

Energy 



1
00:00:04,789 --> 00:00:01,910
so over the years I've encountered a

2
00:00:06,980 --> 00:00:04,799
number of people who had a lot of new

3
00:00:10,490 --> 00:00:06,990
sorts of theories cosmological models

4
00:00:14,570 --> 00:00:10,500
physical models models that replace

5
00:00:16,160 --> 00:00:14,580
relativity like various sorts of

6
00:00:18,890 --> 00:00:16,170
interesting ideas and I'm not sure what

7
00:00:21,170 --> 00:00:18,900
to do with them if and they often they

8
00:00:23,420 --> 00:00:21,180
say that they're right and Einstein is

9
00:00:25,939 --> 00:00:23,430
wrong or something like that you know

10
00:00:29,150 --> 00:00:25,949
that that sort of category I started

11
00:00:31,790 --> 00:00:29,160
preparing this talk literally 40 years

12
00:00:33,889 --> 00:00:31,800
ago when I was an undergraduate and I

13
00:00:37,010 --> 00:00:33,899

was taking my initial physics classes

14

00:00:40,040 --> 00:00:37,020

and I remember learning about Newtonian

15

00:00:41,630 --> 00:00:40,050

physics and you in Newtonian physics we

16

00:00:44,540 --> 00:00:41,640

learned that force equals mass times

17

00:00:48,170 --> 00:00:44,550

acceleration so if you push something it

18

00:00:50,690 --> 00:00:48,180

moves we know that then I learned a

19

00:00:52,490 --> 00:00:50,700

completely different formulation for the

20

00:00:54,799 --> 00:00:52,500

same sort of thing and that is

21

00:00:58,279 --> 00:00:54,809

Hamilton's principle which is behind

22

00:01:01,760 --> 00:00:58,289

Lagrangian dynamics and that says that a

23

00:01:04,280 --> 00:01:01,770

system follows a path in which the

24

00:01:06,740 --> 00:01:04,290

difference between the kinetic energy

25

00:01:07,969 --> 00:01:06,750

and the potential energy is minimized

26

00:01:11,990 --> 00:01:07,979

it's called the principle of least

27

00:01:15,410 --> 00:01:12,000

action and both of these approaches give

28

00:01:16,730 --> 00:01:15,420

you exactly the same answer and so this

29

00:01:18,230 --> 00:01:16,740

was this was mind-blowing

30

00:01:21,679 --> 00:01:18,240

there's there's a way of looking at the

31

00:01:23,090 --> 00:01:21,689

universe where there's a principle and

32

00:01:27,310 --> 00:01:23,100

there's a way of looking at the universe

33

00:01:32,810 --> 00:01:27,320

where there's a process very interesting

34

00:01:36,200 --> 00:01:32,820

also other Newtonian laws or things that

35

00:01:38,390 --> 00:01:36,210

evolved from Newtonian laws can be

36

00:01:40,340 --> 00:01:38,400

matched with conservation laws so we've

37

00:01:42,620 --> 00:01:40,350

got the conservation of energy and the

38

00:01:45,590 --> 00:01:42,630

conservation of momentum again a

39

00:01:48,980 --> 00:01:45,600

principle conservation versus a process

40

00:01:51,499 --> 00:01:48,990

so the world seems to be divided so far

41

00:01:54,499 --> 00:01:51,509

into principle and process let's keep

42

00:01:57,410 --> 00:01:54,509

going in optics we learn Fermat's

43

00:01:59,719 --> 00:01:57,420

principle so Fermat's principle says

44

00:02:01,580 --> 00:01:59,729

that light takes the path of least time

45

00:02:05,569 --> 00:02:01,590

so if we're looking at a fish in a pond

46

00:02:07,490 --> 00:02:05,579

the path that the light takes makes a

47

00:02:09,240 --> 00:02:07,500

bend because light travels faster

48

00:02:12,570 --> 00:02:09,250

through air than through the higher

49

00:02:14,160 --> 00:02:12,580

index medium of the water and so we can

50

00:02:15,540 --> 00:02:14,170

tell the path that way but there's

51
00:02:18,000 --> 00:02:15,550
another way of looking at it and that's

52
00:02:20,280 --> 00:02:18,010
through Snell's law which tells us that

53
00:02:23,820 --> 00:02:20,290
at the shift of index of refraction

54
00:02:25,680 --> 00:02:23,830
there's going to be a bend and so on and

55
00:02:28,740 --> 00:02:25,690
so on and this is you can base this on

56
00:02:30,060 --> 00:02:28,750
phase matching conditions and so on so

57
00:02:33,960 --> 00:02:30,070
again there is sort of this principle

58
00:02:37,380 --> 00:02:33,970
and then there's a process let's see is

59
00:02:40,470 --> 00:02:37,390
there more before I do actually which

60
00:02:43,229 --> 00:02:40,480
one do you feel better with how many of

61
00:02:45,000 --> 00:02:43,239
you prefer looking at the general

62
00:02:47,880 --> 00:02:45,010
principle in order to understand

63
00:02:50,310 --> 00:02:47,890

something and how many of you prefer

64

00:02:52,080 --> 00:02:50,320

looking at the process examples to

65

00:02:55,350 --> 00:02:52,090

understand something okay we're almost

66

00:02:57,030 --> 00:02:55,360

evenly divided okay let's take a look at

67

00:02:59,870 --> 00:02:57,040

thermodynamics and I've got three

68

00:03:02,820 --> 00:02:59,880

examples from thermodynamics one

69

00:03:03,990 --> 00:03:02,830

involves how system evolves in time and

70

00:03:07,020 --> 00:03:04,000

we know from the second law of

71

00:03:09,960 --> 00:03:07,030

thermodynamics that the entropy must be

72

00:03:12,479 --> 00:03:09,970

maximized so system moves to a position

73

00:03:15,449 --> 00:03:12,489

where the number of options that that

74

00:03:16,830 --> 00:03:15,459

system has is maximized there's another

75

00:03:19,289 --> 00:03:16,840

way of looking at that and that is

76

00:03:22,259 --> 00:03:19,299

through the microscopic interactions if

77

00:03:25,080 --> 00:03:22,269

you put a bag into a hot water a tea bag

78

00:03:28,140 --> 00:03:25,090

that particles diffuse or it diffuse out

79

00:03:30,090 --> 00:03:28,150

and you can look through particle by

80

00:03:32,070 --> 00:03:30,100

particle what happens and eventually the

81

00:03:35,270 --> 00:03:32,080

tea gets distributed fully and the

82

00:03:38,400 --> 00:03:35,280

entropy is maximized principle process a

83

00:03:41,009 --> 00:03:38,410

second thermodynamics concept let's take

84

00:03:45,080 --> 00:03:41,019

a look at a system at rest so we know

85

00:03:48,840 --> 00:03:45,090

that if we have for example a reactant

86

00:03:52,170 --> 00:03:48,850

and a product that eventually they

87

00:03:53,610 --> 00:03:52,180

equalize they stabilize and so at that

88

00:03:54,990 --> 00:03:53,620

point you can say the system is at

89

00:03:57,180 --> 00:03:55,000

equilibrium

90

00:03:59,240 --> 00:03:57,190

what's constant the temperature the

91

00:04:02,370 --> 00:03:59,250

pressure the chemical a tallulah briam

92

00:04:04,229 --> 00:04:02,380

we can also look at this from a

93

00:04:06,170 --> 00:04:04,239

different point of view and that is an

94

00:04:08,789 --> 00:04:06,180

active process this was initially

95

00:04:11,280 --> 00:04:08,799

developed by Einstein among others and

96

00:04:13,290 --> 00:04:11,290

that says that each process is

97

00:04:15,360 --> 00:04:13,300

dynamically balanced by its

98

00:04:17,940 --> 00:04:15,370

verse in other words there's constant

99

00:04:19,979 --> 00:04:17,950

motion from the product to the reactant

100

00:04:22,020 --> 00:04:19,989

and back and forth both of these

101

00:04:24,750 --> 00:04:22,030

describe the same thing principle

102

00:04:27,150 --> 00:04:24,760

process third thermodynamics example

103

00:04:29,610 --> 00:04:27,160

heat from friction we know that if we

104

00:04:31,950 --> 00:04:29,620

rub one stick against another that the

105

00:04:34,620 --> 00:04:31,960

the kinetic energy that we've put into

106

00:04:36,480 --> 00:04:34,630

the sticks is going to eventually end up

107

00:04:38,730 --> 00:04:36,490

as heat energy and so there's a

108

00:04:40,890 --> 00:04:38,740

conservation of energy we can balance

109

00:04:42,660 --> 00:04:40,900

that by another view and that is looking

110

00:04:44,550 --> 00:04:42,670

at the microscopic interactions when you

111

00:04:46,770 --> 00:04:44,560

rub one stick against another one

112

00:04:48,780 --> 00:04:46,780

molecule causes another molecule to

113

00:04:53,100 --> 00:04:48,790

vibrate the vibrations produce heat and

114

00:04:56,720 --> 00:04:53,110

so on electro magnetics so we know that

115

00:05:01,740 --> 00:04:56,730

current produces a magnetic field

116

00:05:03,560 --> 00:05:01,750

Maxwell observed electromagnetic

117

00:05:05,820 --> 00:05:03,570

interactions for a long time and very

118

00:05:07,740 --> 00:05:05,830

carefully codified them into a long

119

00:05:09,570 --> 00:05:07,750

series of equations which were

120

00:05:13,170 --> 00:05:09,580

eventually reduced to Maxwell's four

121

00:05:15,360 --> 00:05:13,180

equations one of these is amperes law

122

00:05:18,300 --> 00:05:15,370

which I'm shown here and in particular

123

00:05:22,070 --> 00:05:18,310

I've boxed the equation that says the

124

00:05:24,210 --> 00:05:22,080

curl of the magnetic field B is equal to

125

00:05:26,850 --> 00:05:24,220

something that's related to the current

126

00:05:29,400 --> 00:05:26,860

so what this is saying is that if you

127

00:05:30,990 --> 00:05:29,410

pass current through a wire it produces

128

00:05:33,480 --> 00:05:31,000

a magnetic field and the picture shows

129

00:05:35,060 --> 00:05:33,490

that if you've got two wires in which

130

00:05:37,800 --> 00:05:35,070

you're passing current through them

131

00:05:39,810 --> 00:05:37,810

those magnetic fields interact and the

132

00:05:44,490 --> 00:05:39,820

wires can either attract or repel each

133

00:05:46,020 --> 00:05:44,500

other let's take a look at an other way

134

00:05:49,560 --> 00:05:46,030

of looking at this and that is

135

00:05:51,630 --> 00:05:49,570

electrostatics and special relativity so

136

00:05:54,690 --> 00:05:51,640

if you take a look at just a wire in the

137

00:05:57,360 --> 00:05:54,700

top picture here you can see that we've

138

00:06:00,450 --> 00:05:57,370

got electrons in the wire in the metal

139

00:06:02,340 --> 00:06:00,460

and they're balanced by the ionic cores

140

00:06:04,770 --> 00:06:02,350

which are the positive charges and so

141

00:06:07,440 --> 00:06:04,780

everything's neutral but we also know

142

00:06:10,650 --> 00:06:07,450

from special relativity that when things

143

00:06:13,380 --> 00:06:10,660

move they tend to contract that's

144

00:06:16,310 --> 00:06:13,390

Lorentz contraction or they appear to

145

00:06:19,470 --> 00:06:16,320

contract from a stationary observer and

146

00:06:21,870 --> 00:06:19,480

so if you look at this wire while the

147

00:06:23,790 --> 00:06:21,880

electrons are moving it appears that the

148

00:06:26,610 --> 00:06:23,800

elect that the electrons are in higher

149

00:06:26,820 --> 00:06:26,620

density because the the electrons and

150

00:06:34,350 --> 00:06:26,830

the

151
00:06:36,870 --> 00:06:34,360
that wire becomes not electrically

152
00:06:39,990 --> 00:06:36,880
neutral if you're looking at it the

153
00:06:42,540 --> 00:06:40,000
right way then if you have another wire

154
00:06:45,510 --> 00:06:42,550
that's adjacent to it that's also para

155
00:06:48,630 --> 00:06:45,520
passing a current those two wires will

156
00:06:50,730 --> 00:06:48,640
appear to each other to be non net non

157
00:06:52,770 --> 00:06:50,740
neutral and so there can either be

158
00:06:54,540 --> 00:06:52,780
repulsion or contraction due to special

159
00:06:57,000 --> 00:06:54,550
relativity this was a particularly

160
00:06:59,220 --> 00:06:57,010
interesting one for me and I went to a

161
00:07:00,390 --> 00:06:59,230
fellow in my department who's an electro

162
00:07:03,090 --> 00:07:00,400
magnetics theorist

163
00:07:07,040 --> 00:07:03,100

really a brilliant guy and I was talking

164

00:07:09,570 --> 00:07:07,050

to him about how you can derive a

165

00:07:11,790 --> 00:07:09,580

magnetism which is not one of the four

166

00:07:15,930 --> 00:07:11,800

basic forces how you can derive it from

167

00:07:17,640 --> 00:07:15,940

relativity and he was very puzzled and I

168

00:07:19,170 --> 00:07:17,650

said well where do you think magnetism

169

00:07:22,620 --> 00:07:19,180

comes from and he said for Maxwell's

170

00:07:24,450 --> 00:07:22,630

equations and I said but relativity

171

00:07:26,480 --> 00:07:24,460

explains it and he said no relativity

172

00:07:29,100 --> 00:07:26,490

comes from Maxwell's equations also I

173

00:07:33,380 --> 00:07:29,110

was flabbergasted but that really is

174

00:07:36,810 --> 00:07:33,390

another legitimate view so we have the

175

00:07:38,370 --> 00:07:36,820

principle view in the process view let's

176

00:07:40,650 --> 00:07:38,380

take a look again this one's a little

177

00:07:42,680 --> 00:07:40,660

more subtle and I'll go through it it's

178

00:07:45,420 --> 00:07:42,690

really for specialists but we know that

179

00:07:47,370 --> 00:07:45,430

semiconductors have electrons that it

180

00:07:49,290 --> 00:07:47,380

can exist at various levels they can

181

00:07:51,540 --> 00:07:49,300

exist in what's called a conduction band

182

00:07:53,280 --> 00:07:51,550

they can exist in a valence band and

183

00:07:55,860 --> 00:07:53,290

they cannot exist in the forbidden gap

184

00:07:58,170 --> 00:07:55,870

and silicon is an example of this all

185

00:07:59,760 --> 00:07:58,180

the electronics that we work on is based

186

00:08:02,850 --> 00:07:59,770

upon the fact that there's a forbidden

187

00:08:05,400 --> 00:08:02,860

gap in energy so where does that come

188

00:08:07,980 --> 00:08:05,410

from well as a student I learned that

189

00:08:11,550 --> 00:08:07,990

there's actually a periodic potential in

190

00:08:13,890 --> 00:08:11,560

a material and that so you can view the

191

00:08:17,340 --> 00:08:13,900

red dots as being the ionic cores and

192

00:08:19,380 --> 00:08:17,350

you can simplify that with the Green

193

00:08:22,440 --> 00:08:19,390

Line saying that there's sort of a step

194

00:08:24,420 --> 00:08:22,450

function periodic potential and so when

195

00:08:25,950 --> 00:08:24,430

the electron is traveling through the

196

00:08:28,560 --> 00:08:25,960

semiconductor it has a certain

197

00:08:31,050 --> 00:08:28,570

wavelength associated with it when that

198

00:08:34,500 --> 00:08:31,060

wavelength is such that it keeps on

199

00:08:35,800 --> 00:08:34,510

hitting these barrier walls the electron

200

00:08:39,430 --> 00:08:35,810

says I'm fed up I'm not going

201
00:08:42,040 --> 00:08:39,440
it reflects therefore that electron is

202
00:08:44,019 --> 00:08:42,050
encountering the forbidden gap if the

203
00:08:46,480 --> 00:08:44,029
electron has more energy shorter

204
00:08:48,580 --> 00:08:46,490
wavelength or less energy longer

205
00:08:50,500 --> 00:08:48,590
wavelength it doesn't in kit encounter

206
00:08:53,530 --> 00:08:50,510
this periodic potential in the same way

207
00:08:55,329 --> 00:08:53,540
and so from the periodic potential we

208
00:08:58,180 --> 00:08:55,339
can derive a band gap it's sort of a

209
00:08:59,620 --> 00:08:58,190
Fourier transform approach then I

210
00:09:01,960 --> 00:08:59,630
learned another thing in solid-state

211
00:09:03,910 --> 00:09:01,970
physics and this is a complicated

212
00:09:06,400 --> 00:09:03,920
diagram so bear with me let's just start

213
00:09:09,280 --> 00:09:06,410

on the right hand side so this shows

214

00:09:12,430 --> 00:09:09,290

energy and it's an atom and we know that

215

00:09:14,380 --> 00:09:12,440

an atom has electronic orbitals the red

216

00:09:16,900 --> 00:09:14,390

line the blue line the orange line and

217

00:09:19,810 --> 00:09:16,910

these orbital energies for the electron

218

00:09:22,060 --> 00:09:19,820

are discrete now take the atoms and

219

00:09:25,510 --> 00:09:22,070

start smashing them together as you

220

00:09:27,460 --> 00:09:25,520

squeeze them together they encounter the

221

00:09:31,360 --> 00:09:27,470

poly exclusion principle which says that

222

00:09:32,980 --> 00:09:31,370

you cannot have anything in exactly the

223

00:09:36,310 --> 00:09:32,990

same state at the same place at the same

224

00:09:38,769 --> 00:09:36,320

time so the electrons cannot all be in

225

00:09:40,810 --> 00:09:38,779

the same energy so what do they do they

226

00:09:43,240 --> 00:09:40,820

spread out and so the energies of the

227

00:09:46,000 --> 00:09:43,250

electrons spread out as you move the

228

00:09:48,790 --> 00:09:46,010

atoms closer and closer together the

229

00:09:53,170 --> 00:09:48,800

vertical dashed line shows the inter

230

00:09:56,740 --> 00:09:53,180

atomic spacing of the atoms in a solid

231

00:10:00,040 --> 00:09:56,750

and so at that spacing what do you end

232

00:10:03,250 --> 00:10:00,050

up with you end up with bands a gap and

233

00:10:03,610 --> 00:10:03,260

bands and so we end up with the same

234

00:10:05,350 --> 00:10:03,620

thing

235

00:10:08,350 --> 00:10:05,360

this was mind-blowing to me as a student

236

00:10:10,840 --> 00:10:08,360

two totally different ways of deriving

237

00:10:13,150 --> 00:10:10,850

semiconductor band structure now which

238

00:10:15,730 --> 00:10:13,160

one is process in which one is principle

239

00:10:18,850 --> 00:10:15,740

so let's step back a little bit and take

240

00:10:20,410 --> 00:10:18,860

a look so I just divided things into

241

00:10:23,430 --> 00:10:20,420

process in principle but it's really a

242

00:10:30,160 --> 00:10:26,910

principle can be a conservation concept

243

00:10:32,699 --> 00:10:30,170

process might be kinetics principle can

244

00:10:36,400 --> 00:10:32,709

be a purpose the purpose of least action

245

00:10:39,790 --> 00:10:36,410

the process might be the mechanism you

246

00:10:43,090 --> 00:10:39,800

push this it moves it might be what what

247

00:10:45,800 --> 00:10:43,100

happens versus how it happens principle

248

00:10:48,290 --> 00:10:45,810

tends to be more abstract process tensed

249

00:10:50,780 --> 00:10:48,300

a more concrete principle tends to be a

250

00:10:52,940 --> 00:10:50,790

global thing process tends to be local

251
00:10:55,670 --> 00:10:52,950
and so in looking at the semiconductor

252
00:10:58,130 --> 00:10:55,680
example the periodic potential is global

253
00:11:00,170 --> 00:10:58,140
the spreading of atomic orbitals is

254
00:11:02,990 --> 00:11:00,180
local and so therefore that's how I

255
00:11:04,610 --> 00:11:03,000
would divide these two concepts then we

256
00:11:05,900 --> 00:11:04,620
want to go a little bit farther and

257
00:11:08,570 --> 00:11:05,910
that's why I call this whole thing

258
00:11:10,910 --> 00:11:08,580
dualism so we know the philosophical

259
00:11:13,880 --> 00:11:10,920
concept of dualism which divides the

260
00:11:16,730 --> 00:11:13,890
world into mind and body or mind and

261
00:11:18,950 --> 00:11:16,740
matter and there's a real parallel here

262
00:11:21,800 --> 00:11:18,960
because I've got very little time I

263
00:11:23,870 --> 00:11:21,810

won't go into that much but so in

264

00:11:26,300 --> 00:11:23,880

semiconductors draw a structure band

265

00:11:28,190 --> 00:11:26,310

structure we also have a principle in

266

00:11:30,280 --> 00:11:28,200

process so let's take a look at another

267

00:11:32,570 --> 00:11:30,290

one and this is the really tricky one

268

00:11:35,750 --> 00:11:32,580

microscopic interactions so we know that

269

00:11:38,660 --> 00:11:35,760

microscopic interactions are described

270

00:11:41,000 --> 00:11:38,670

by quantum mechanics quantum mechanics

271

00:11:42,290 --> 00:11:41,010

one of the operational equations for

272

00:11:44,660 --> 00:11:42,300

quantum mechanics is the Schrodinger

273

00:11:47,180 --> 00:11:44,670

equation here I show an example of the

274

00:11:49,670 --> 00:11:47,190

time dependent Schrodinger equation how

275

00:11:51,950 --> 00:11:49,680

does this work well let's say that we

276

00:11:54,710 --> 00:11:51,960

have here the the example that's always

277

00:11:57,380 --> 00:11:54,720

brought up the example of the double

278

00:11:59,570 --> 00:11:57,390

slits so you're sending electrons one at

279

00:12:01,490 --> 00:11:59,580

a time through double slits the electron

280

00:12:04,550 --> 00:12:01,500

goes through one slit or another slit

281

00:12:06,680 --> 00:12:04,560

you know the story it keeps on going and

282

00:12:08,990 --> 00:12:06,690

you would expect that if you're sending

283

00:12:11,360 --> 00:12:09,000

particles through slits you'd end up

284

00:12:14,000 --> 00:12:11,370

with just sort of a smear pattern on the

285

00:12:16,040 --> 00:12:14,010

target but you don't get a smear pattern

286

00:12:18,380 --> 00:12:16,050

instead you get a series of lines that

287

00:12:20,900 --> 00:12:18,390

says that the electrons these particles

288

00:12:24,590 --> 00:12:20,910

have wave-like characteristics which

289

00:12:26,360 --> 00:12:24,600

cause interference patterns from waves

290

00:12:29,110 --> 00:12:26,370

so we've got waves

291

00:12:32,810 --> 00:12:29,120

we've got particles very very disturbing

292

00:12:35,380 --> 00:12:32,820

but yet quantum mechanic mechanics tells

293

00:12:37,820 --> 00:12:35,390

us what happens it doesn't tell us why

294

00:12:39,170 --> 00:12:37,830

let's take a look at another example and

295

00:12:41,630 --> 00:12:39,180

there are many many let's take a look at

296

00:12:44,410 --> 00:12:41,640

black holes so we know that there's an

297

00:12:47,590 --> 00:12:44,420

event horizon in black holes and if

298

00:12:52,490 --> 00:12:47,600

anything encounters the event horizon

299

00:12:55,110 --> 00:12:52,500

impasse it'll apart particles

300

00:12:57,920 --> 00:12:55,120

radiation everything falls into the

301

00:13:01,050 --> 00:12:57,930

black hole never to come out again

302

00:13:02,879 --> 00:13:01,060

except for Hawking radiation

303

00:13:04,829 --> 00:13:02,889

so Hawking figured out that there is a

304

00:13:08,040 --> 00:13:04,839

way to radiate particles from a black

305

00:13:11,220 --> 00:13:08,050

hole and this has to do with pair

306

00:13:13,189 --> 00:13:11,230

creation so in the vacuum you're

307

00:13:15,629 --> 00:13:13,199

constantly creating

308

00:13:19,319 --> 00:13:15,639

particle-antiparticle pairs they're

309

00:13:22,530 --> 00:13:19,329

created and they recombine and if you

310

00:13:25,259 --> 00:13:22,540

have this pair of creation but occur

311

00:13:28,500 --> 00:13:25,269

near the event horizon and the

312

00:13:32,400 --> 00:13:28,510

antiparticle say a positron falls into

313

00:13:34,710 --> 00:13:32,410

the black hole and the the particle

314

00:13:37,519 --> 00:13:34,720

comes out of the black hole eventually

315

00:13:39,689 --> 00:13:37,529

the antiparticle will recombine with

316

00:13:41,939 --> 00:13:39,699

another particle inside the black hole

317

00:13:44,910 --> 00:13:41,949

and disappear and you've ended up with a

318

00:13:46,740 --> 00:13:44,920

particle outside great so that works so

319

00:13:49,560 --> 00:13:46,750

you actually can radiate from a black

320

00:13:52,319 --> 00:13:49,570

hole in that way so when I heard about

321

00:13:54,870 --> 00:13:52,329

this I was really puzzled why doesn't

322

00:13:56,790 --> 00:13:54,880

the other process occur why don't you

323

00:13:59,430 --> 00:13:56,800

have the antiparticle falling into the

324

00:14:01,410 --> 00:13:59,440

black hole the particle coming out of

325

00:14:03,480 --> 00:14:01,420

the black hole sorry it's the opposite

326

00:14:04,500 --> 00:14:03,490

way why don't you have the particle

327

00:14:06,660 --> 00:14:04,510

falling into the black hole the

328

00:14:08,490 --> 00:14:06,670

antiparticle coming out in which case

329

00:14:10,110 --> 00:14:08,500

ultimately what you've done is you've

330

00:14:11,900 --> 00:14:10,120

just fed the black hole with more

331

00:14:13,680 --> 00:14:11,910

particles you haven't had radiation and

332

00:14:16,949 --> 00:14:13,690

statistically you'd think there'd be an

333

00:14:20,780 --> 00:14:16,959

equal number of anti particles going in

334

00:14:23,970 --> 00:14:20,790

and particles going in so I went to my

335

00:14:27,120 --> 00:14:23,980

uncle who's a well-known cosmologists

336

00:14:30,300 --> 00:14:27,130

and I said Uncle Warner why does it

337

00:14:35,040 --> 00:14:30,310

happen this way and he said well you see

338

00:14:38,970 --> 00:14:35,050

Garrett you cannot have an antiparticle

339

00:14:41,040 --> 00:14:38,980

that in free space has a negative

340

00:14:42,569 --> 00:14:41,050

total energy that commits the sum of the

341

00:14:46,050 --> 00:14:42,579

kinetic energy and the potential energy

342

00:14:48,809 --> 00:14:46,060

and you cannot have an antiparticle in

343

00:14:50,939 --> 00:14:48,819

free space and I said why not

344

00:14:52,949 --> 00:14:50,949

and he said well relativistic quantum

345

00:14:56,340 --> 00:14:52,959

mechanics says you cannot have an

346

00:14:58,110 --> 00:14:56,350

antiparticle in free space is that an

347

00:15:01,769 --> 00:14:58,120

answer well that's what that's what

348

00:15:04,150 --> 00:15:01,779

we're told and that is the answer and so

349

00:15:08,680 --> 00:15:04,160

again once again quantum mechanics

350

00:15:11,050 --> 00:15:08,690

what it doesn't tell us how so therefore

351

00:15:13,360 --> 00:15:11,060

if we want to make our principle versus

352

00:15:17,130 --> 00:15:13,370

process we have quantum mechanics as a

353

00:15:20,200 --> 00:15:17,140

principle what the devil is the process

354

00:15:22,270 --> 00:15:20,210

so there have been a number of theories

355

00:15:23,880 --> 00:15:22,280

that have been proposed one that I

356

00:15:26,070 --> 00:15:23,890

particularly like a stochastic

357

00:15:29,560 --> 00:15:26,080

electrodynamics and stochastic

358

00:15:32,560 --> 00:15:29,570

electrodynamics says that the world is

359

00:15:35,650 --> 00:15:32,570

actually classical with the addition of

360

00:15:37,750 --> 00:15:35,660

zero-point fields so zero point fields

361

00:15:41,110 --> 00:15:37,760

are all over the place and they cause a

362

00:15:43,990 --> 00:15:41,120

jiggling and that jiggling is what we

363

00:15:45,940 --> 00:15:44,000

interpret as quantum behavior and this

364

00:15:48,370 --> 00:15:45,950

was developed originally from some ideas

365

00:15:50,080 --> 00:15:48,380

of by Einstein it was developed over the

366

00:15:52,990 --> 00:15:50,090

years by Boyer and various other people

367

00:15:56,230 --> 00:15:53,000

just this last year de la pena a

368

00:15:58,900 --> 00:15:56,240

professor in Mexico published an amazing

369

00:16:01,000 --> 00:15:58,910

treatise called the emerging quantum and

370

00:16:03,610 --> 00:16:01,010

what he did is he used stochastic

371

00:16:05,590 --> 00:16:03,620

electro dynamic processes to derive

372

00:16:08,830 --> 00:16:05,600

quantum mechanics he derived the

373

00:16:11,110 --> 00:16:08,840

Schrodinger equation he derived a fully

374

00:16:18,700 --> 00:16:11,120

quantum mechanical explanation for

375

00:16:21,580 --> 00:16:18,710

things and this may be a process way of

376

00:16:24,180 --> 00:16:21,590

looking at what quantum mechanics gives

377

00:16:28,720 --> 00:16:24,190

us a principled way of looking at is

378

00:16:34,580 --> 00:16:28,730

stochastic electrodynamics right is

379

00:16:42,440 --> 00:16:36,530

I don't think that's an appropriate

380

00:16:44,570 --> 00:16:42,450

question so has the world come to the

381

00:16:46,130 --> 00:16:44,580

doorstep of Della Pena and Boyer and a

382

00:16:48,440 --> 00:16:46,140

number of other people before who move

383

00:16:50,180 --> 00:16:48,450

develop stochastic electrodynamics no of

384

00:16:51,740 --> 00:16:50,190

course not they've ignored it because

385

00:16:55,000 --> 00:16:51,750

quantum mechanics gives the right answer

386

00:16:58,460 --> 00:16:55,010

so why do you need to go anywhere else

387

00:17:00,830 --> 00:16:58,470

but yet something is missing here so if

388

00:17:04,190 --> 00:17:00,840

we go and we look now at the parallel

389

00:17:05,900 --> 00:17:04,200

theories we've got a series of parallel

390

00:17:09,080 --> 00:17:05,910

theories where there's principle and

391

00:17:15,230 --> 00:17:09,090

process two ways of looking at the same

392

00:17:18,080 --> 00:17:15,240

phenomena in each case and giving us the

393

00:17:20,240 --> 00:17:18,090

same answer the one outlier that I found

394

00:17:23,360 --> 00:17:20,250

ister is a quantum mechanics where there

395

00:17:25,010 --> 00:17:23,370

is no established process way of looking

396

00:17:27,950 --> 00:17:25,020

at it one thing that I found interesting

397

00:17:30,380 --> 00:17:27,960

in looking at this is that Einstein has

398

00:17:32,780 --> 00:17:30,390

his name behind three of these between

399

00:17:35,540 --> 00:17:32,790

detail balance special relativity and

400

00:17:39,170 --> 00:17:35,550

also stochastic electrodynamics to some

401

00:17:41,620 --> 00:17:39,180

extent so I think this tells us the way

402

00:17:45,740 --> 00:17:41,630

that Einstein liked to look at the world

403

00:17:49,150 --> 00:17:45,750

so now I ask you which suits you better

404

00:17:54,340 --> 00:17:49,160

do you prefer one way or the other I

405

00:17:57,170 --> 00:17:54,350

tend to be a process guy but I some of

406

00:18:00,380 --> 00:17:57,180

brilliant people I know are principled

407

00:18:01,550 --> 00:18:00,390

guys so let's let's see where do we get

408

00:18:05,720 --> 00:18:01,560

what do we get from this

409

00:18:09,170 --> 00:18:05,730

so most physical phenomena can be

410

00:18:11,240 --> 00:18:09,180

described by two different approaches

411

00:18:12,500 --> 00:18:11,250

one that I'm calling process one that

412

00:18:15,500 --> 00:18:12,510

I'm calling principle sort of a

413

00:18:18,800 --> 00:18:15,510

dualistic approach quantum mechanics

414

00:18:21,710 --> 00:18:18,810

lacks an accepted theory describing the

415

00:18:23,840 --> 00:18:21,720

process and from at least my way of

416

00:18:25,970 --> 00:18:23,850

understanding this is the problem with

417

00:18:29,750 --> 00:18:25,980

quantum mechanics this is what we need

418

00:18:32,450 --> 00:18:29,760

to balance what we understand in quantum

419

00:18:36,290 --> 00:18:32,460

mechanics then to answer the basic

420

00:18:37,940 --> 00:18:36,300

question of which is right which theory

421

00:18:39,920 --> 00:18:37,950

is right when someone comes up with a

422

00:18:41,990 --> 00:18:39,930

theory that explains what relativity

423

00:18:45,060 --> 00:18:42,000

explains and says no this shows that

424

00:18:49,980 --> 00:18:45,070

Einstein is wrong No

425

00:18:52,950 --> 00:18:49,990

nature just is how we describe it is up

426

00:18:55,470 --> 00:18:52,960

to us but we often make the mistake of

427

00:18:58,169 --> 00:18:55,480

thinking that our descriptions are a

428

00:19:02,370 --> 00:18:58,179

reality the descriptions are just a

429

00:19:05,340 --> 00:19:02,380

description and so my answer to many

430

00:19:17,240 --> 00:19:05,350

questions about one view versus another

431

00:19:31,799 --> 00:19:27,419

York I'd like to make a couple of quills

432

00:19:33,870 --> 00:19:31,809

or perhaps clarifications for for the

433

00:19:36,120 --> 00:19:33,880

the sake of the non physicists in the

434

00:19:37,980 --> 00:19:36,130

audience I'd like to point out that you

435

00:19:40,500 --> 00:19:37,990

are consistently referring to anti

436

00:19:43,380 --> 00:19:40,510

particles when what you really meant

437

00:19:45,419 --> 00:19:43,390

were negative energy virtual particles

438

00:19:47,970 --> 00:19:45,429

in terms of the conventional matter

439

00:19:50,010 --> 00:19:47,980

antimatter a black hole will produce as

440

00:19:54,000 --> 00:19:50,020

many electrons as positrons you can tell

441

00:19:58,620 --> 00:19:56,669

another small quibble is that I I think

442

00:20:00,570 --> 00:19:58,630

you've misrepresented Einsteins of

443

00:20:05,460 --> 00:20:00,580

legions yeah he originally derived

444

00:20:08,850 --> 00:20:05,470

relativity from Maxwell's equations in

445

00:20:11,760 --> 00:20:08,860

fact his first thought experiment in the

446

00:20:14,039 --> 00:20:11,770

area was his realization that if you

447

00:20:17,400 --> 00:20:14,049

could somehow move with a ray of light

448

00:20:19,740 --> 00:20:17,410

at the same speed you would see that

449

00:20:21,600 --> 00:20:19,750

it's fields were not obeying Maxwell's

450

00:20:23,370 --> 00:20:21,610

equations okay so I've got a quibble

451

00:20:25,890 --> 00:20:23,380

with you on that one

452

00:20:30,000 --> 00:20:25,900

the way that something historically

453

00:20:32,880 --> 00:20:30,010

evolved doesn't mean doesn't define the

454

00:20:35,700 --> 00:20:32,890

way that we have to look at it and so

455

00:20:37,470 --> 00:20:35,710

very often we start from some specific

456

00:20:45,419 --> 00:20:37,480

and get a general and later say the

457

00:20:51,140 --> 00:20:45,429

general gives us the specific I just

458

00:20:54,659 --> 00:20:51,150

like to quote quickly a little known

459

00:20:55,400 --> 00:20:54,669

Cambridge mathematician from many years

460

00:20:59,669 --> 00:20:55,410

ago

461

00:21:04,490 --> 00:20:59,679

Gee's Spencer Browne and he went a lot

462

00:21:09,240 --> 00:21:04,500

on the definitions of words so explain

463

00:21:14,100 --> 00:21:09,250

explain that is to lay out flat as on a

464

00:21:20,100 --> 00:21:14,110

map or a diagram and so miss the

465

00:21:29,549 --> 00:21:20,110

complexity of the reality or royalty of

466

00:21:32,190 --> 00:21:29,559

the wells as Cheers here it in regards

467

00:21:35,100 --> 00:21:32,200

to your quantum mechanical dismissal of

468

00:21:36,900 --> 00:21:35,110

the double slit experiment I would at

469

00:21:39,870 --> 00:21:36,910

least like to propose a little quibble

470

00:21:41,669 --> 00:21:39,880

as well and that is when you analyze the

471

00:21:44,250 --> 00:21:41,679

double slit with single particles going

472

00:21:46,680 --> 00:21:44,260

through the slits Paul Dirac another

473

00:21:49,590 --> 00:21:46,690

famous physicist of standard model a

474

00:21:51,360 --> 00:21:49,600

hero said of particle never interacts

475

00:21:54,180 --> 00:21:51,370

with another it always interacts with

476
00:21:57,060 --> 00:21:54,190
itself so if we look at the particle in

477
00:22:00,270 --> 00:21:57,070
terms of a wave packet extending past

478
00:22:02,039 --> 00:22:00,280
both slits then we kind of at least

479
00:22:04,320 --> 00:22:02,049
understand the interference that's

480
00:22:07,340 --> 00:22:04,330
occurring and of course the collapse of

481
00:22:09,650 --> 00:22:07,350
the wave packet onto a single dot

482
00:22:11,789 --> 00:22:09,660
looking like an interference pattern

483
00:22:14,490 --> 00:22:11,799
seems to make a little more sense that

484
00:22:17,669 --> 00:22:14,500
way just it's a con we don't disagree at

485
00:22:19,530 --> 00:22:17,679
all oh god I I agree with you fully and

486
00:22:21,810 --> 00:22:19,540
I'm not I don't want to deride quantum

487
00:22:23,460 --> 00:22:21,820
mechanics it works and various

488
00:22:25,919 --> 00:22:23,470

interpretations of quantum mechanics

489

00:22:28,380 --> 00:22:25,929

such as the one you described work I'm

490

00:22:30,180 --> 00:22:28,390

not saying they're wrong I just what I

491

00:22:31,860 --> 00:22:30,190

do want to say is that there's another

492

00:22:34,409 --> 00:22:31,870

way of looking at it you know and I love

493

00:22:36,440 --> 00:22:34,419

CD as well so conceptually I agree with

494

00:22:40,500 --> 00:22:36,450

you

495

00:22:42,960 --> 00:22:40,510

yes Garrett could it be that the

496

00:22:45,600 --> 00:22:42,970

difficulty in explaining of forming a

497

00:22:47,280 --> 00:22:45,610

process model is that we're trying to do

498

00:22:49,470 --> 00:22:47,290

it in black and white whereas quantum

499

00:22:51,750 --> 00:22:49,480

mechanics is really in color so to speak

500

00:22:55,590 --> 00:22:51,760

in other words we're trying to use a

501
00:22:56,909 --> 00:22:55,600
classical mind type approach to describe

502
00:22:59,520 --> 00:22:56,919
something that is fundamentally not

503
00:23:03,360 --> 00:22:59,530
classically it's quantum like quantum

504
00:23:06,659 --> 00:23:03,370
information so that's a deep question

505
00:23:08,340 --> 00:23:06,669
and I don't obviously I'm not the person

506
00:23:11,909 --> 00:23:08,350
who knows the answer I don't know if

507
00:23:14,640 --> 00:23:11,919
anybody does but I wonder whether we

508
00:23:19,210 --> 00:23:14,650
have sort of warped the way that we

509
00:23:21,850 --> 00:23:19,220
think about reality to conform to the

510
00:23:24,700 --> 00:23:21,860
open Hagen view or other views of

511
00:23:28,930 --> 00:23:24,710
quantum mechanics and so we've gone way

512
00:23:31,960 --> 00:23:28,940
out on a limb to try to understand

513
00:23:34,210 --> 00:23:31,970

something very very strange when in fact

514

00:23:37,899 --> 00:23:34,220

we don't need to do that we can

515

00:23:41,169 --> 00:23:37,909

understand it from a more simple process

516

00:23:44,289 --> 00:23:41,179

point of view that fits our intuition

517

00:23:48,780 --> 00:23:44,299

better I don't know but I wonder about