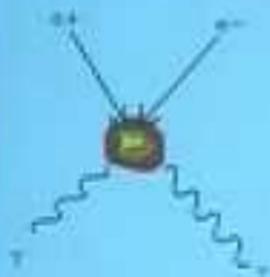
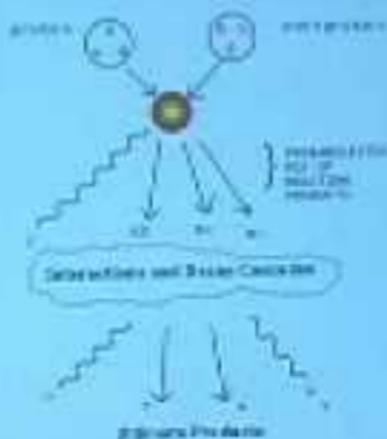


Positrons and Antiprotons

When electrons (e^-) meet positrons (e^+) they simply annihilate into a pair of gamma rays.



Protons (and antiprotons) are composite, made of 3 quarks (antiquarks) each, so they produce a complicated spray of unstable reaction products.



1
00:00:09,990 --> 00:00:03,030
is that better okay yes

2
00:00:16,950 --> 00:00:13,190
well this is uh more of a technical talk

3
00:00:20,870 --> 00:00:16,960
uh but partly inspired by

4
00:00:23,830 --> 00:00:20,880
the fact that ufo reports frequently

5
00:00:25,429 --> 00:00:23,840
discuss impressive maneuverability at

6
00:00:28,070 --> 00:00:25,439
with

7
00:00:30,310 --> 00:00:28,080
usually no indication of conventionally

8
00:00:33,430 --> 00:00:30,320
known drives

9
00:00:35,670 --> 00:00:33,440
and to cut to the chase just in case i

10
00:00:38,470 --> 00:00:35,680
should run out of time

11
00:00:38,869 --> 00:00:38,480
a a sufficiently advanced technology can

12
00:00:40,630 --> 00:00:38,879
use

13
00:00:43,110 --> 00:00:40,640

antimatter annihilation to power a

14

00:00:47,270 --> 00:00:43,120

reaction drive whose only exhaust is an

15

00:00:52,310 --> 00:00:49,670

this would not be visible it would be

16

00:00:55,189 --> 00:00:52,320

very hard to detect by any means

17

00:00:56,389 --> 00:00:55,199

but it is potentially a testable

18

00:00:59,590 --> 00:00:56,399

hypothesis from

19

00:01:01,670 --> 00:00:59,600

retrospective evidence that already

20

00:01:03,590 --> 00:01:01,680

exists

21

00:01:05,429 --> 00:01:03,600

just as a note by a sufficiently

22

00:01:08,870 --> 00:01:05,439

advanced technology

23

00:01:11,670 --> 00:01:08,880

i mean something that can

24

00:01:11,990 --> 00:01:11,680

accomplish anything that can be known

25

00:01:14,710 --> 00:01:12,000

that

26

00:01:16,310 --> 00:01:14,720

is known to be physically possible uh

27

00:01:19,990 --> 00:01:16,320

but that does not require any

28

00:01:20,710 --> 00:01:20,000

new physics simply uh on the grounds

29

00:01:24,550 --> 00:01:20,720

that uh

30

00:01:26,550 --> 00:01:24,560

i felt that a hypothesis is

31

00:01:32,230 --> 00:01:26,560

more credible if it sticks to things

32

00:01:35,990 --> 00:01:35,109

now there's been a fair amount of

33

00:01:39,190 --> 00:01:36,000

discussion

34

00:01:41,670 --> 00:01:39,200

about theoretical space propulsion

35

00:01:42,230 --> 00:01:41,680

at the moment the only physics we know

36

00:01:44,789 --> 00:01:42,240

of

37

00:01:46,870 --> 00:01:44,799

relevant to space propulsion involves a

38

00:01:49,109 --> 00:01:46,880

law of equal action and reaction

39

00:01:49,990 --> 00:01:49,119

the only way you can move in one

40

00:01:53,350 --> 00:01:50,000

direction

41

00:01:55,350 --> 00:01:53,360

is to throw something else reaction mass

42

00:01:58,950 --> 00:01:55,360

as i call it

43

00:02:02,230 --> 00:01:58,960

in the other direction there are some

44

00:02:07,670 --> 00:02:04,709

that basically involve getting your

45

00:02:09,910 --> 00:02:07,680

reaction mass from outside the vehicle

46

00:02:11,190 --> 00:02:09,920

but they still adhere to newton's third

47

00:02:12,949 --> 00:02:11,200

law

48

00:02:19,270 --> 00:02:12,959

and the most powerful known reaction

49

00:02:23,670 --> 00:02:21,990

i i was told after i submitted my

50

00:02:25,990 --> 00:02:23,680

abstract that it would be good to

51
00:02:26,710 --> 00:02:26,000
provide a brief primer on on what

52
00:02:29,110 --> 00:02:26,720
antimatter

53
00:02:29,750 --> 00:02:29,120
is to begin with so every type of

54
00:02:31,670 --> 00:02:29,760
particle

55
00:02:34,949 --> 00:02:31,680
making up normal matter has a

56
00:02:38,070 --> 00:02:34,959
corresponding anti-particle

57
00:02:39,110 --> 00:02:38,080
um the relation between antimatter and

58
00:02:42,869 --> 00:02:39,120
normal matter

59
00:02:45,670 --> 00:02:42,879
is that uh every measurable property

60
00:02:46,470 --> 00:02:45,680
is either identical or exactly the

61
00:02:48,630 --> 00:02:46,480
opposite

62
00:02:50,309 --> 00:02:48,640
between the two mass is one of the

63
00:02:52,470 --> 00:02:50,319

identical properties

64

00:02:54,630 --> 00:02:52,480

antimatter particles have the same mass

65

00:02:57,990 --> 00:02:54,640

as matter particles

66

00:02:59,030 --> 00:02:58,000

electrical charge is one of the reversed

67

00:03:01,030 --> 00:02:59,040

properties

68

00:03:03,270 --> 00:03:01,040

the anti-electron is also called the

69

00:03:04,309 --> 00:03:03,280

positron because it has a positive

70

00:03:10,149 --> 00:03:04,319

charge

71

00:03:14,070 --> 00:03:10,159

when matter and antimatter meet they

72

00:03:15,509 --> 00:03:14,080

annihilate releasing energy

73

00:03:17,110 --> 00:03:15,519

and just historically the first

74

00:03:20,790 --> 00:03:17,120

anti-particle discovered was the

75

00:03:25,990 --> 00:03:23,910

okay now electron positron

76

00:03:27,670 --> 00:03:26,000

annihilation is nice and simple they

77

00:03:29,910 --> 00:03:27,680

simply meet each other

78

00:03:33,190 --> 00:03:29,920

and convert into a pair of gamma rays

79

00:03:35,110 --> 00:03:33,200

carrying all of the energy

80

00:03:36,710 --> 00:03:35,120

now in accelerators we've been studying

81

00:03:39,270 --> 00:03:36,720

anti-protons for

82

00:03:40,070 --> 00:03:39,280

decades now their annihilation is more

83

00:03:42,789 --> 00:03:40,080

complicated

84

00:03:44,710 --> 00:03:42,799

partly because a proton is a composite

85

00:03:46,550 --> 00:03:44,720

object made of three quarks

86

00:03:48,149 --> 00:03:46,560

an antiproton of course is made of three

87

00:03:50,390 --> 00:03:48,159

antiquarks

88

00:03:52,149 --> 00:03:50,400

and partly because the energy release is

89

00:03:53,030 --> 00:03:52,159

so much bigger that completely new

90

00:03:55,429 --> 00:03:53,040

particles

91

00:03:57,350 --> 00:03:55,439

or rather particle antiparticle pairs

92

00:04:00,229 --> 00:03:57,360

can be created out of the energy

93

00:04:02,149 --> 00:04:00,239

this is a reversible process but there

94

00:04:03,990 --> 00:04:02,159

is no material particle lighter than the

95

00:04:05,910 --> 00:04:04,000

electron so there's no alternative but

96

00:04:08,630 --> 00:04:05,920

photons here

97

00:04:09,190 --> 00:04:08,640

the primary annihilation gives you a

98

00:04:12,869 --> 00:04:09,200

mess

99

00:04:15,750 --> 00:04:12,879

of unstable reaction products

100

00:04:17,270 --> 00:04:15,760

that ultimately are all going to decay

101

00:04:22,150 --> 00:04:17,280

or mutually annihilate

102

00:04:28,550 --> 00:04:26,390

um the now if a single antiproton

103

00:04:31,270 --> 00:04:28,560

annihilates inside a large

104

00:04:32,469 --> 00:04:31,280

nucleus uh most of the intermediate

105

00:04:34,230 --> 00:04:32,479

products are strongly

106

00:04:36,469 --> 00:04:34,240

interacting mesons which are very

107

00:04:37,670 --> 00:04:36,479

efficient at transferring energy to the

108

00:04:40,150 --> 00:04:37,680

rest of the nucleus

109

00:04:42,629 --> 00:04:40,160

so most aside from photons most of the

110

00:04:45,110 --> 00:04:42,639

energy appears as thermal

111

00:04:46,629 --> 00:04:45,120

excitation in a nucleus that's literally

112

00:04:49,590 --> 00:04:46,639

been blown apart

113

00:04:50,629 --> 00:04:49,600

by the excess energy however if an

114

00:04:54,830 --> 00:04:50,639

anti-proton

115

00:04:57,510 --> 00:04:54,840

annihilates an isolated proton the

116

00:04:59,749 --> 00:04:57,520

uh ultimate products all break down into

117

00:05:01,590 --> 00:04:59,759

photons and neutrinos and the neutrinos

118

00:05:03,189 --> 00:05:01,600

end up with the lion's share of the

119

00:05:06,150 --> 00:05:03,199

energy

120

00:05:07,350 --> 00:05:06,160

uh for technical reasons that i can get

121

00:05:10,310 --> 00:05:07,360

into

122

00:05:12,390 --> 00:05:10,320

later on if anybody is really interested

123

00:05:14,310 --> 00:05:12,400

now for a reaction drive

124

00:05:15,909 --> 00:05:14,320

the faster you throw away your reaction

125

00:05:17,830 --> 00:05:15,919

mass the more efficient your drive is

126

00:05:20,150 --> 00:05:17,840

the more thrust you get per unit of

127

00:05:21,670 --> 00:05:20,160

fuel you're using up the ultimate

128

00:05:24,150 --> 00:05:21,680

reaction drive

129

00:05:25,590 --> 00:05:24,160

would have an exhaust velocity equal to

130

00:05:28,230 --> 00:05:25,600

the speed of light

131

00:05:30,790 --> 00:05:28,240

now since uh which essentially amounts

132

00:05:33,909 --> 00:05:30,800

to turning your fuel mass into radiation

133

00:05:35,670 --> 00:05:33,919

and beaming it out the back um

134

00:05:38,070 --> 00:05:35,680

you might think that you can do that

135

00:05:39,909 --> 00:05:38,080

with antimatter since it annihilates

136

00:05:40,710 --> 00:05:39,919

matter completely into energy except

137

00:05:43,110 --> 00:05:40,720

that

138

00:05:45,110 --> 00:05:43,120

the aforementioned neutrino problem the

139

00:05:45,749 --> 00:05:45,120
neutrinos fly off in all directions

140

00:05:47,189 --> 00:05:45,759
equally

141

00:05:49,189 --> 00:05:47,199
you can't direct them you can't

142

00:05:51,350 --> 00:05:49,199
manipulate them

143

00:05:52,469 --> 00:05:51,360
so much of the energy is lost in terms

144

00:05:55,590 --> 00:05:52,479
of neutrinos

145

00:05:59,590 --> 00:05:55,600
that a a rich mix antimatter rocket

146

00:06:04,830 --> 00:06:02,390
but that assumes you're just burning the

147

00:06:07,749 --> 00:06:04,840
matter antimatter mix in a reaction

148

00:06:10,950 --> 00:06:07,759
chamber

149

00:06:13,670 --> 00:06:10,960
the trick is to pre-accelerate

150

00:06:14,309 --> 00:06:13,680
the particles you're going to annihilate

151

00:06:16,710 --> 00:06:14,319

uh

152

00:06:18,550 --> 00:06:16,720

as in a particle accelerator on earth

153

00:06:20,710 --> 00:06:18,560

you accelerate both the proton and the

154

00:06:23,510 --> 00:06:20,720

antiproton to high speed

155

00:06:25,029 --> 00:06:23,520

but in the same direction not ramming

156

00:06:26,309 --> 00:06:25,039

them into each other the way we do for

157

00:06:29,350 --> 00:06:26,319

experiments

158

00:06:32,870 --> 00:06:29,360

they annihilate in at high speed

159

00:06:36,309 --> 00:06:32,880

the reaction products inherit that

160

00:06:38,790 --> 00:06:36,319

center of mass motion and then

161

00:06:40,710 --> 00:06:38,800

you put in a retrieval stage the stuff

162

00:06:43,749 --> 00:06:40,720

that you can interact with

163

00:06:46,309 --> 00:06:43,759

you capture reprocess the energy

164

00:06:47,830 --> 00:06:46,319

use it to power the acceleration for the

165

00:06:51,110 --> 00:06:47,840

next particle pair

166

00:06:53,110 --> 00:06:51,120

meanwhile the neutrinos escape

167

00:06:54,950 --> 00:06:53,120

all of the momentum that has been put

168

00:06:55,430 --> 00:06:54,960

into them by the pre-acceleration is

169

00:06:58,870 --> 00:06:55,440

just

170

00:07:02,469 --> 00:06:58,880

carried out of the chamber and you get a

171

00:07:06,629 --> 00:07:02,479

net thrust

172

00:07:09,510 --> 00:07:06,639

uh i'm going to skip quickly over

173

00:07:10,150 --> 00:07:09,520

the math here it we can refer to it in

174

00:07:13,430 --> 00:07:10,160

question

175

00:07:16,710 --> 00:07:13,440

and answer if people really want um

176

00:07:20,070 --> 00:07:16,720

but this graphic illustrates

177

00:07:22,070 --> 00:07:20,080

the drive attributes

178

00:07:23,189 --> 00:07:22,080

in a perhaps somewhat more accessible

179

00:07:26,629 --> 00:07:23,199

way

180

00:07:28,830 --> 00:07:26,639

down here at the bottom i've

181

00:07:30,710 --> 00:07:28,840

plotted the fraction of retrievable

182

00:07:33,350 --> 00:07:30,720

energy the

183

00:07:35,350 --> 00:07:33,360

amount of annihilation energy that can

184

00:07:38,710 --> 00:07:35,360

be captured and used

185

00:07:39,430 --> 00:07:38,720

and that actually depends on how big

186

00:07:42,230 --> 00:07:39,440

your engine

187

00:07:43,990 --> 00:07:42,240

is and how much free path you have for

188

00:07:46,550 --> 00:07:44,000

intermediate reaction products to

189

00:07:47,510 --> 00:07:46,560

decay if something is still a pion of

190

00:07:50,309 --> 00:07:47,520

some sort

191

00:07:51,990 --> 00:07:50,319

you can intercept it and use it it will

192

00:07:55,830 --> 00:07:52,000

decay naturally into

193

00:07:57,830 --> 00:07:55,840

neutrinos and photons and

194

00:07:59,749 --> 00:07:57,840

that that's that's where those neutrinos

195

00:08:03,430 --> 00:07:59,759

come from it's a process that takes

196

00:08:05,589 --> 00:08:03,440

time um

197

00:08:07,909 --> 00:08:05,599

and requires a certain amount of free

198

00:08:11,909 --> 00:08:07,919

path to be completed

199

00:08:12,869 --> 00:08:11,919

um now fortunately the math on the

200

00:08:15,909 --> 00:08:12,879

previous page

201
00:08:17,110 --> 00:08:15,919
indicates that the higher the mass

202
00:08:20,390 --> 00:08:17,120
retention

203
00:08:21,510 --> 00:08:20,400
that is the fewer neutrino decays you

204
00:08:23,670 --> 00:08:21,520
allow

205
00:08:25,670 --> 00:08:23,680
the higher your effective exhaust

206
00:08:29,990 --> 00:08:25,680
velocity the amount of thrust

207
00:08:31,990 --> 00:08:30,000
you get per unit of fuel um

208
00:08:33,829 --> 00:08:32,000
that this is a good thing because that

209
00:08:36,709 --> 00:08:33,839
means that the smaller your engine the

210
00:08:40,870 --> 00:08:36,719
more powerful and efficient it can be

211
00:08:43,750 --> 00:08:40,880
um just for comparison a

212
00:08:44,630 --> 00:08:43,760
a lean mix antimatter rocket where

213
00:08:48,470 --> 00:08:44,640

you're

214

00:08:51,269 --> 00:08:48,480

doing simple uh a burning like effect

215

00:08:53,190 --> 00:08:51,279

and have perhaps five percent antimatter

216

00:08:54,230 --> 00:08:53,200

would have about this thrust to mass

217

00:08:56,710 --> 00:08:54,240

ratio

218

00:08:57,829 --> 00:08:56,720

an ideal fusion rocket would be down

219

00:09:00,070 --> 00:08:57,839

here

220

00:09:02,150 --> 00:09:00,080

an ideal fission rocket would be down

221

00:09:03,110 --> 00:09:02,160

here and the chemical rockets that we're

222

00:09:05,350 --> 00:09:03,120

actually building

223

00:09:07,030 --> 00:09:05,360

nowadays would be so far down into the

224

00:09:11,670 --> 00:09:07,040

corner that there's no room for the

225

00:09:17,110 --> 00:09:14,550

now what that means in terms of the

226
00:09:20,829 --> 00:09:17,120
performance of such a drive system

227
00:09:24,310 --> 00:09:20,839
if oh sorry i

228
00:09:27,670 --> 00:09:24,320
overshot this shaded area

229
00:09:31,430 --> 00:09:27,680
here shows the approximate

230
00:09:33,110 --> 00:09:31,440
regime for an engine of reasonable size

231
00:09:34,870 --> 00:09:33,120
a few meters across

232
00:09:37,590 --> 00:09:34,880
and you can see that our effective

233
00:09:41,030 --> 00:09:37,600
exhaust velocity is indeed very close

234
00:09:44,790 --> 00:09:41,040
to the ultimate possible limit uh

235
00:09:47,750 --> 00:09:44,800
a vehicle with a a drive of this type

236
00:09:50,470 --> 00:09:47,760
if it made a constant 1g thrust trip

237
00:09:51,750 --> 00:09:50,480
from the moon to the earth it would use

238
00:09:54,470 --> 00:09:51,760

up

239

00:09:55,430 --> 00:09:54,480

0.42 kilograms of fuel mass for each

240

00:09:58,389 --> 00:09:55,440

metric ton

241

00:09:59,269 --> 00:09:58,399

of vehicle mass that's about one pound