1
00:00:33,920 --> 00:00:30,290
ten-nine go for main engine start we

2
00:00:38,510 --> 00:00:33,930
have main engine start four three two

3
00:00:40,700 --> 00:00:38,520
one zero and liftoff liftoff of the

4
00:01:17,980 --> 00:00:40,710
space shuttle and it has cleared the

5
00:01:21,050 --> 00:01:20,270
hello and welcome aboard the space

6
00:01:23,630 --> 00:01:21,060
shuttle Endeavour

7
00:01:26,450 --> 00:01:23,640
for we're orbiting almost 300 kilometers

8
00:01:28,639 --> 00:01:26,460
above the earth our primary mission on

9
00:01:32,179 --> 00:01:28,649
this flight was to deploy a tracking and

10
00:01:35,300 --> 00:01:32,189
data relay satellite or TDRs feeders for

11
00:01:36,950 --> 00:01:35,310
short and when it becomes operational it

12
00:01:38,899 --> 00:01:36,960
will relay communications between

13
00:01:45,109 --> 00:01:38,909

orbiting spacecraft and tracking

14
00:01:54,789 --> 00:01:45,119
stations on the ground a few days ago we

15
00:02:00,080 --> 00:01:57,380
but deploying tigress wasn't our only

16
00:02:02,090 --> 00:02:00,090
mission on this flight two of our crew

17
00:02:03,859 --> 00:02:02,100
members put on the protective Evo suits

18
00:02:10,160 --> 00:02:03,869
and went outside the orbiter on an

19
00:02:11,780 --> 00:02:10,170
important space law science experiments

20
00:02:14,259 --> 00:02:11,790
to conduct but for one of our

21
00:02:16,880 --> 00:02:14,269
experiments we brought along some toys

22
00:02:18,500 --> 00:02:16,890
each of these toys work because of

23
00:02:21,320 --> 00:02:18,510
important scientific and mathematical

24
00:02:34,339 --> 00:02:21,330
principles principles that we often take

25
00:02:44,360 --> 00:02:34,349
for granted on the ground that means

26
00:02:46,339 --> 00:02:44,370
that everything around if you don't

27
00:02:49,309 --> 00:02:46,349
understand microgravity your teacher can

28
00:02:51,740 --> 00:02:49,319
help you out but for now we need you to

29
00:02:53,660 --> 00:02:51,750
help us with these experiments we want

30
00:02:55,940 --> 00:02:53,670
to find out if the toys act differently

31
00:02:57,770 --> 00:02:55,950
in space than they do on earth but first

32
00:03:01,759 --> 00:02:57,780
we have to know how they work on earth

33
00:03:03,830 --> 00:03:01,769
this is where we need your help we want

34
00:03:06,080 --> 00:03:03,840
you to experiment the same kinds of toys

35
00:03:07,940 --> 00:03:06,090
we have here on the shuttle then when

36
00:03:09,379 --> 00:03:07,950
you become experts with them try to

37
00:03:11,390 --> 00:03:09,389
predict how they will act in

38
00:03:13,460 --> 00:03:11,400

microgravity after you've made your

39
00:03:16,059 --> 00:03:13,470
predictions what do we do with the toy

40
00:03:18,580 --> 00:03:16,069
and see if you were right

41
00:03:20,649 --> 00:03:18,590
remember this is a team effort and we're

42
00:03:36,069 --> 00:03:20,659
counting on you to make our experiment a

43
00:03:38,440 --> 00:03:36,079
success in this scene here I'm trying to

44
00:03:40,059 --> 00:03:38,450
get the rat to flip on my hand but as

45
00:03:42,039 --> 00:03:40,069
you can see what happens instead is that

46
00:03:44,500 --> 00:03:42,049
his legs push against my hand and he

47
00:03:47,020 --> 00:03:44,510
spins up and away now in the next scene

48
00:03:49,059 --> 00:03:47,030
what I did was tape his feet to a book

49
00:03:51,670 --> 00:03:49,069
now the book is so much more massive

50
00:03:54,009 --> 00:03:51,680
than the rat that when the rat pushes on

51
00:03:56,199 --> 00:03:54,019
it with his feet the book turns only

52
00:03:58,179 --> 00:03:56,209
very slowly and the rat because he's

53
00:04:11,839 --> 00:03:58,189
taped cannot jump up and away like he

54
00:04:17,940 --> 00:04:14,670
watch what happens when the suction cup

55
00:04:21,360 --> 00:04:17,950
releases now see the spring jumper takes

56
00:04:39,360 --> 00:04:21,370
off we'll watch it again and boy look

57
00:04:41,460 --> 00:04:39,370
how fast that travels across this the

58
00:04:44,280 --> 00:04:41,470
big question with this scene is will the

59
00:04:46,290 --> 00:04:44,290
Frog swim as well in air as he does in

60
00:04:48,180 --> 00:04:46,300
water well if you watch the picture here

61
00:04:49,950 --> 00:04:48,190
you'll notice that no he does not

62
00:04:51,900 --> 00:04:49,960
I try all different ways of getting that

63
00:04:54,240 --> 00:04:51,910

frog to swim in a straight line but

64
00:04:56,730 --> 00:04:54,250
because the air is much less dense than

65
00:05:09,730 --> 00:04:56,740
water I can't get him to do it so the

66
00:05:14,270 --> 00:05:12,230
we'll take a look at the submarine here

67
00:05:15,920 --> 00:05:14,280
and I'll let it go and you can see that

68
00:05:18,500 --> 00:05:15,930
as it turns through the air both the

69
00:05:20,150 --> 00:05:18,510
propeller and the submarine turn instead

70
00:05:23,360 --> 00:05:20,160
of in the water where only the propeller

71
00:05:24,980 --> 00:05:23,370
turns now I'll take a look at what

72
00:05:26,630 --> 00:05:24,990
happens if I hold on to the propeller

73
00:05:31,730 --> 00:05:26,640
and you can see that the submarine turns

74
00:05:33,770 --> 00:05:31,740
around it both go and it takes off one

75
00:05:36,200 --> 00:05:33,780
more time this time I've attached small

76
00:05:39,410 --> 00:05:36,210
pieces of paper on to the propeller to

77
00:05:43,070 --> 00:05:39,420
make the propeller larger and we'll see

78
00:05:49,340 --> 00:05:43,080
what happens when we let this go I'll

79
00:05:54,050 --> 00:05:49,350
move back so we can get a really takes

80
00:05:55,730 --> 00:05:54,060
off we've taped a pen on to the end of

81
00:05:57,260 --> 00:05:55,740
the submarine propeller to see what

82
00:05:59,360 --> 00:05:57,270
would happen and if the submarine would

83
00:06:01,460 --> 00:05:59,370
change the way it moved well it turns

84
00:06:03,650 --> 00:06:01,470
out that it did as you can tell it flops

85
00:06:06,830 --> 00:06:03,660
around quite a bit more we had a harder

86
00:06:09,410 --> 00:06:06,840
time keeping it under control let's look

87
00:06:11,360 --> 00:06:09,420
at the swimming fish now this fish swims

88
00:06:12,230 --> 00:06:11,370

real well in water but watch what's

89
00:06:14,150 --> 00:06:12,240
happening now

90
00:06:17,980 --> 00:06:14,160
he's really struggling and not getting

91
00:06:22,540 --> 00:06:17,990
anywhere just sort of floating around

92
00:06:28,580 --> 00:06:26,180
well try it one more time whoops I think

93
00:06:31,340 --> 00:06:28,590
I had a little rotation and he's turning

94
00:06:32,870 --> 00:06:31,350
around just sort of flopping around not

95
00:06:37,550 --> 00:06:32,880
really getting anywhere it's trying to

96
00:06:39,350 --> 00:06:37,560
swim through air one of the things you

97
00:06:42,230 --> 00:06:39,360
can do to help the fish swim better in

98
00:06:44,450 --> 00:06:42,240
air is to impress the size of the fin it

99
00:06:46,910 --> 00:06:44,460
also turns out that releasing the fish

100
00:06:49,310 --> 00:06:46,920
very gently has an impact on which

101
00:06:51,170 --> 00:06:49,320
direction the fish will swim I finally

102
00:07:04,779 --> 00:06:51,180
got it right in this scene here and you

103
00:07:08,360 --> 00:07:06,980
we'll look at the flapping bird in

104
00:07:10,520 --> 00:07:08,370
microgravity and you can see what

105
00:07:12,439 --> 00:07:10,530
happens here just flies around in

106
00:07:14,390 --> 00:07:12,449
circles it doesn't seem to have any

107
00:07:18,379 --> 00:07:14,400
direction of travel let's look at it

108
00:07:20,959 --> 00:07:18,389
again in slow motion just goes around

109
00:07:26,360 --> 00:07:20,969
doesn't go straight as it does on the

110
00:07:30,860 --> 00:07:26,370
earth in one gravity and it looks like

111
00:07:37,219 --> 00:07:30,870
it's turning around the wings now just

112
00:07:46,679 --> 00:07:37,229
soar it without the wings flapping and

113
00:07:55,709 --> 00:07:53,999

I tried throwing this paper maple seeds

114
00:07:57,899 --> 00:07:55,719
several different ways you can see it

115
00:08:00,119 --> 00:07:57,909
didn't go very well when I threw it

116
00:08:02,399 --> 00:08:00,129
holding on to the wing now I held on to

117
00:08:05,159 --> 00:08:02,409
the bottom and threw it and it turned

118
00:08:08,159 --> 00:08:05,169
just a little bit I finally got the hang

119
00:08:22,290 --> 00:08:08,169
of it you can see a turning now very

120
00:08:27,150 --> 00:08:25,390
I'm throwing the paper boomerang and

121
00:08:29,980 --> 00:08:27,160
we'll see what happens

122
00:08:31,930 --> 00:08:29,990
goes into the side of the wall if there

123
00:08:34,029 --> 00:08:31,940
had been more room I think the paper

124
00:08:36,430 --> 00:08:34,039
boomerang would have come back now this

125
00:08:39,730 --> 00:08:36,440
time I threw it and flipped it with a

126
00:08:41,320 --> 00:08:39,740
lot of rotation but not much forward

127
00:08:58,030 --> 00:08:41,330
velocity and it just keeps going

128
00:09:00,340 --> 00:08:58,040
straight boy that thing shot up like a

129
00:09:02,560 --> 00:09:00,350
rocket and that caught me by surprise I

130
00:09:04,150 --> 00:09:02,570
didn't expect that in this microgravity

131
00:09:07,630 --> 00:09:04,160
environment that it would go up to that

132
00:09:09,190 --> 00:09:07,640
quickly even in slow motion it comes off

133
00:09:24,670 --> 00:09:09,200
and hits me in the chest even before I

134
00:09:26,500 --> 00:09:24,680
can react here I have a single graviton

135
00:09:28,360 --> 00:09:26,510
that's floating free in the cabin and

136
00:09:32,950 --> 00:09:28,370
it's spinning you can see it wants to

137
00:09:34,510 --> 00:09:32,960
spin about the wheel inside as well but

138
00:09:36,430 --> 00:09:34,520

I'm trying to get it to tip over and I

139
00:09:38,290 --> 00:09:36,440
can bump it on the sides on the top on

140
00:09:40,329 --> 00:09:38,300
the bottom and I can't make it tip over

141
00:09:43,230 --> 00:09:40,339
it's stable about the axis I let it go

142
00:09:45,700 --> 00:09:43,240
in which is the spin axis up and down

143
00:09:48,010 --> 00:09:45,710
this is the same configuration I've got

144
00:09:50,050 --> 00:09:48,020
one spinning graviton here and I've

145
00:09:52,150 --> 00:09:50,060
oriented it so the spin axis is pointing

146
00:09:53,470 --> 00:09:52,160
at the camera again I'm just bumping it

147
00:09:55,780 --> 00:09:53,480
on the sides and the top and the bottom

148
00:09:58,970 --> 00:09:55,790
and I cannot get at the tip it's stable

149
00:10:00,740 --> 00:09:58,980
about the axis I let it go in

150
00:10:03,319 --> 00:10:00,750
this should be a graphic demonstration

151
00:10:05,329 --> 00:10:03,329
of a spinning and Anan spinning graviton

152
00:10:06,980 --> 00:10:05,339
you see the spinning graviton stays

153
00:10:09,410 --> 00:10:06,990
stable while the other one tends to

154
00:10:13,699 --> 00:10:09,420
tumble end over end because it has no

155
00:10:18,139 --> 00:10:13,709
stable spin axis I'll do this one more

156
00:10:19,759 --> 00:10:18,149
time the one that's not spinning just

157
00:10:24,100 --> 00:10:19,769
tumbles free well the other one

158
00:10:27,170 --> 00:10:24,110
maintains the orientation I let it go in

159
00:10:32,150 --> 00:10:27,180
okay here I have two spinning gravitons

160
00:10:33,800 --> 00:10:32,160
and they're both stable as they spin you

161
00:10:36,139 --> 00:10:33,810
can see this time because they're both

162
00:10:41,840 --> 00:10:36,149
stable they don't tumble either one of

163
00:10:43,850 --> 00:10:41,850

them as you might expect here I have a

164
00:10:45,650 --> 00:10:43,860
curious combination of two gravitons

165
00:10:47,870 --> 00:10:45,660
that are attached together on a wiffle

166
00:10:49,670 --> 00:10:47,880
ball and I have them both spinning in

167
00:10:51,259 --> 00:10:49,680
the same direction so I would think I

168
00:10:53,780 --> 00:10:51,269
would have thought they'd be very stable

169
00:10:55,340 --> 00:10:53,790
in this configuration but because they

170
00:11:01,710 --> 00:10:55,350
weren't perfectly aligned with each

171
00:11:05,850 --> 00:11:04,139
WAM came apart and really gave me a

172
00:11:07,019 --> 00:11:05,860
surprise let's take a look at that in

173
00:11:14,370 --> 00:11:07,029
slow motion you can see how the

174
00:11:18,660 --> 00:11:16,530
now this time I took those two gravitons

175
00:11:21,060 --> 00:11:18,670
and I rotated them in opposite

176
00:11:23,940 --> 00:11:21,070
directions from each other and because

177
00:11:26,670 --> 00:11:23,950
their angular momentum vectors are in

178
00:11:28,770 --> 00:11:26,680
opposite directions their stability axes

179
00:11:30,180 --> 00:11:28,780
cancel each other so I'd expect to be

180
00:11:32,640 --> 00:11:30,190
able to let this go and just have it

181
00:11:35,970 --> 00:11:32,650
tumble now obviously I can't make them

182
00:11:37,380 --> 00:11:35,980
both spin exactly the same speed so the

183
00:11:39,030 --> 00:11:37,390
one of them that's gonna have a little

184
00:11:41,340 --> 00:11:39,040
bit of stability but you can see I can

185
00:11:44,220 --> 00:11:41,350
bump this stack and I can make it wobble

186
00:11:46,440 --> 00:11:44,230
around a little bit as I bump it here

187
00:11:48,390 --> 00:11:46,450
you see it will wobble some it has some

188
00:11:50,370 --> 00:11:48,400

tendency for stability but not as much

189
00:11:52,920 --> 00:11:50,380
as a single graviton would have floating

190
00:11:56,430 --> 00:11:52,930
on its own I can make it wobble pretty

191
00:11:58,320 --> 00:11:56,440
wide end over end so having two of them

192
00:12:03,000 --> 00:11:58,330
spinning opposite directions cancelled

193
00:12:08,410 --> 00:12:05,920
now we're getting complicated I have

194
00:12:10,840 --> 00:12:08,420
three gravitons all hooked to the same

195
00:12:13,270 --> 00:12:10,850
wiffleball orthogonal to each other

196
00:12:15,190 --> 00:12:13,280
that is their alignment is 90 degrees to

197
00:12:17,440 --> 00:12:15,200
each other and I'm going to spin them

198
00:12:19,410 --> 00:12:17,450
all in the same direction with reference

199
00:12:23,440 --> 00:12:19,420
to their attachment to the wiffle ball

200
00:12:26,110 --> 00:12:23,450
as I do this you would expect that the

201
00:12:28,060 --> 00:12:26,120
angular momentum vectors of each of the

202
00:12:30,070 --> 00:12:28,070
gravitons would add up to a single

203
00:12:32,860 --> 00:12:30,080
vector which would be right between all

204
00:12:35,020 --> 00:12:32,870
three so as I let this go and it tends

205
00:12:37,660 --> 00:12:35,030
to rotate the only access that it will

206
00:12:39,310 --> 00:12:37,670
rotate around is an axis that you can

207
00:12:40,960 --> 00:12:39,320
see if you put a pencil between all

208
00:12:43,000 --> 00:12:40,970
three of the gravitons it's rotating

209
00:12:45,310 --> 00:12:43,010
about that axis that's equidistance from

210
00:12:48,010 --> 00:12:45,320
all three of them now as it continues to

211
00:12:49,600 --> 00:12:48,020
spin up by the natural character of the

212
00:12:58,470 --> 00:12:49,610
friction in the gravitons it eventually

213
00:13:03,790 --> 00:13:01,720

here's the same combination again I have

214
00:13:05,139 --> 00:13:03,800
three gravitons mounted orthogonal II to

215
00:13:07,329 --> 00:13:05,149
the wiffle ball and I'm going to spin

216
00:13:09,040 --> 00:13:07,339
them all up in the same direction and

217
00:13:10,630 --> 00:13:09,050
before I spin them up you can see how

218
00:13:12,340 --> 00:13:10,640
they tumble end-over-end there is no

219
00:13:19,230 --> 00:13:12,350
stability there because none of them are

220
00:13:21,400 --> 00:13:19,240
rotating as I spin all three of them up

221
00:13:23,410 --> 00:13:21,410
initially when I let them go you'll see

222
00:13:31,210 --> 00:13:23,420
them begin to rotate around that same

223
00:13:33,940 --> 00:13:31,220
axis that's right between all three but

224
00:13:35,680 --> 00:13:33,950
one of the gravitons comes off and look

225
00:13:37,900 --> 00:13:35,690
what happens to the remaining two as

226
00:13:40,300 --> 00:13:37,910
that bottom graviton came off the

227
00:13:41,829 --> 00:13:40,310
remaining two gravitons now are rotating

228
00:13:49,389 --> 00:13:41,839
around an axis right between the two of

229
00:13:52,230 --> 00:13:49,399
them again I was here's an experiment

230
00:13:54,670 --> 00:13:52,240
that's a good demonstration of how a non

231
00:13:56,380 --> 00:13:54,680
spinning graviton behaves just like a

232
00:13:58,060 --> 00:13:56,390
ball on the end of a string I can change

233
00:13:59,500 --> 00:13:58,070
the acts of a rotation just like you

234
00:14:04,770 --> 00:13:59,510
could with anything attached to a string

235
00:14:11,100 --> 00:14:08,160
but once I spin this graviton up look

236
00:14:13,260 --> 00:14:11,110
how it maintains that stability around

237
00:14:15,420 --> 00:14:13,270
its rotation axis I can spin it around

238
00:14:18,180 --> 00:14:15,430

and around and it wants to stay in an

239
00:14:21,180 --> 00:14:18,190
orientation so that the spin axis is

240
00:14:25,110 --> 00:14:21,190
parallel to the axis of rotation that

241
00:14:27,810 --> 00:14:25,120
I'm holding the string in now look how I

242
00:14:31,080 --> 00:14:27,820
change the orientation and eventually

243
00:14:34,050 --> 00:14:31,090
the graviton ended up changing the

244
00:14:37,250 --> 00:14:34,060
orientation of its rotation so it

245
00:14:40,890 --> 00:14:37,260
matched the rotation axis of the string

246
00:14:46,570 --> 00:14:40,900
very interesting change in the way the

247
00:14:51,880 --> 00:14:48,280
eventually I'll take it back to a

248
00:14:54,100 --> 00:14:51,890
horizontal rotation so the rotation axis

249
00:14:57,430 --> 00:14:54,110
of the string is vertical and you'll see

250
00:14:59,769 --> 00:14:57,440
the graviton again orient itself so it's

251
00:15:13,750 --> 00:14:59,779
been axis this vertical to match the

252
00:15:15,790 --> 00:15:13,760
rotation I'm making with the string this

253
00:15:17,380 --> 00:15:15,800
rattle back is a very curious device

254
00:15:19,000 --> 00:15:17,390
here on the ground because if you rotate

255
00:15:20,370 --> 00:15:19,010
it on a table it will eventually turn

256
00:15:22,300 --> 00:15:20,380
around and spin the opposite direction

257
00:15:24,430 --> 00:15:22,310
what you're seeing here are three

258
00:15:26,949 --> 00:15:24,440
sequences of me spinning it around each

259
00:15:30,040 --> 00:15:26,959
of its axis I spend it end over end with

260
00:15:36,430 --> 00:15:30,050
the fixed side horizontal and then end

261
00:15:38,410 --> 00:15:36,440
over in with the thick side vertical and

262
00:15:40,300 --> 00:15:38,420
then in the last sequence I spin it

263
00:15:42,460 --> 00:15:40,310

around its longest accident and you just

264
00:15:44,319 --> 00:15:42,470
see it spins in no case did it ever turn

265
00:15:50,370 --> 00:15:44,329
around and do the peculiar things it

266
00:16:00,960 --> 00:15:58,710
I was playing with the clacker balls one

267
00:16:02,730 --> 00:16:00,970
afternoon on the shuttle and I had let

268
00:16:05,070 --> 00:16:02,740
them go and they drifted apart and they

269
00:16:07,170 --> 00:16:05,080
did this funny motion so what I tried to

270
00:16:09,240 --> 00:16:07,180
do was get that funny motion to repeat

271
00:16:11,700 --> 00:16:09,250
itself I experimented a little bit I

272
00:16:13,140 --> 00:16:11,710
tried various different actions by

273
00:16:15,300 --> 00:16:13,150
spinning them in one direction or the

274
00:16:18,660 --> 00:16:15,310
other I wound up taping the clackers so

275
00:16:20,760 --> 00:16:18,670
they stood apart and then I flipped them

276
00:16:22,110 --> 00:16:20,770
well first end over end and that didn't

277
00:16:25,560 --> 00:16:22,120
seem to repeat the motion that I

278
00:16:28,080 --> 00:16:25,570
accidentally had discovered and then

279
00:16:30,390 --> 00:16:28,090
spinning it around along the axis of the

280
00:16:32,250 --> 00:16:30,400
handle produced the flipping motion that

281
00:16:36,120 --> 00:16:32,260
you see here and that was quite

282
00:16:37,980 --> 00:16:36,130
remarkable as it spun around there was a

283
00:16:39,720 --> 00:16:37,990
little bit of imbalance and it seemed to

284
00:16:59,910 --> 00:16:39,730
flip end over end which was unexpected

285
00:17:03,670 --> 00:17:02,320
before flight I had to practice with the

286
00:17:05,799 --> 00:17:03,680
clacker balls a bit since I had never

287
00:17:07,660 --> 00:17:05,809
played with them before I became quite

288
00:17:13,540 --> 00:17:07,670

proficient in using the clacker balls in

289
00:17:16,030 --> 00:17:13,550
this fashion however while I was able to

290
00:17:18,579 --> 00:17:16,040
get one ball to displace the other on

291
00:17:23,140 --> 00:17:18,589
the ground I was never able to get the

292
00:17:24,790 --> 00:17:23,150
clacker balls to do this in space it was

293
00:17:26,250 --> 00:17:24,800
more difficult to produce this motion

294
00:17:32,020 --> 00:17:26,260
with the balls in this orientation

295
00:17:35,590 --> 00:17:34,090
in this next orientation it was a little

296
00:17:37,690 --> 00:17:35,600
bit easier to get them to even come

297
00:17:41,080 --> 00:17:37,700
close to displacing one another but I

298
00:17:42,580 --> 00:17:41,090
was never really successful I believe it

299
00:17:44,560 --> 00:17:42,590
was easier here because of the

300
00:17:47,080 --> 00:17:44,570
orientation of my arm relative to my

301
00:17:48,790 --> 00:17:47,090
body made it just a bit easier in

302
00:17:54,020 --> 00:17:48,800
getting the balls to behave as I wanted

303
00:17:59,570 --> 00:17:57,290
on earth gravity produced just enough

304
00:18:01,070 --> 00:17:59,580
drag on the stationary ball by weighing

305
00:18:04,190 --> 00:18:01,080
it down just enough so that you could

306
00:18:05,990 --> 00:18:04,200
produce the desired motion that is have

307
00:18:07,700 --> 00:18:06,000
one sit still and the other one spin

308
00:18:09,170 --> 00:18:07,710
around and hit it and then it's staying

309
00:18:29,190 --> 00:18:09,180
still than the other one continuing the

310
00:18:34,180 --> 00:18:32,110
this experiment is the demonstration of

311
00:18:37,480 --> 00:18:34,190
the concept of momentum the racquetball

312
00:18:39,610 --> 00:18:37,490
has less mass than the pool ball and as

313
00:18:42,399 --> 00:18:39,620

a result after a collision it will

314
00:18:44,529 --> 00:18:42,409
always travel faster than the pool ball

315
00:18:46,360 --> 00:18:44,539
even if I throw the pool ball at the

316
00:18:48,039 --> 00:18:46,370
racquet ball here you'll notice it does

317
00:18:50,860 --> 00:18:48,049
move faster because it does have less

318
00:18:54,789 --> 00:18:50,870
mass now if I tape the two of them

319
00:18:57,460 --> 00:18:54,799
together and again hit the racquet ball

320
00:19:01,360 --> 00:18:57,470
with another pool ball you'll see it

321
00:19:03,519 --> 00:19:01,370
curves around the pool ball in his final

322
00:19:05,860 --> 00:19:03,529
demonstration I hit the two pool balls

323
00:19:23,169 --> 00:19:05,870
and because the racquet ball has not

324
00:19:28,279 --> 00:19:25,549
this fallen Cup was one of the more

325
00:19:30,560 --> 00:19:28,289
difficult toys I demonstrated on the

326
00:19:32,239 --> 00:19:30,570
flight you can see that the ball just

327
00:19:35,119 --> 00:19:32,249
won't stay in the cup as it does on

328
00:19:36,830 --> 00:19:35,129
earth of course on earth we have gravity

329
00:19:40,129 --> 00:19:36,840
holding the ball in the cup but in this

330
00:19:42,259 --> 00:19:40,139
microgravity environment when I put the

331
00:19:48,440 --> 00:19:42,269
ball in the cup and then push to hold it

332
00:19:50,239 --> 00:19:48,450
I've actually pushed the ball away so I

333
00:19:55,460 --> 00:19:50,249
never could get the ball to stay inside

334
00:19:57,169 --> 00:19:55,470
the cup we'll try again you can see I

335
00:20:11,749 --> 00:19:57,179
just push on the ball and that pushes

336
00:20:16,019 --> 00:20:14,039
in this scene I try to throw this

337
00:20:17,460 --> 00:20:16,029
ping-pong ball the old-fashioned way but

338
00:20:20,070 --> 00:20:17,470

it doesn't curve down toward the target

339
00:20:22,200 --> 00:20:20,080
like I would expect on earth so I have

340
00:20:24,269 --> 00:20:22,210
to change my throwing style I throw it

341
00:20:26,639 --> 00:20:24,279
straight at the target without any twist

342
00:20:28,619 --> 00:20:26,649
at all and then I attempt to throw

343
00:20:30,570 --> 00:20:28,629
another ball with some twist to see if

344
00:20:32,999 --> 00:20:30,580
it changes the direction of the ball as

345
00:20:38,609 --> 00:20:33,009
it goes to the target let me try this

346
00:20:40,230 --> 00:20:38,619
again straight with no spin oops now one

347
00:20:41,909 --> 00:20:40,240
thing you'll have to remember is that

348
00:20:43,739 --> 00:20:41,919
the velcro of the ball does have to

349
00:20:46,799 --> 00:20:43,749
touch the target let me try this again

350
00:20:48,749 --> 00:20:46,809
there we go and then I'll throw it one

351
00:20:52,730 --> 00:20:48,759
more time with some spin to see if the

352
00:20:56,669 --> 00:20:52,740
trajectory toward the target curves

353
00:20:58,769 --> 00:20:56,679
looks to me like it did a little bit now

354
00:21:00,779 --> 00:20:58,779
in this scene I take the target off of

355
00:21:03,539 --> 00:21:00,789
the lockers so that it's free-floating

356
00:21:05,970 --> 00:21:03,549
and this is a good demonstration of how

357
00:21:09,090 --> 00:21:05,980
one object will react when you hit it

358
00:21:12,090 --> 00:21:09,100
with another object in space now it's

359
00:21:13,830 --> 00:21:12,100
floating around in part because of the

360
00:21:15,659 --> 00:21:13,840
way that the first ball hit it so I'll

361
00:21:18,029 --> 00:21:15,669
throw another ball to try to change the

362
00:21:31,680 --> 00:21:18,039
direction of the floating I got it to

363
00:21:36,010 --> 00:21:33,640

horseshoes doesn't played the same way

364
00:21:38,110 --> 00:21:36,020
in space as it is on earth here I try to

365
00:21:40,000 --> 00:21:38,120
throw a shoe the old-fashioned way and

366
00:21:42,750 --> 00:21:40,010
as you can see that without the effect

367
00:21:44,670 --> 00:21:42,760
of gravity this shoe just bounces off I

368
00:21:47,800 --> 00:21:44,680
try it one more time

369
00:21:49,300 --> 00:21:47,810
just to demonstrate the point and then I

370
00:21:51,370 --> 00:21:49,310
decide I'm going to change my technique

371
00:21:53,380 --> 00:21:51,380
instead of throwing the shoe right at

372
00:21:55,210 --> 00:21:53,390
the pole I'm going to use a spinning

373
00:21:57,820 --> 00:21:55,220
motion to see if I can catch the pole

374
00:22:00,430 --> 00:21:57,830
and in fact that's exactly what happens

375
00:22:02,320 --> 00:22:00,440
at this point the shoe is pretty stable

376
00:22:04,480 --> 00:22:02,330
in a spinning motion around the pole and

377
00:22:07,120 --> 00:22:04,490
in fact this ended up spinning for a

378
00:22:09,220 --> 00:22:07,130
total of about five minutes without the

379
00:22:11,890 --> 00:22:09,230
effect of gravity it doesn't slow down

380
00:22:13,780 --> 00:22:11,900
and settle at the bottom of the pole in

381
00:22:16,000 --> 00:22:13,790
this demonstration I take the horseshoe

382
00:22:18,250 --> 00:22:16,010
pole off of the locker and let it free

383
00:22:19,180 --> 00:22:18,260
float will I throw the shoes at it that

384
00:22:22,720 --> 00:22:19,190
didn't work too well

385
00:22:24,610 --> 00:22:22,730
in this demonstration I decide I'm going

386
00:22:26,950 --> 00:22:24,620
to throw a horseshoe at the pole in

387
00:22:30,910 --> 00:22:26,960
three different places to see how the

388
00:22:33,700 --> 00:22:30,920

pole reacts in the first demonstration I

389
00:22:36,010 --> 00:22:33,710
throw it as low as I can to the base and

390
00:22:37,990 --> 00:22:36,020
as you can see there isn't much spinning

391
00:22:41,070 --> 00:22:38,000
motion of the pole itself as it reacts

392
00:22:43,330 --> 00:22:41,080
from having the shoe thrown against it

393
00:22:47,290 --> 00:22:43,340
I'm gonna try a different technique how

394
00:22:49,900 --> 00:22:47,300
about the middle okay I begin to see the

395
00:22:54,220 --> 00:22:49,910
pole turn as it reacts to the shoe being

396
00:22:56,110 --> 00:22:54,230
thrown at it and it floats away one last

397
00:22:57,820 --> 00:22:56,120
try by throwing this horseshoe at the

398
00:23:00,190 --> 00:22:57,830
tip of the pole to see if I can get it

399
00:23:10,499 --> 00:23:00,200
to turn even more as it free floats away

400
00:23:10,509 --> 00:23:24,340
certainly seems to

401
00:23:29,120 --> 00:23:26,420
basketball is a sport that's near and

402
00:23:30,860 --> 00:23:29,130
dear to my heart here on earth and I was

403
00:23:33,050 --> 00:23:30,870
very interested in seeing how basketball

404
00:23:34,730 --> 00:23:33,060
would be different in space as you can

405
00:23:37,760 --> 00:23:34,740
see I started out with a standard free

406
00:23:39,830 --> 00:23:37,770
throw type shot and the ball just caroms

407
00:23:41,270 --> 00:23:39,840
off in a funny direction not anywhere

408
00:23:48,410 --> 00:23:41,280
close to what you would expect from

409
00:23:50,510 --> 00:23:48,420
shooting the same shot here on earth so

410
00:23:52,700 --> 00:23:50,520
I keep changing the angle from which I'm

411
00:23:54,650 --> 00:23:52,710
shooting and I'm finding that it is

412
00:24:00,620 --> 00:23:54,660
pretty darn tough to make a shot in

413
00:24:02,060 --> 00:24:00,630

space finally I look at it and and I

414
00:24:04,640 --> 00:24:02,070
think that the only way to get the ball

415
00:24:07,040 --> 00:24:04,650
in the hoop is either to come up real

416
00:24:08,690 --> 00:24:07,050
close and slam it through or to try to

417
00:24:11,150 --> 00:24:08,700
bounce it off the ceiling that's the

418
00:24:13,340 --> 00:24:11,160
only angle that seems to work and note

419
00:24:14,660 --> 00:24:13,350
that the ball stops in the in the basket

420
00:24:17,180 --> 00:24:14,670
it doesn't get pulled all the way

421
00:24:20,060 --> 00:24:17,190
through the next thing we tried was

422
00:24:24,960 --> 00:24:20,070
attaching the hoop to a free-floating

423
00:24:29,880 --> 00:24:27,120
you can see that every time I hit the

424
00:24:31,740 --> 00:24:29,890
book which is now the backboard with the

425
00:24:33,180 --> 00:24:31,750
very lightweight basketball I can

426
00:24:34,950 --> 00:24:33,190
actually make the book and the hoop

427
00:24:36,240 --> 00:24:34,960
start spinning well that makes life

428
00:24:38,850 --> 00:24:36,250
difficult when you're trying to make a

429
00:24:40,500 --> 00:24:38,860
basket up there and I ended up coming up

430
00:24:42,180 --> 00:24:40,510
with a very simple approach just hold

431
00:24:44,220 --> 00:24:42,190
the book steady otherwise it becomes

432
00:24:47,190 --> 00:24:44,230
very difficult to make a shot with a

433
00:24:48,510 --> 00:24:47,200
free-floating basket and backboard one

434
00:24:50,130 --> 00:24:48,520
of the things that's always impressed me

435
00:24:52,890 --> 00:24:50,140
here on earth was the ability of the

436
00:24:55,049 --> 00:24:52,900
professional basketball players to spin

437
00:24:57,000 --> 00:24:55,059
around and make these really neat moves

438
00:24:59,460 --> 00:24:57,010

well I was trying some of that in space

439
00:25:04,460 --> 00:24:59,470
you can see it's pretty difficult it's

440
00:25:08,549 --> 00:25:06,930
finally managed after a while after a

441
00:25:10,830 --> 00:25:08,559
number of tries to figure out a way to

442
00:25:14,159 --> 00:25:10,840
go head over heels and accomplish a slam

443
00:25:37,810 --> 00:25:14,169
dunk this is my entry into the NBA slam

444
00:25:43,220 --> 00:25:40,430
now I know on earth you think this toy

445
00:25:45,350 --> 00:25:43,230
works very well but in space we couldn't

446
00:25:47,000 --> 00:25:45,360
get it to work at all we had this thing

447
00:25:48,950 --> 00:25:47,010
floating around but without the effect

448
00:25:51,620 --> 00:25:48,960
of gravity it just doesn't work the same

449
00:25:53,030 --> 00:25:51,630
way now I took this toy looked at it for

450
00:25:54,890 --> 00:25:53,040
a number of minutes and tried to figure

451
00:25:56,570 --> 00:25:54,900
out what in the world do I do that this

452
00:25:58,010 --> 00:25:56,580
thing up here it took me a while to

453
00:26:00,470 --> 00:25:58,020
finally come up with something that

454
00:26:03,470 --> 00:26:00,480
appeared to be unique in space about

455
00:26:06,800 --> 00:26:03,480
this toy watch when I close and open up

456
00:26:08,570 --> 00:26:06,810
the Jacob's Ladder every time I did this

457
00:26:12,380 --> 00:26:08,580
the ladder would turn into a different

458
00:26:15,350 --> 00:26:12,390
configuration it was completely random

459
00:26:17,270 --> 00:26:15,360
and we the astronauts couldn't ever

460
00:26:19,730 --> 00:26:17,280
really predict what would happen when we

461
00:26:32,419 --> 00:26:19,740
pulled apart Jacob's Ladder to this day

462
00:26:36,510 --> 00:26:34,799
Here I am trying to produce standing

463
00:26:38,100 --> 00:26:36,520

compressional waves by holding one end

464
00:26:39,780 --> 00:26:38,110
still and moving the other end in and

465
00:26:41,789 --> 00:26:39,790
out the result had some transverse

466
00:26:43,440 --> 00:26:41,799
motion to it because my hand also had

467
00:26:44,760 --> 00:26:43,450
some up-and-down motion in the next

468
00:26:47,010 --> 00:26:44,770
sequence I tried to produce

469
00:26:48,840 --> 00:26:47,020
compressional waves by moving my hand in

470
00:26:50,490 --> 00:26:48,850
and out a bit faster then I tried to

471
00:26:52,710 --> 00:26:50,500
produce the same type of wave by moving

472
00:26:56,520 --> 00:26:52,720
both ends next I tried to stretch the

473
00:26:58,500 --> 00:26:56,530
wave out and then I transition to

474
00:27:01,560 --> 00:26:58,510
producing transverse waves first slowly

475
00:27:18,070 --> 00:27:01,570
and then with a higher frequency and

476
00:27:22,220 --> 00:27:20,360
these magnetic rings are really

477
00:27:25,400 --> 00:27:22,230
interesting I've got them arranged on

478
00:27:28,010 --> 00:27:25,410
this plastic rod so that the poles of

479
00:27:31,010 --> 00:27:28,020
the magnets are opposite to each other

480
00:27:34,039 --> 00:27:31,020
and they repel or push away you can see

481
00:27:39,110 --> 00:27:34,049
when I release the Rings they spring out

482
00:27:41,980 --> 00:27:39,120
equally along the plastic rod and it

483
00:27:44,990 --> 00:27:41,990
doesn't matter whether I hold the rod up

484
00:27:46,730 --> 00:27:45,000
or whether I hold it down because in

485
00:27:48,770 --> 00:27:46,740
this microgravity environment there is

486
00:27:51,860 --> 00:27:48,780
no up-and-down they spread out equally

487
00:27:53,230 --> 00:27:51,870
along the plastic rod and push away from

488
00:27:55,820 --> 00:27:53,240

each other

489
00:28:00,110 --> 00:27:55,830
now I'm gonna rotate the plastic rod

490
00:28:02,600 --> 00:28:00,120
very slowly we'll see what happens the

491
00:28:04,850 --> 00:28:02,610
rod is rotating so slowly that the

492
00:28:07,159 --> 00:28:04,860
magnetic force still keeps the Rings

493
00:28:09,380 --> 00:28:07,169
pushed away from each other and the

494
00:28:14,049 --> 00:28:09,390
spacing is about equal about what it was

495
00:28:19,909 --> 00:28:17,090
now I'll rotate the rod faster now see

496
00:28:22,370 --> 00:28:19,919
what happens now the rotational force

497
00:28:35,090 --> 00:28:22,380
has overcome the magnetic force and the

498
00:28:38,970 --> 00:28:37,620
the magnetic marbles were a lot of fun

499
00:28:42,240 --> 00:28:38,980
to play with what we were looking at

500
00:28:44,159 --> 00:28:42,250
initially was how far apart can we hold

501
00:28:46,470 --> 00:28:44,169
two marbles and have them still be

502
00:28:48,330 --> 00:28:46,480
attracted to each other the first time

503
00:28:50,039 --> 00:28:48,340
we did it we had the opposite poles

504
00:28:53,460 --> 00:28:50,049
facing each other so they would be most

505
00:28:55,529 --> 00:28:53,470
attracting the second time we tried

506
00:28:57,720 --> 00:28:55,539
about the same distance apart only with

507
00:29:08,140 --> 00:28:57,730
the like pole facing each other and sure

508
00:29:12,760 --> 00:29:10,960
this time the marbles were just a little

509
00:29:20,140 --> 00:29:12,770
bit too far apart and they didn't

510
00:29:25,150 --> 00:29:23,140
I put them closer together but I started

511
00:29:27,730 --> 00:29:25,160
the one on the right in your screen with

512
00:29:29,950 --> 00:29:27,740
a little bit of motion and that motion

513
00:29:31,960 --> 00:29:29,960

was just enough to overcome the

514
00:29:39,550 --> 00:29:31,970
attractive force so they did not come

515
00:29:44,170 --> 00:29:42,130
now I'm looking at the influence of one

516
00:29:46,480 --> 00:29:44,180
marble on the other without touching it

517
00:29:48,730 --> 00:29:46,490
seeing how close I can come with one

518
00:29:50,290 --> 00:29:48,740
marble and how much I can make the

519
00:29:56,650 --> 00:29:50,300
second marble which is free floating

520
00:29:58,600 --> 00:29:56,660
spin as a result you can see that every

521
00:30:00,400 --> 00:29:58,610
time I make a pass around the marble I'm

522
00:30:03,040 --> 00:30:00,410
affecting the spin of them are going

523
00:30:07,630 --> 00:30:03,050
actually I'm even pulling it towards the

524
00:30:09,910 --> 00:30:07,640
marble in my hand now I'm looking at

525
00:30:11,500 --> 00:30:09,920
releasing one marble with two marbles

526
00:30:14,470 --> 00:30:11,510
attached together to see if there's any

527
00:30:15,820 --> 00:30:14,480
difference in the attraction it looks

528
00:30:18,070 --> 00:30:15,830
like the two marbles are pretty happy

529
00:30:24,350 --> 00:30:18,080
being by themselves and that third

530
00:30:31,130 --> 00:30:27,260
this time I'm putting the third marble

531
00:30:32,780 --> 00:30:31,140
in motion and sure enough it if it gets

532
00:30:40,310 --> 00:30:32,790
close enough it is attracted by the

533
00:30:41,960 --> 00:30:40,320
other two now I have strings of four

534
00:30:45,710 --> 00:30:41,970
marbles each and we're going to see if

535
00:30:47,720 --> 00:30:45,720
they come together that's a

536
00:30:51,860 --> 00:30:47,730
funny-looking snake-like thing we got a

537
00:30:53,330 --> 00:30:51,870
big kick out of seeing that then you tap

538
00:30:58,100 --> 00:30:53,340

it in the middle and it turns into a

539
00:31:00,200 --> 00:30:58,110
ring this time I have two sets of four

540
00:31:02,450 --> 00:31:00,210
marbles and they had the like pole

541
00:31:04,520 --> 00:31:02,460
facing each other so they were repelling

542
00:31:06,260 --> 00:31:04,530
each other and they would swing back and

543
00:31:09,400 --> 00:31:06,270
forth and back and forth and they

544
00:31:17,390 --> 00:31:09,410
actually did repel each other and

545
00:31:20,210 --> 00:31:17,400
they're pushing each other away now I've

546
00:31:22,070 --> 00:31:20,220
got one set of five marbles one big one

547
00:31:23,900 --> 00:31:22,080
in the middle and two little ones on

548
00:31:26,510 --> 00:31:23,910
either side and I'm seeing what

549
00:31:31,850 --> 00:31:26,520
influence I can have on those five with

550
00:31:38,060 --> 00:31:31,860
one small marble and look it attaches to

551
00:31:43,040 --> 00:31:40,370
this time I start with the blue face of

552
00:31:44,960 --> 00:31:43,050
the small marble and the five marbles

553
00:31:47,000 --> 00:31:44,970
together facing each other

554
00:31:48,650 --> 00:31:47,010
initially they repelled but eventually

555
00:31:51,260 --> 00:31:48,660
the attractive force overcame it and

556
00:31:52,970 --> 00:31:51,270
they came together the next thing we

557
00:31:55,910 --> 00:31:52,980
took a look at was a string of marbles

558
00:31:59,750 --> 00:31:55,920
we wanted to see how they reacted when

559
00:32:01,790 --> 00:31:59,760
we spun them around as I spin them it

560
00:32:03,680 --> 00:32:01,800
becomes more and more difficult as I go

561
00:32:05,840 --> 00:32:03,690
faster and faster for the marbles to

562
00:32:10,970 --> 00:32:05,850
stay together where do you think they're

563
00:32:13,220 --> 00:32:10,980

gonna let go now I have two rings of

564
00:32:14,840 --> 00:32:13,230
magnetic marbles I passed them very

565
00:32:17,150 --> 00:32:14,850
close to each other and they show no

566
00:32:19,940 --> 00:32:17,160
sign of attracting they seem to be very

567
00:32:23,510 --> 00:32:19,950
happy just being on their own their own

568
00:32:25,190 --> 00:32:23,520
little ring but if they get close enough

569
00:32:32,870 --> 00:32:25,200
and they're moving slowly enough they

570
00:32:37,730 --> 00:32:32,880
will attract let's try it with them very

571
00:32:40,130 --> 00:32:37,740
close together moving very slowly you

572
00:32:41,900 --> 00:32:40,140
can see they just are very happy beyond

573
00:32:44,090 --> 00:32:41,910
their own and there is not nearly as

574
00:32:58,400 --> 00:32:44,100
much attractive force as there was

575
00:33:13,070 --> 00:33:11,420
a comeback can wasn't quite as

576
00:33:15,590 --> 00:33:13,080
interesting on orbit as it is here on

577
00:33:17,630 --> 00:33:15,600
the ground I could let it go here as I

578
00:33:19,700 --> 00:33:17,640
spun it up and you can see how its

579
00:33:24,950 --> 00:33:19,710
rotation rate increases and decreases as

580
00:33:26,510 --> 00:33:24,960
the medal weight catches up I also tried

581
00:33:28,400 --> 00:33:26,520
to spin it up before I let it go and you

582
00:33:29,630 --> 00:33:28,410
can see it rotates quickly one direction

583
00:33:31,940 --> 00:33:29,640
and slightly goes the other direction

584
00:33:34,520 --> 00:33:31,950
back and forth until it comes to a stop

585
00:33:36,230 --> 00:33:34,530
but because you can't lay it on a table

586
00:33:37,970 --> 00:33:36,240
and spin it up and have it roll down the

587
00:33:53,480 --> 00:33:37,980
table or come back to you as you let it

588
00:33:55,010 --> 00:33:53,490

go it's not as interesting here in this

589
00:33:56,930 --> 00:33:55,020
first sequence with the car on track

590
00:33:58,730 --> 00:33:56,940
I had wound the car up and just let it

591
00:34:00,470 --> 00:33:58,740
go without the track and here because of

592
00:34:02,750 --> 00:34:00,480
action-reaction you see the car doing

593
00:34:04,430 --> 00:34:02,760
and end-over-end wheelie next i tried to

594
00:34:06,140 --> 00:34:04,440
get the car to run on the wall the main

595
00:34:08,120 --> 00:34:06,150
result when I release it is that the car

596
00:34:09,680 --> 00:34:08,130
Springs back toward me off the wall from

597
00:34:11,570 --> 00:34:09,690
the little force I had applied with my

598
00:34:13,340 --> 00:34:11,580
hand to hold it there getting the car to

599
00:34:15,169 --> 00:34:13,350
run on the track was a bit easier in

600
00:34:16,850 --> 00:34:15,179
space than on earth because the car

601
00:34:18,710 --> 00:34:16,860
didn't have to build up as much velocity

602
00:34:20,900 --> 00:34:18,720
to stay on the track as it did on earth

603
00:34:22,130 --> 00:34:20,910
in the second sequence I got the car

604
00:34:24,560 --> 00:34:22,140
started and then let it go

605
00:34:25,220 --> 00:34:24,570
here you see that second sequence in

606
00:34:27,650 --> 00:34:25,230
slow motion

607
00:34:29,270 --> 00:34:27,660
wherever the car is on the track the

608
00:34:33,919 --> 00:34:29,280
whole system car and track together

609
00:34:35,630 --> 00:34:33,929
moves toward that general direction next

610
00:34:40,070 --> 00:34:35,640
I started the car on the track by giving

611
00:34:41,750 --> 00:34:40,080
it a push rather than winding it up in

612
00:34:43,250 --> 00:34:41,760
this case we wanted to see how long the

613
00:34:44,750 --> 00:34:43,260

car would stay on the track if I held

614
00:34:49,310 --> 00:34:44,760
the track steady enough where I wouldn't

615
00:34:51,080 --> 00:34:49,320
bounce the car off the track even though

616
00:34:52,669 --> 00:34:51,090
I knew intuitively by the laws of

617
00:34:55,010 --> 00:34:52,679
physics that this would be the case it

618
00:34:56,930 --> 00:34:55,020
was amazing to me that any forward

619
00:34:58,210 --> 00:34:56,940
velocity of the car at all was enough to

620
00:35:00,560 --> 00:34:58,220
provide the necessary centripetal

621
00:35:20,790 --> 00:35:00,570
acceleration to keep the car on the

622
00:35:24,630 --> 00:35:22,710
here in this second sequence where I

623
00:35:27,000 --> 00:35:24,640
just push the car rather than winding it

624
00:35:29,700 --> 00:35:27,010
up in this view the car ends up stopping

625
00:35:31,680 --> 00:35:29,710
on the top of the track this was amazing

626
00:35:34,020 --> 00:35:31,690
even in space to see the car creep along

627
00:35:44,359 --> 00:35:34,030
ever so slowly and then stop and sit

628
00:35:48,049 --> 00:35:46,549
finally the car comes off the track and

629
00:36:02,470 --> 00:35:48,059
winds up in the center of the track

630
00:36:06,460 --> 00:36:04,510
next in a demonstration of centripetal

631
00:36:08,470 --> 00:36:06,470
acceleration I get the car started on

632
00:36:10,089 --> 00:36:08,480
the track and then open the track once

633
00:36:14,470 --> 00:36:10,099
there is an opening the car flies out in

634
00:36:16,150 --> 00:36:14,480
a straight line ok I just like to remind

635
00:36:18,910 --> 00:36:16,160
all the folks that are watching out

636
00:36:20,859 --> 00:36:18,920
there that especially the children that

637
00:36:23,170 --> 00:36:20,869
science applies to everything even toys

638
00:36:25,720 --> 00:36:23,180

and we hope that our demonstrations

639
00:36:28,660 --> 00:36:25,730
today have given you just a taste of

640
00:36:30,040 --> 00:36:28,670
scientific research in space and we want

641
00:36:32,859 --> 00:36:30,050
to encourage all the children out there

642
00:36:34,359 --> 00:36:32,869
that do well in science and math and to

643
00:36:37,240 --> 00:36:34,369
learn all you can about the world around

644
00:36:38,710 --> 00:36:37,250
you because we need people like you to

645
00:36:41,620 --> 00:36:38,720
design and maybe even fly the

646
00:36:43,089 --> 00:36:41,630
experiments of the future so as we say