26,080
doesn't work because the extra gravity

665
00:25:29,590 --> 00:25:27,760
source has its own inertia

666
00:25:30,870 --> 00:25:29,600
inertial mass and gravitational mass

667
00:25:34,470 --> 00:25:30,880
stay coupled

668
00:25:38,070 --> 00:25:34,480
but this uncouples inertial mass

669
00:25:39,750 --> 00:25:38,080
from energy content mass and this should

670
00:25:41,669 --> 00:25:39,760
sound familiar

671
00:25:43,110 --> 00:25:41,679
because it means you can change inertia

672
00:25:45,590 --> 00:25:43,120
without changing

673
00:25:46,310 --> 00:25:45,600
the energy content mass the amount of

674
00:25:49,350 --> 00:25:46,320
stuff

675
00:25:51,750 --> 00:25:49,360
if you will in an object

676
00:25:53,510 --> 00:25:51,760
a self-contained pressurization system

677
00:25:55,029 --> 00:25:53,520
won't change the total energy content

678
00:25:57,830 --> 00:25:55,039
but it can still add or remove

679
00:25:59,669 --> 00:25:57,840
pressure if pressure has inertia we can

680
00:26:00,549 --> 00:25:59,679
manipulate the inertia of objects on the

681
00:26:04,710 --> 00:26:00,559
rim of our

682
00:26:07,350 --> 00:26:04,720
rotating wheel now once again

683
00:26:09,190 --> 00:26:07,360
with the best available materials this

684
00:26:11,909 --> 00:26:09,200
version of the inertial wheel

685
00:26:13,590 --> 00:26:11,919
could accelerate at nearly uh i won't

686
00:26:16,950 --> 00:26:13,600
recite all the zeros this is

687
00:26:18,870 --> 00:26:16,960
half a microgravity um

688
00:26:22,230 --> 00:26:18,880

that's 11 orders of magnitude better

689
00:26:25,269 --> 00:26:22,240
than the unbalanced gravity drive

690
00:26:28,549 --> 00:26:25,279
so one way or another

691
00:26:31,350 --> 00:26:28,559
it looks like we have a inner

692
00:26:33,269 --> 00:26:31,360
violation of momentum conservation if

693
00:26:34,070 --> 00:26:33,279
the pressure terms and the stress energy

694
00:26:37,510 --> 00:26:34,080
tensor

695
00:26:39,029 --> 00:26:37,520
contribute to inertia then we can build

696
00:26:41,190 --> 00:26:39,039
an inertial wheel drive

697
00:26:44,710 --> 00:26:41,200
if they don't contribute to inertia we

698
00:26:46,470 --> 00:26:44,720
can build an unbalanced gravity drive

699
00:26:48,070 --> 00:26:46,480
so now we'll go farther out into

700
00:26:50,230 --> 00:26:48,080
speculation

701
00:26:51,350 --> 00:26:50,240
for somewhat over 40 years physicists

702
00:26:53,510 --> 00:26:51,360
have speculated about

703
00:26:55,830 --> 00:26:53,520
tachyons hypothetical particles that

704
00:26:57,669 --> 00:26:55,840
always move faster than light

705
00:26:59,350 --> 00:26:57,679
they're a marginally respectable topic

706
00:27:01,029 --> 00:26:59,360
in relativity

707
00:27:03,190 --> 00:27:01,039
and they're an abomination in quantum

708
00:27:04,630 --> 00:27:03,200
field theory

709
00:27:07,350 --> 00:27:04,640
although they're consistent with

710
00:27:09,350 --> 00:27:07,360
relativity and respect conservation laws

711
00:27:11,269 --> 00:27:09,360
their ftl movement means that like

712
00:27:12,990 --> 00:27:11,279
non-relativistic interactions

713
00:27:15,510 --> 00:27:13,000

they can create the local appearance of

714
00:27:17,990 --> 00:27:15,520
non-conservation

715
00:27:18,549 --> 00:27:18,000
so some properties of tachyons this

716
00:27:20,789 --> 00:27:18,559
factor

717
00:27:21,750 --> 00:27:20,799
square root of 1 minus v squared over c

718
00:27:25,190 --> 00:27:21,760
squared

719
00:27:26,710 --> 00:27:25,200
is ubiquitous in relativistic

720
00:27:29,750 --> 00:27:26,720
transformations

721
00:27:30,549 --> 00:27:29,760
and if v is bigger than c it becomes an

722
00:27:32,549 --> 00:27:30,559
imaginary

723
00:27:34,070 --> 00:27:32,559
value which is why it's usually

724
00:27:34,470 --> 00:27:34,080
considered to be meaningless to talk

725
00:27:37,669 --> 00:27:34,480
about

726
00:27:40,789 --> 00:27:37,679
having something move faster than light

727
00:27:43,990 --> 00:27:40,799
however if the rest mass of an object

728
00:27:44,950 --> 00:27:44,000
is also imaginary the imaginary factors

729
00:27:47,190 --> 00:27:44,960
cancel

730
00:27:48,470 --> 00:27:47,200
and the mass momentum and total energy

731
00:27:51,110 --> 00:27:48,480
of such a particle

732
00:27:53,669 --> 00:27:51,120
become real values as long as it keeps

733
00:27:56,230 --> 00:27:53,679
moving faster than light

734
00:27:57,590 --> 00:27:56,240
fundamentally you get three kinds of

735
00:28:01,269 --> 00:27:57,600
particles

736
00:28:04,950 --> 00:28:01,279
are sometimes called

737
00:28:07,830 --> 00:28:04,960
tardions so we know they exist

738
00:28:09,430 --> 00:28:07,840

we interact with massless particles all

739
00:28:11,430 --> 00:28:09,440
the time

740
00:28:13,430 --> 00:28:11,440
so we know that there's no barrier to

741
00:28:15,590 --> 00:28:13,440
interactions between two different kinds

742
00:28:19,110 --> 00:28:15,600
of particles on this chart

743
00:28:22,070 --> 00:28:19,120
tachyons if they exist would simply add

744
00:28:23,269 --> 00:28:22,080
another category that covers the

745
00:28:25,350 --> 00:28:23,279
remaining velocity

746
00:28:27,110 --> 00:28:25,360
regime we've got always slower than

747
00:28:28,149 --> 00:28:27,120
light we've got always moving at the

748
00:28:30,070 --> 00:28:28,159
speed of light

749
00:28:31,669 --> 00:28:30,080
we've got always moving faster than

750
00:28:37,350 --> 00:28:31,679
light and all of them

751
00:28:43,430 --> 00:28:41,669
um now both tardions and tachyons

752
00:28:46,389 --> 00:28:43,440
gain energy and momentum as they

753
00:28:49,430 --> 00:28:46,399
approach the speed of light

754
00:28:52,070 --> 00:28:49,440
now as they slow to rest tardions

755
00:28:53,430 --> 00:28:52,080
lose all of their momentum but still

756
00:28:55,510 --> 00:28:53,440
have a minimum energy

757
00:28:57,269 --> 00:28:55,520
their their rest mass and its associated

758
00:28:59,110 --> 00:28:57,279
energy content

759
00:29:01,269 --> 00:28:59,120
now moving close to the speed of light

760
00:29:03,909 --> 00:29:01,279
tachyons look similar

761
00:29:05,590 --> 00:29:03,919
but as they accelerate to faster and

762
00:29:06,950 --> 00:29:05,600
faster speeds they do something

763
00:29:09,750 --> 00:29:06,960

different it's their total

764
00:29:10,470 --> 00:29:09,760
energy that goes to zero and their

765
00:29:13,750 --> 00:29:10,480
momentum

766
00:29:14,789 --> 00:29:13,760
that goes to a minimum value so in terms

767
00:29:16,230 --> 00:29:14,799
of space drives

768
00:29:18,149 --> 00:29:16,240
a tachyon would be a something for

769
00:29:20,549 --> 00:29:18,159
nothing particle

770
00:29:22,230 --> 00:29:20,559
you can create if you can create them in

771
00:29:25,430 --> 00:29:22,240
the infinite velocity state

772
00:29:27,430 --> 00:29:25,440
the instantaneous propagation state

773
00:29:29,350 --> 00:29:27,440
they have zero energy and non-zero

774
00:29:31,750 --> 00:29:29,360
momentum you can generate thrust while

775
00:29:33,990 --> 00:29:31,760
expending no energy

776
00:29:36,389 --> 00:29:34,000
uh that same zero energy state is why

777
00:29:38,870 --> 00:29:36,399
quantum theorists hate tachyons

778
00:29:39,990 --> 00:29:38,880
any theory that allows tachyonic states

779
00:29:42,310 --> 00:29:40,000
predicts an infrared

780
00:29:45,510 --> 00:29:42,320
catastrophe where infinite numbers of

781
00:29:47,430 --> 00:29:45,520
zero-energy tachyons get generated

782
00:29:49,110 --> 00:29:47,440
the reason string theorists require

783
00:29:50,950 --> 00:29:49,120
extra spatial dimensions

784
00:29:53,269 --> 00:29:50,960
is to prevent any string states from

785
00:29:56,310 --> 00:29:53,279
being tachyons

786
00:29:56,710 --> 00:29:56,320
if you try to uh do string theory in

787
00:29:58,310 --> 00:29:56,720
just

788
00:30:00,470 --> 00:29:58,320

the four dimensions we think we know

789
00:30:02,870 --> 00:30:00,480
about uh you discover that that the

790
00:30:04,549 --> 00:30:02,880
lowest energy string state is a tachyon

791
00:30:07,029 --> 00:30:04,559
and this makes field theorists very very

792
00:30:10,549 --> 00:30:09,110
and let's go even farther out for a

793
00:30:13,510 --> 00:30:10,559
moment and consider

794
00:30:15,110 --> 00:30:13,520
negative mass the weak energy condition

795
00:30:18,789 --> 00:30:15,120
which i mentioned before

796
00:30:20,789 --> 00:30:18,799
is a feature of general relativity

797
00:30:22,950 --> 00:30:20,799
that does not follow from the field

798
00:30:25,830 --> 00:30:22,960
equations but is

799
00:30:26,389 --> 00:30:25,840
a constraint on what sort of values are

800
00:30:28,389 --> 00:30:26,399
allowed

801
00:30:30,630 --> 00:30:28,399
in the stress energy source term of the

802
00:30:32,789 --> 00:30:30,640
field equation

803
00:30:34,789 --> 00:30:32,799
there are several energy conditions and

804
00:30:37,470 --> 00:30:34,799
all of them are not conclusions

805
00:30:39,430 --> 00:30:37,480
of general relativity but rather

806
00:30:41,190 --> 00:30:39,440
expectations

807
00:30:43,190 --> 00:30:41,200
i tend to think of them these days as

808
00:30:45,510 --> 00:30:43,200
pious hopes

809
00:30:48,950 --> 00:30:45,520
about what sorts of situations are

810
00:30:50,870 --> 00:30:48,960
permitted by non-gravitational physics

811
00:30:53,269 --> 00:30:50,880
the weak energy condition expressed in

812
00:30:57,110 --> 00:30:53,279
words says that energy densities can't

813
00:31:00,870 --> 00:30:59,430

uh unfortunately it's already known to

814
00:31:03,190 --> 00:31:00,880
be false

815
00:31:06,149 --> 00:31:03,200
the casimir effect demonstrates the

816
00:31:08,710 --> 00:31:06,159
existence of a negative energy density

817
00:31:09,590 --> 00:31:08,720
now it's believed though not proven that

818
00:31:12,070 --> 00:31:09,600
a suitably

819
00:31:14,149 --> 00:31:12,080
averaged form of the weak energy

820
00:31:14,710 --> 00:31:14,159
condition still holds in the casimir

821
00:31:17,750 --> 00:31:14,720
effect

822
00:31:20,950 --> 00:31:17,760
but in in its raw form

823
00:31:23,509 --> 00:31:20,960
the the condition does not so even this

824
00:31:25,990 --> 00:31:23,519
partial and provisional violation

825
00:31:29,430 --> 00:31:26,000
prompt speculation that the principle

826
00:31:33,509 --> 00:31:31,909
so what if the weak energy condition is

827
00:31:35,909 --> 00:31:33,519
not a universal rule

828
00:31:37,830 --> 00:31:35,919
but a biased extrapolation from our

829
00:31:39,990 --> 00:31:37,840
limited experience

830
00:31:41,990 --> 00:31:40,000
then it may be possible to create

831
00:31:44,710 --> 00:31:42,000
configurations of matter and fields that

832
00:31:46,789 --> 00:31:44,720
have negative total energy

833
00:31:48,870 --> 00:31:46,799
they would therefore have negative mass

834
00:31:50,549 --> 00:31:48,880
and negative inertia

835
00:31:52,549 --> 00:31:50,559
an object with negative inertia

836
00:31:56,070 --> 00:31:52,559
accelerates in the opposite direction to

837
00:31:59,269 --> 00:31:58,549
now let's think about a spacecraft

838
00:32:02,950 --> 00:31:59,279

attached to an

839
00:32:05,350 --> 00:32:02,960
object of exactly equal negative mass

840
00:32:06,549 --> 00:32:05,360
if the craft now pushes the negative

841
00:32:08,549 --> 00:32:06,559
mass backwards

842
00:32:10,070 --> 00:32:08,559
the reaction will cause it to accelerate

843
00:32:12,389 --> 00:32:10,080
forward

844
00:32:14,389 --> 00:32:12,399
the object with negative inertia will

845
00:32:17,350 --> 00:32:14,399
react to the backward push

846
00:32:19,350 --> 00:32:17,360
by accelerating forward at the same rate

847
00:32:21,029 --> 00:32:19,360
no conservation law is violated

848
00:32:23,110 --> 00:32:21,039
because the total energy and momentum of

849
00:32:26,070 --> 00:32:23,120
the system remains zero no matter how

850
00:32:31,190 --> 00:32:29,430
now why this is unlikely quantum systems

851
00:32:32,230 --> 00:32:31,200
tend to decay into the lowest energy

852
00:32:35,269 --> 00:32:32,240
state available

853
00:32:36,149 --> 00:32:35,279
releasing energy if negative mass states

854
00:32:38,630 --> 00:32:36,159
are possible

855
00:32:40,310 --> 00:32:38,640
they should be ubiquitous but we don't

856
00:32:42,549 --> 00:32:40,320
observe them

857
00:32:43,990 --> 00:32:42,559
uh the negative energy density of the

858
00:32:46,070 --> 00:32:44,000
casimir vacuum

859
00:32:47,590 --> 00:32:46,080
isn't a violation of this statement of

860
00:32:50,389 --> 00:32:47,600
non-observation

861
00:32:52,230 --> 00:32:50,399
because it is only stable under boundary

862
00:32:53,750 --> 00:32:52,240
conditions that embody much higher

863
00:32:55,750 --> 00:32:53,760

positive energy densities

864
00:32:59,350 --> 00:32:55,760
so the system as a whole requires

865
00:33:04,470 --> 00:33:02,470
so an overview of the theory i i hope

866
00:33:06,230 --> 00:33:04,480
i'm on time here

867
00:33:07,990 --> 00:33:06,240
current space propulsion systems have

868
00:33:09,990 --> 00:33:08,000
very limited capabilities

869
00:33:11,830 --> 00:33:10,000
better technology can improve this but

870
00:33:14,710 --> 00:33:11,840
any rocket type drive will be

871
00:33:16,470 --> 00:33:14,720
limited by conservation laws

872
00:33:18,710 --> 00:33:16,480
alternatives to the rocket that are also

873
00:33:19,990 --> 00:33:18,720
bound by these laws have unsatisfactory

874
00:33:21,830 --> 00:33:20,000
features

875
00:33:23,590 --> 00:33:21,840
but there are valid theoretical reasons

876
00:33:25,669 --> 00:33:23,600
for suspecting that these conservation

877
00:33:27,669 --> 00:33:25,679
laws may not actually hold

878
00:33:30,310 --> 00:33:27,679
or it may at least allow apparent local

879
00:33:32,230 --> 00:33:30,320
violations

880
00:33:34,389 --> 00:33:32,240
now even if the theories justifying

881
00:33:36,630 --> 00:33:34,399
these speculative drives are true

882
00:33:38,789 --> 00:33:36,640
useful application is out of the reach

883
00:33:40,789 --> 00:33:38,799
of current technology

884
00:33:43,110 --> 00:33:40,799
now i find it interesting that several

885
00:33:45,750 --> 00:33:43,120
of these drives can be improved

886
00:33:48,710 --> 00:33:45,760
just with advances in material science

887
00:33:50,870 --> 00:33:48,720
rather than more exotic technologies

888
00:33:52,549 --> 00:33:50,880

some of them may be testable or nearly

889
00:33:57,269 --> 00:33:52,559
to the point of being testable

890
00:33:57,279 --> 00:34:04,789
and that's the end of my talk

891
00:34:08,470 --> 00:34:06,630
thank you you are not only on time but

892
00:34:10,069 --> 00:34:08,480
we have uh

893
00:34:11,829 --> 00:34:10,079
a little more than five minutes for

894
00:34:17,829 --> 00:34:11,839
questions

895
00:34:20,710 --> 00:34:19,109
just a quick question york could you

896
00:34:21,990 --> 00:34:20,720
elaborate on the infrared catastrophe

897
00:34:22,389 --> 00:34:22,000
you mentioned i didn't catch what that

898
00:34:25,669 --> 00:34:22,399
was

899
00:34:27,990 --> 00:34:25,679
about uh okay the

900
00:34:28,790 --> 00:34:28,000
the infrared catastrophe is basically

901
00:34:31,750 --> 00:34:28,800
because

902
00:34:32,230 --> 00:34:31,760
there there there is a state in which

903
00:34:35,669 --> 00:34:32,240
attack

904
00:34:39,109 --> 00:34:35,679
a new tachyon can be created without

905
00:34:41,669 --> 00:34:39,119
any expenditure of energies uh

906
00:34:44,550 --> 00:34:41,679
when you study the the feynman diagrams

907
00:34:47,109 --> 00:34:44,560
for potential tachyonic interactions

908
00:34:48,069 --> 00:34:47,119
uh you basically find an infinite

909
00:34:51,109 --> 00:34:48,079
cross-section

910
00:34:55,750 --> 00:34:51,119
for emitting tachyons in a certain state

911
00:34:59,030 --> 00:34:55,760
uh this this leads to something like a

912
00:35:01,910 --> 00:34:59,040
a direct vacuum hypothesis

913
00:35:04,230 --> 00:35:01,920

where the cosmos should already be full

914
00:35:05,190 --> 00:35:04,240
of of tachyons in a certain state of

915
00:35:07,190 --> 00:35:05,200
motion and

916
00:35:08,950 --> 00:35:07,200
of course because we don't actually have

917
00:35:12,390 --> 00:35:08,960
a good theory

918
00:35:14,470 --> 00:35:12,400
for tachyon interactions we we don't

919
00:35:15,829 --> 00:35:14,480
know what exactly that universe would

920
00:35:18,550 --> 00:35:15,839
look like but we don't think we're

921
00:35:22,470 --> 00:35:20,069
oh it's called infrared because it

922
00:35:23,990 --> 00:35:22,480
involves dropping to zero energy

923
00:35:28,470 --> 00:35:24,000
it's in contrast to the genes

924
00:35:33,430 --> 00:35:31,030
york i think that the um the solid

925
00:35:35,190 --> 00:35:33,440
rubber tire model might be recoverable

926
00:35:38,310 --> 00:35:35,200
so that the theoretical

927
00:35:40,550 --> 00:35:38,320
models are not disproven because

928
00:35:43,349 --> 00:35:40,560
the compression expansion of rubber has

929
00:35:44,950 --> 00:35:43,359
hysteresis that shows up as heat

930
00:35:46,550 --> 00:35:44,960
the energy gain that supposedly was

931
00:35:47,750 --> 00:35:46,560
coming from this was instantly being

932
00:35:49,990 --> 00:35:47,760
dissipated just in

933
00:35:52,150 --> 00:35:50,000
in the heat and the rolling of the of

934
00:35:55,190 --> 00:35:52,160
the wheels

935
00:35:56,390 --> 00:35:55,200
well the issue with the compression and

936
00:36:00,870 --> 00:35:56,400
expansion doesn't

937
00:36:04,150 --> 00:36:00,880
relate to energy as such but to

938
00:36:06,790 --> 00:36:04,160

the inertial transient the work done

939
00:36:07,829 --> 00:36:06,800
on the tire which is where the heat

940
00:36:10,470 --> 00:36:07,839
comes from

941
00:36:12,790 --> 00:36:10,480
that then has to be dissipated yes

942
00:36:15,030 --> 00:36:12,800
that's changing the energy density

943
00:36:16,310 --> 00:36:15,040
but that is many orders of magnitude

944
00:36:19,109 --> 00:36:16,320
smaller than

945
00:36:21,190 --> 00:36:19,119
the change in the mass density created

946
00:36:23,589 --> 00:36:21,200
by the compression of the rubber

947
00:36:24,829 --> 00:36:23,599
uh therefore at best that becomes a

948
00:36:27,829 --> 00:36:24,839
minuscule

949
00:36:28,470 --> 00:36:27,839
correction um now it's entirely possible

950
00:36:32,069 --> 00:36:28,480
that there are

951
00:36:35,190 --> 00:36:32,079
other considerations in the theory that

952
00:36:36,390 --> 00:36:35,200
avert this difficulty but as it stands

953
00:36:38,829 --> 00:36:36,400
the equation as

954
00:36:40,870 --> 00:36:38,839
as written seems to be making a very odd

955
00:36:45,910 --> 00:36:40,880
prediction

956
00:36:49,589 --> 00:36:47,829
uh what if things are not continuous

957
00:36:52,069 --> 00:36:49,599
could we be a little bit more specific

958
00:36:59,670 --> 00:36:56,150
what if space and time are discrete

959
00:37:02,470 --> 00:36:59,680
um if space and time are discrete

960
00:37:03,990 --> 00:37:02,480
it becomes very difficult to understand

961
00:37:07,349 --> 00:37:04,000
some aspects of

962
00:37:10,630 --> 00:37:07,359
the lawrence transforms um

963
00:37:11,270 --> 00:37:10,640

and of course general relativity itself

964
00:37:14,550 --> 00:37:11,280
is

965
00:37:16,310 --> 00:37:14,560
written in the form of a field equation

966
00:37:18,550 --> 00:37:16,320
on continuous quantities

967
00:37:20,829 --> 00:37:18,560
to construct a discrete version you have

968
00:37:22,230 --> 00:37:20,839
to make significant changes in the

969
00:37:23,910 --> 00:37:22,240
theory

970
00:37:25,510 --> 00:37:23,920
since i was working within the context

971
00:37:27,510 --> 00:37:25,520
of that theory

972
00:37:40,470 --> 00:37:27,520
i didn't really look into how the

973
00:37:44,310 --> 00:37:42,630
york i can't speak with authority on

974
00:37:45,670 --> 00:37:44,320
this but i worked for a company that

975
00:37:50,390 --> 00:37:45,680
made

976
00:37:52,630 --> 00:37:50,400
closures for vials of injectable drugs

977
00:37:53,430 --> 00:37:52,640
and they typically were composed of a

978
00:37:56,790 --> 00:37:53,440
molded

979
00:37:59,349 --> 00:37:56,800
rubber stopper and a uh an aluminum cap

980
00:38:02,710 --> 00:37:59,359
that held the stopper in place

981
00:38:06,310 --> 00:38:02,720
and uh my colleagues in the the

982
00:38:06,870 --> 00:38:06,320
rubber division of that company insisted

983
00:38:10,310 --> 00:38:06,880
that

984
00:38:13,030 --> 00:38:10,320
rubber is not compressible it's

985
00:38:14,870 --> 00:38:13,040
like an elastic incompressible liquid

986
00:38:16,829 --> 00:38:14,880
i've never proved it myself

987
00:38:21,190 --> 00:38:16,839
but it might might be something to

988
00:38:24,550 --> 00:38:23,589

uh strictly speaking there is no such

989
00:38:27,510 --> 00:38:24,560
thing as an

990
00:38:27,910 --> 00:38:27,520
incompressible material every material

991
00:38:31,829 --> 00:38:27,920
has

992
00:38:34,950 --> 00:38:31,839
shown up with one of

993
00:38:36,630 --> 00:38:34,960
infinite value therefore uh when you

994
00:38:37,510 --> 00:38:36,640
apply pressure to things you can

995
00:38:41,190 --> 00:38:37,520
compress them

996
00:38:46,550 --> 00:38:44,790
one more question um yeah york maybe we

997
00:38:47,670 --> 00:38:46,560
can clarify that when it comes to

998
00:38:49,030 --> 00:38:47,680
compressing things you use the bulk

999
00:38:50,550 --> 00:38:49,040
modulus and you probably want to

1000
00:38:52,069 --> 00:38:50,560
compress it from all directions like put

1001
00:38:53,670 --> 00:38:52,079
it in and put it in a

1002
00:38:55,030 --> 00:38:53,680
pressure chamber but if you squeeze it

1003
00:38:56,150 --> 00:38:55,040
in one direction it can squeeze out in

1004
00:38:57,430 --> 00:38:56,160
another direction

1005
00:38:59,349 --> 00:38:57,440
i think that maybe that's what he's

1006
00:38:59,990 --> 00:38:59,359
referring to in which case if you push

1007
00:39:01,510 --> 00:39:00,000
the tire

1008
00:39:03,190 --> 00:39:01,520
down in one direction it can squeeze out

1009
00:39:04,069 --> 00:39:03,200
in another direction without necessarily

1010
00:39:08,390 --> 00:39:04,079
compressing

1011
00:39:10,710 --> 00:39:08,400
maybe that's what he's saying um

1012
00:39:12,630 --> 00:39:10,720
that might very well be a process that

1013
00:39:14,470 --> 00:39:12,640

is happening and i would expect it to be

1014
00:39:16,870 --> 00:39:14,480
happening but in a

1015
00:39:17,990 --> 00:39:16,880
solid rubber tire under lateral

1016
00:39:21,510 --> 00:39:18,000
compression

1017
00:39:23,990 --> 00:39:21,520
the rubber to either side of the

1018
00:39:24,950 --> 00:39:24,000
compressing force has to be contributing

1019
00:39:27,750 --> 00:39:24,960
something

1020
00:39:29,990 --> 00:39:27,760
to holding it in place and creating an

1021
00:39:32,390 --> 00:39:30,000
actual density increase