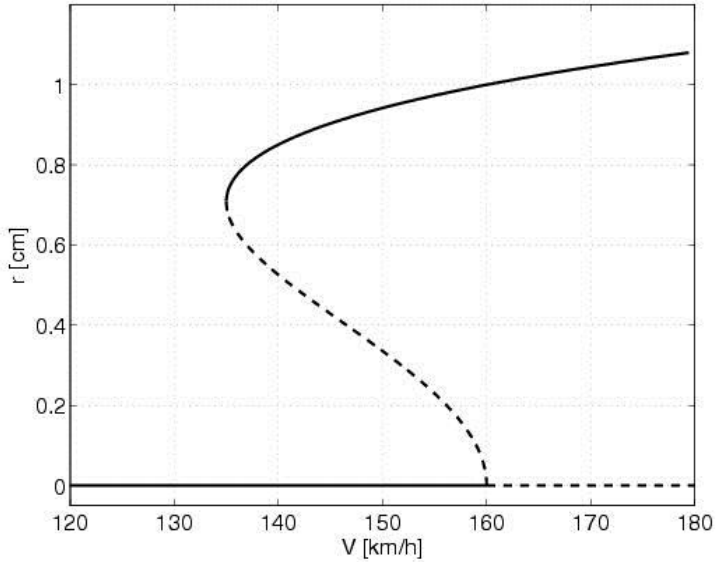
Die Berechnung der kritischen Geschwindigkeit eines Eisenbahnfahrzeuges: Die richtige, die falsche und die Zufallsmethode

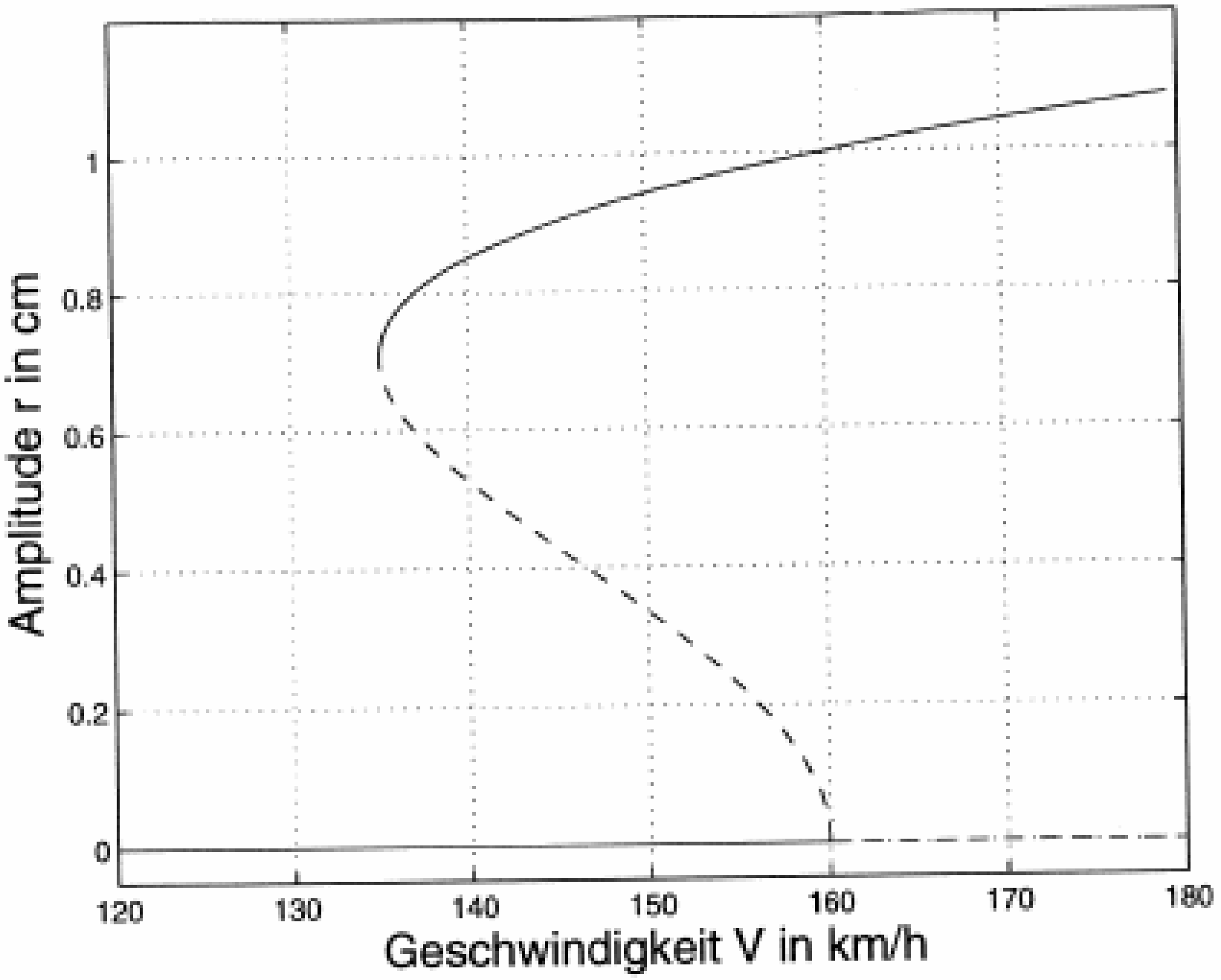


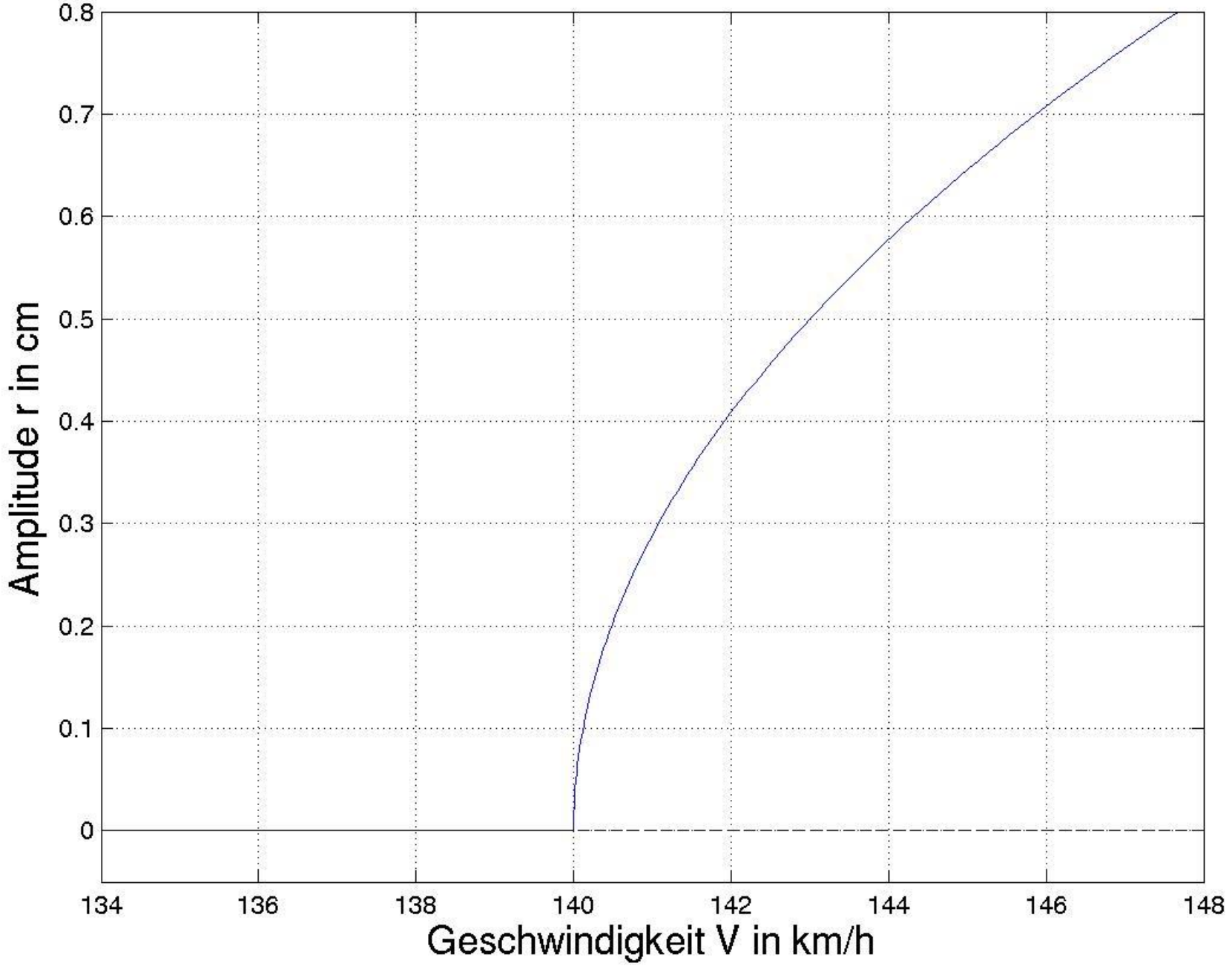
Hans True

DTU Informatics,

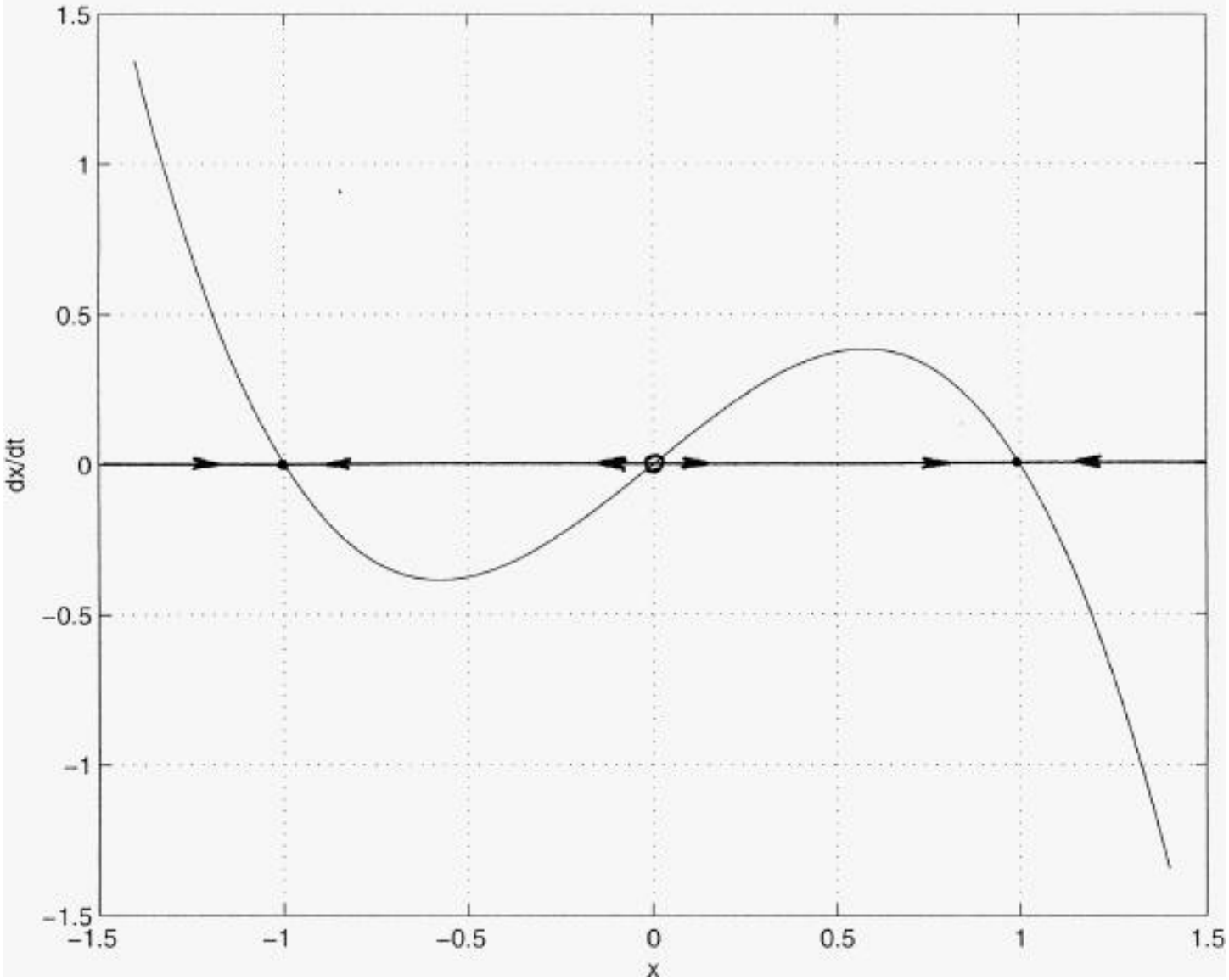
Die Dänische Technische Universität

und True Consult

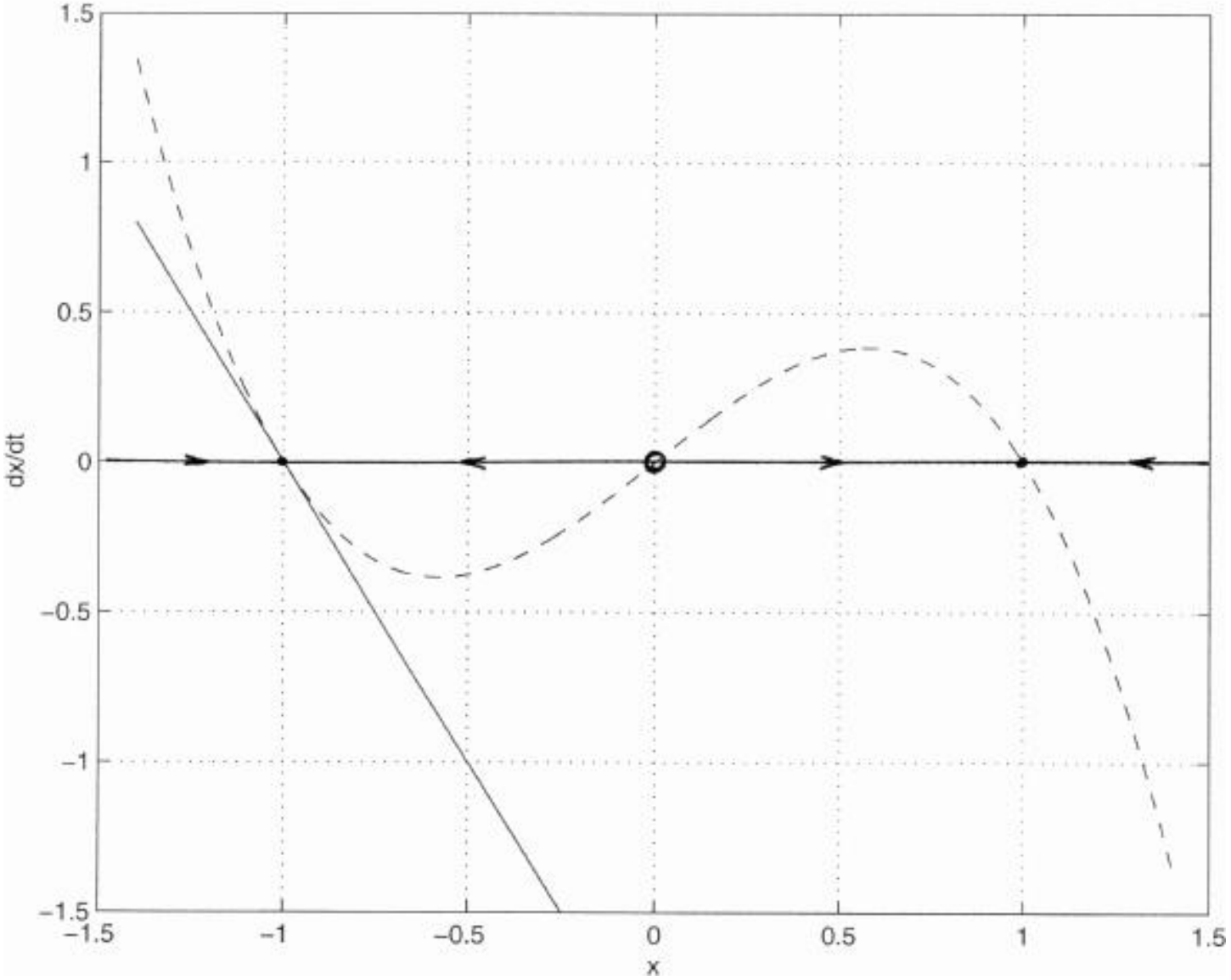

Amplitude r in cm
0
0.2
0.4
0.6
0.8
1
120
130
140
150
160
170
180
Geschwindigkeit V in km/h

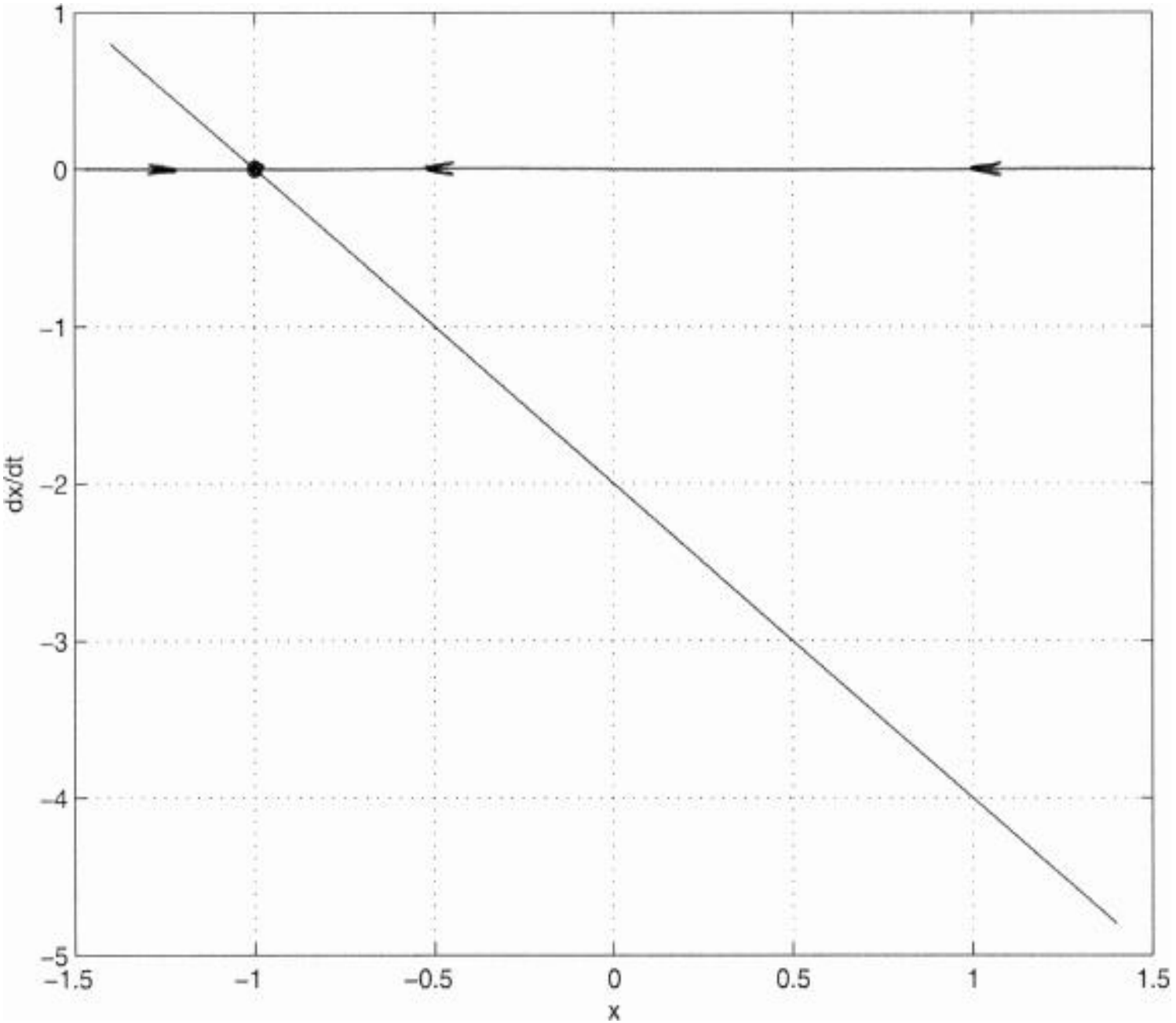

0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
Amplitude r in cm
134
136
138
140
142
144
146
148
Geschwindigkeit V in km/h

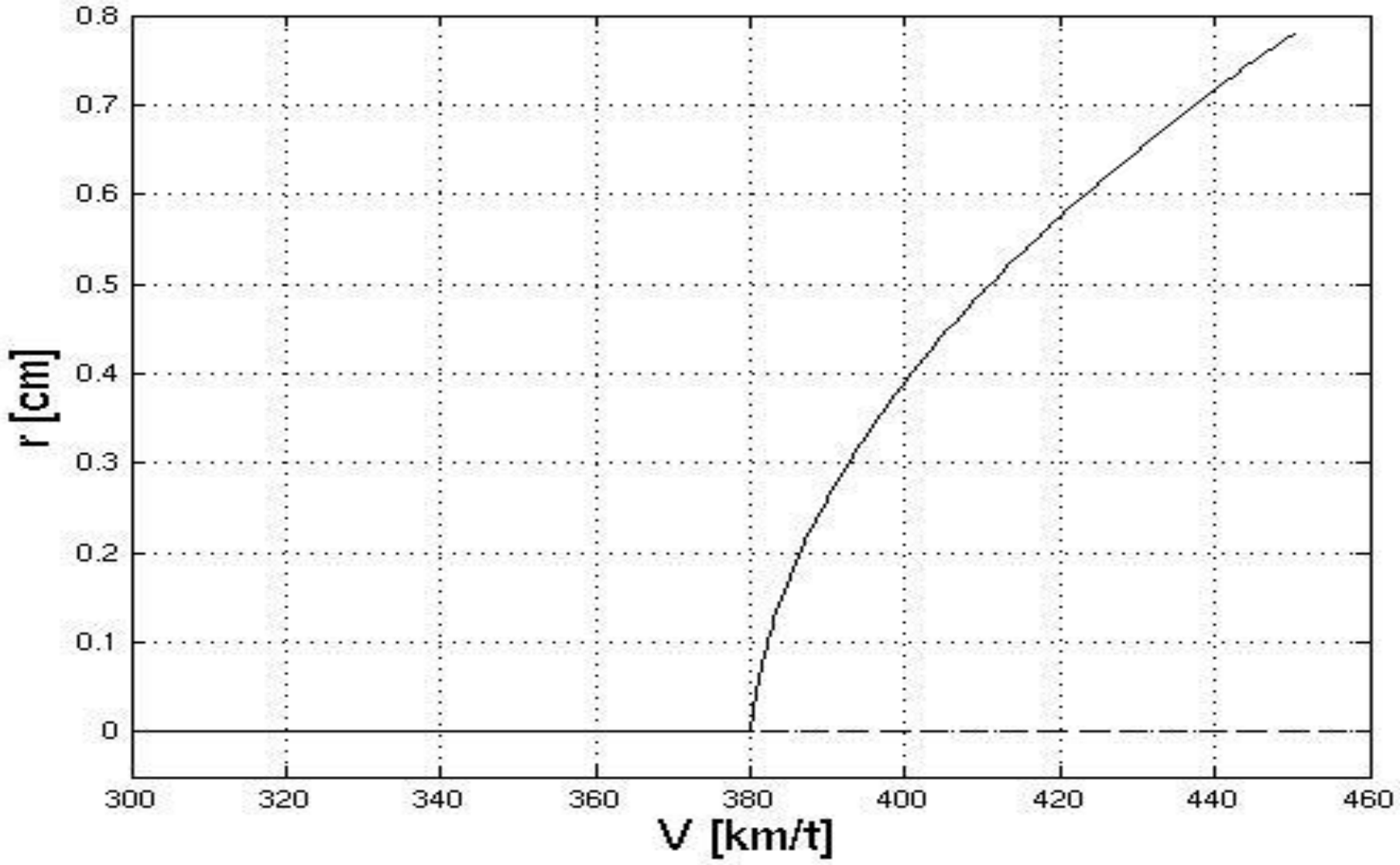
$$\frac{dx}{dt} = -x(x-a)(x+a);$$

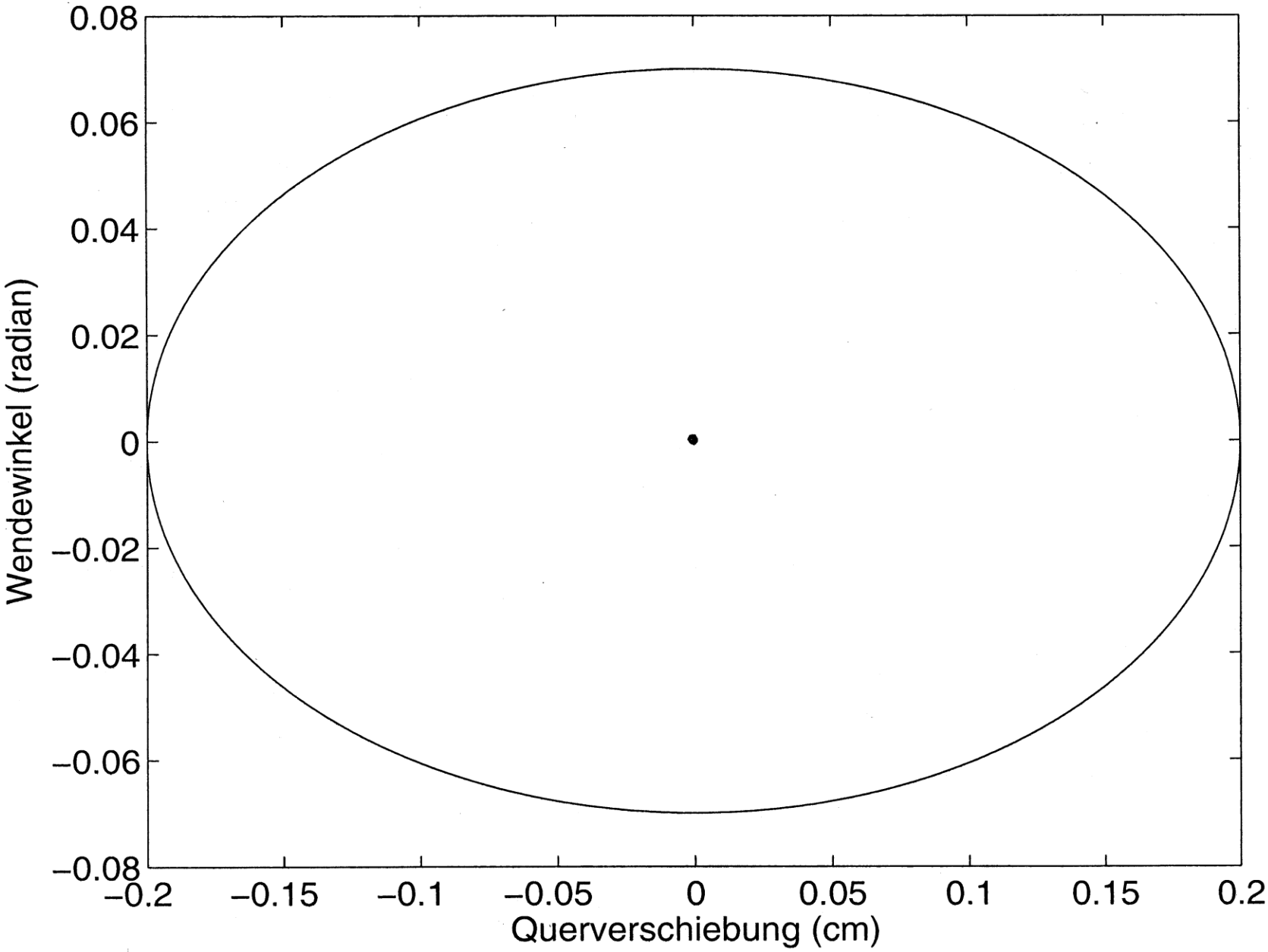


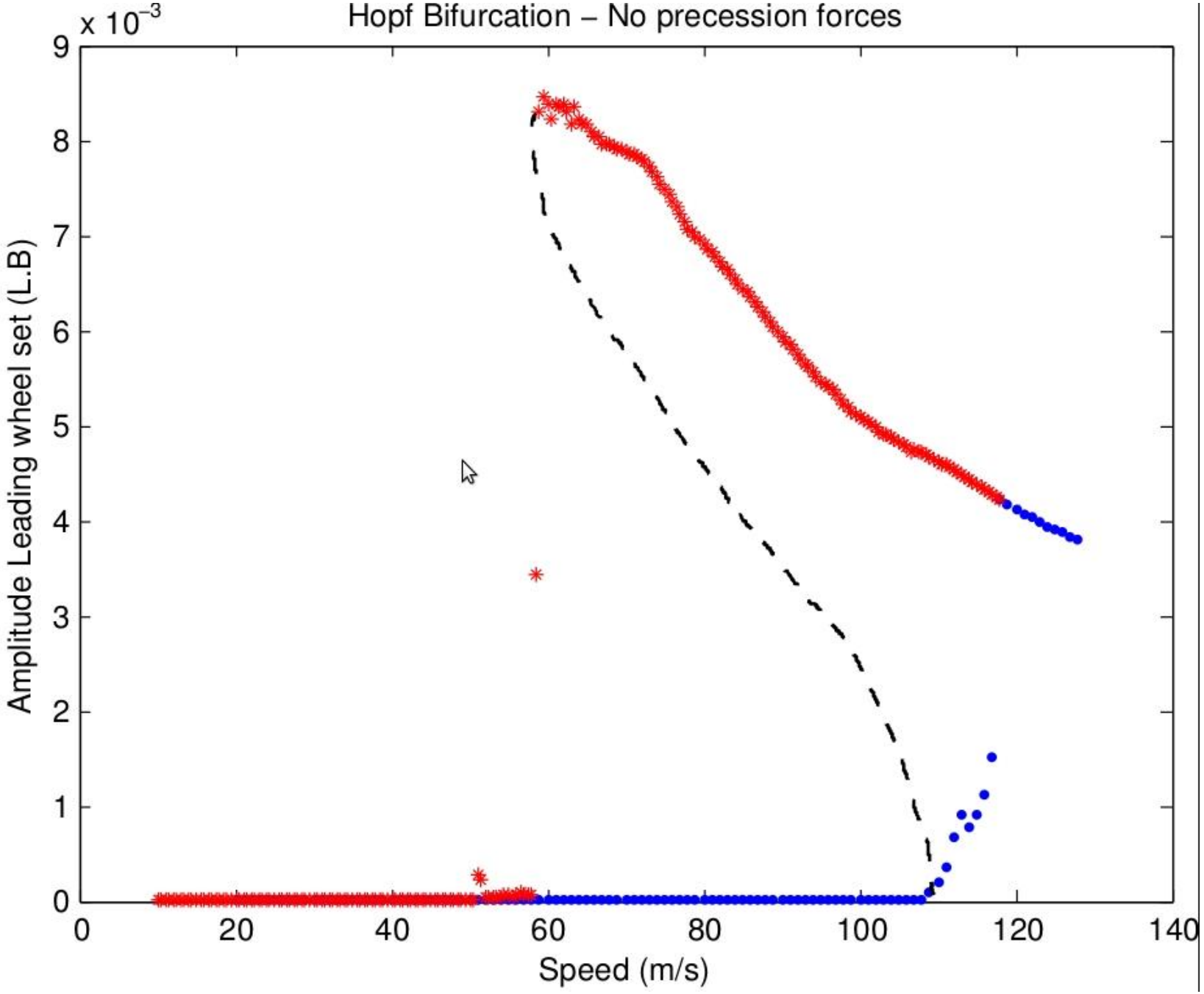
$$\frac{dx}{dt} = -x(x-a)(x+a);$$

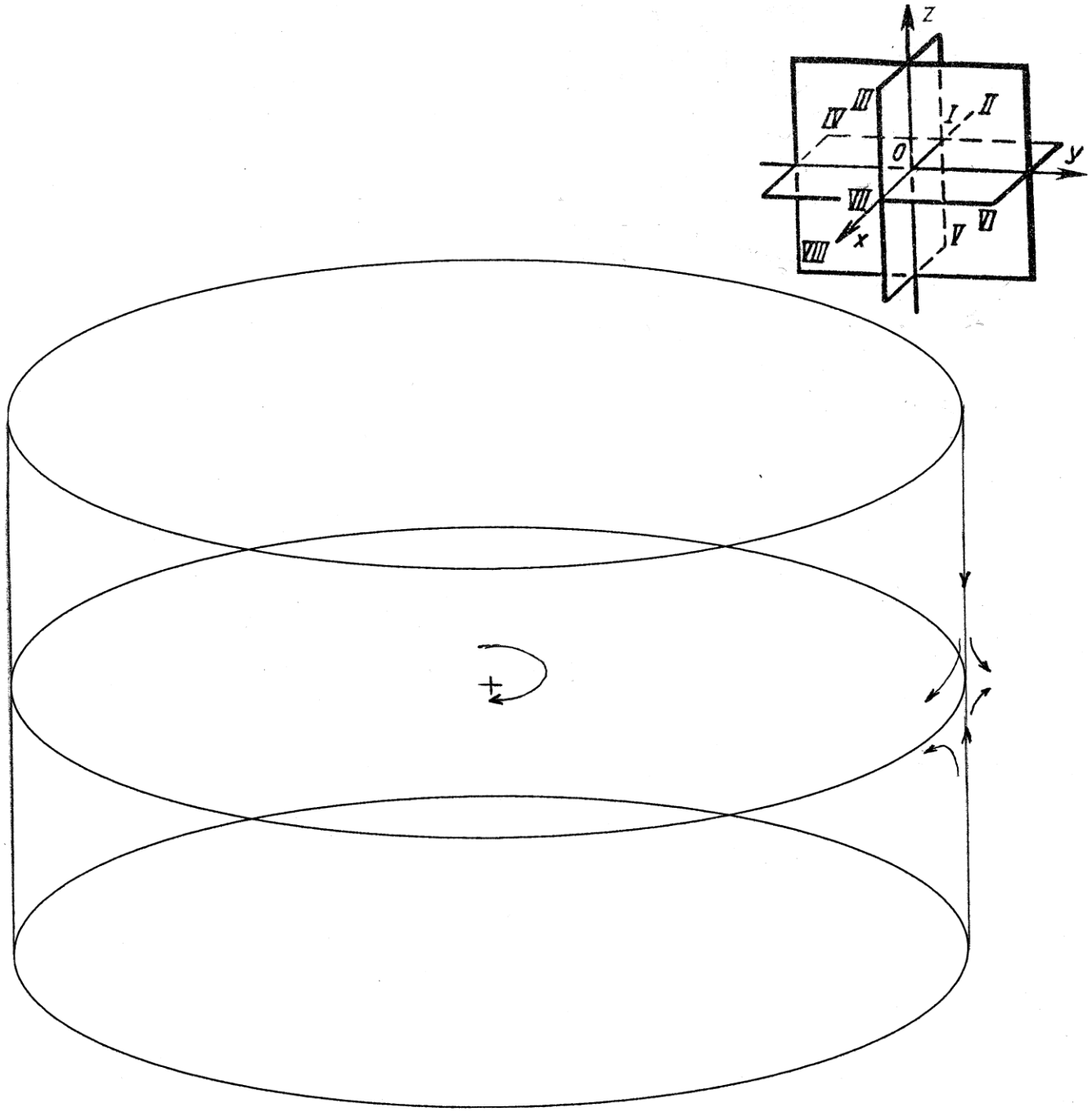


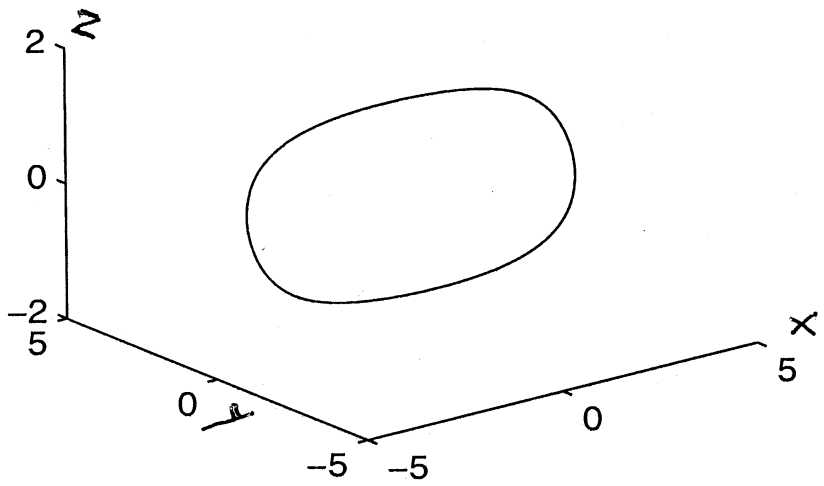

1
0
−1
−2
−3
−4
−5
dx/dt
−1.5
−1
−0.5
0
0.5
1
1.5
x

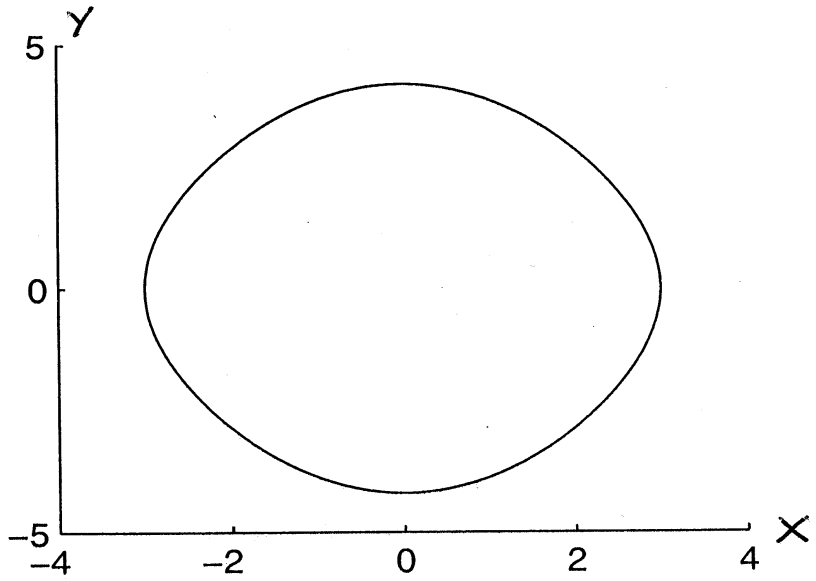

0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
r [cm]
300
320
340
360
380
400
420
440
460
V [km/t]

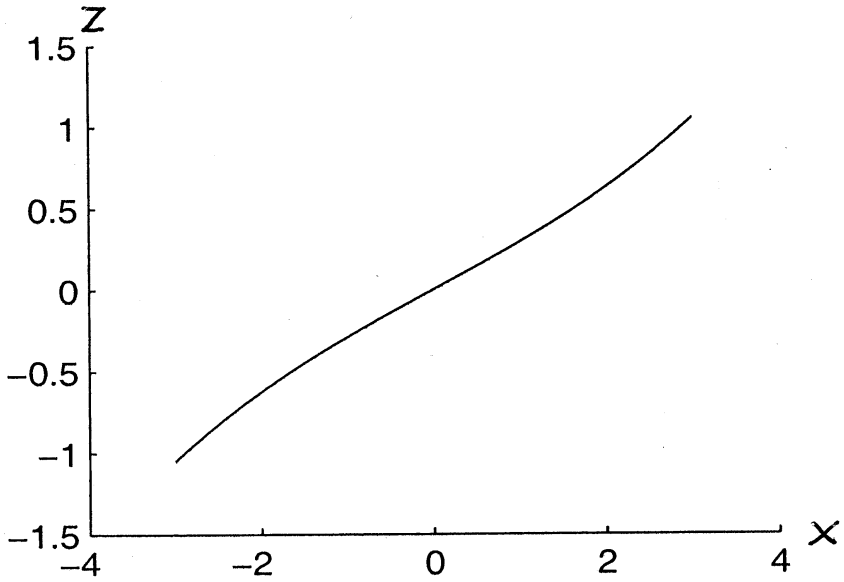

0.08
0.06
0.04
0.02
0
−0.02
−0.04
−0.06
−0.08
Wendewinkel (radian)
−0.2
−0.15
−0.1
−0.05
0
0.05
0.1
0.15
0.2
Querverschiebung (cm)

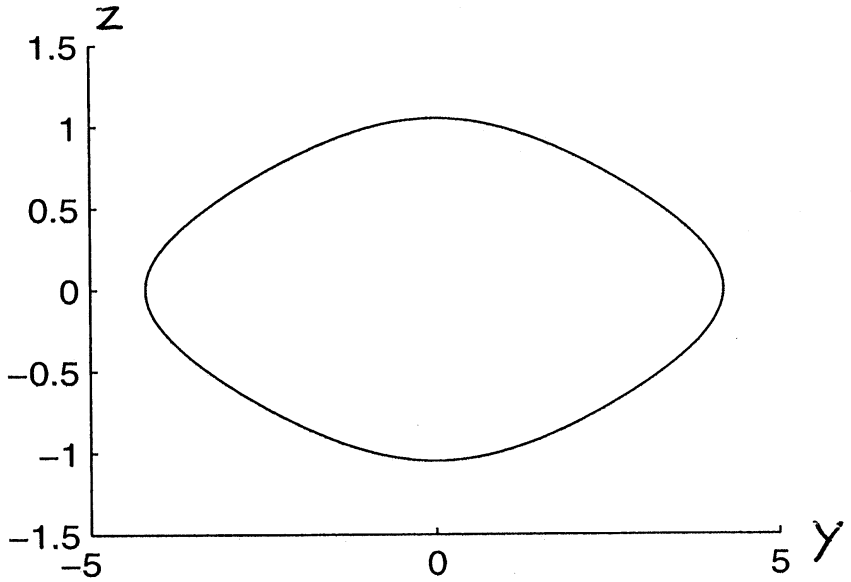

Hopf Bifurcation – No precession forces
x 10^-3
Amplitude Leading wheel set (L.B)
Speed (m/s)
0
1
2
3
4
5
6
7
8
9
0
20
40
60
80
100
120
140

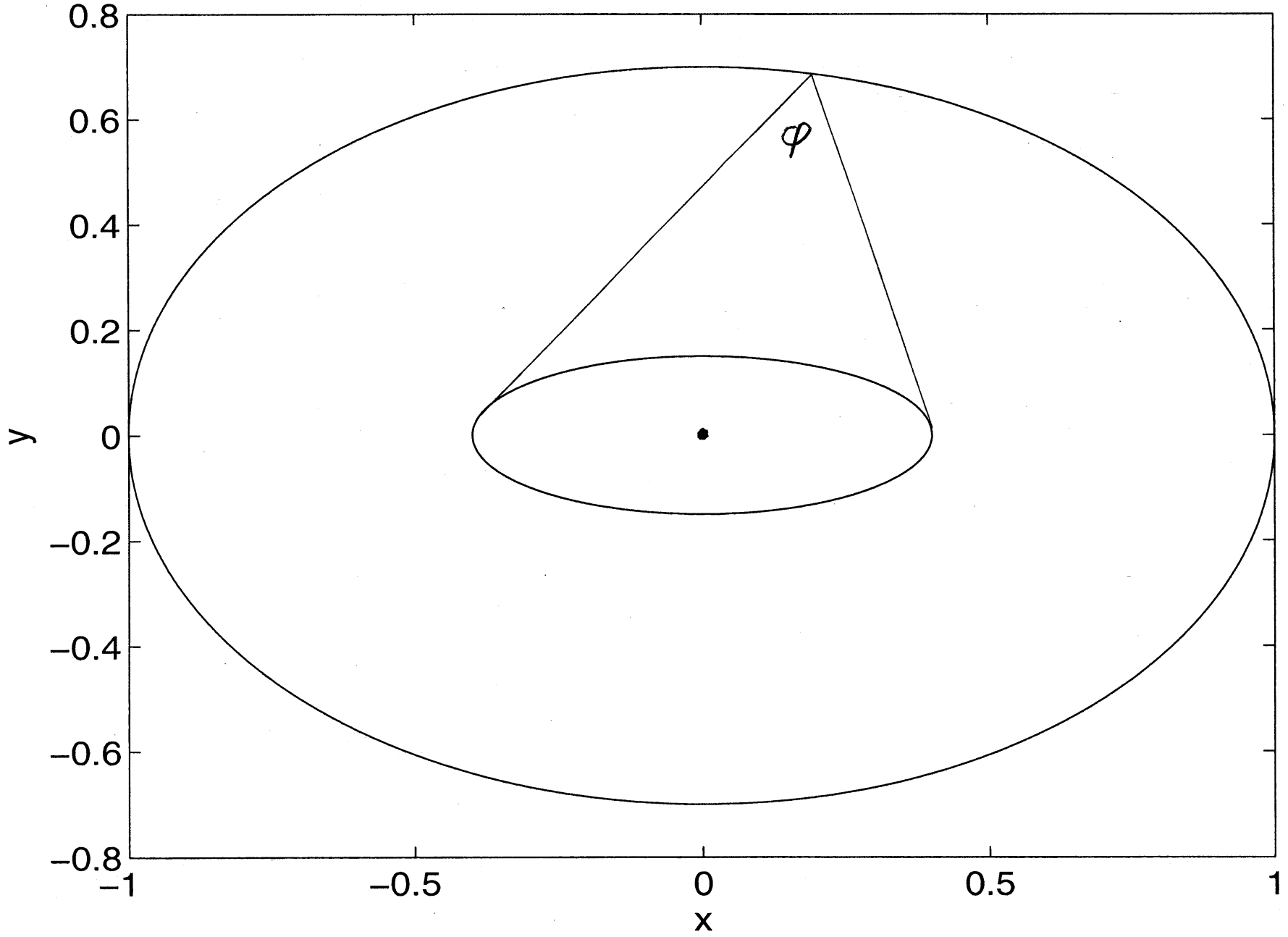

z
y
x
O
I
II
III
IV
V
VI
VII
VIII


Z
2
0
−2
5
0
Y
−5
−5
0
5
X


Y
5
0
−5
−4
−2
0
2
4
X


Z
1.5
1
0.5
0
−0.5
−1
−1.5
−4
−2
0
2
4
X


Z
1.5
1
0.5
0
−0.5
−1
−1.5
−5
0
5
Y


0.8
0.6
0.4
0.2
0
−0.2
−0.4
−0.6
−0.8
−1
−0.5
0
0.5
1
x
y
φ

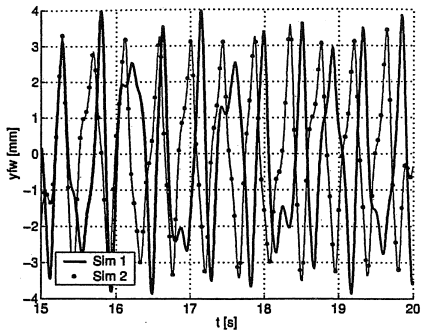


Figure 5.27: Kbps (empty, SPP, 1/30) running at 50 m/s. The chaotic attractor exhibits a sensitivity to the initial condition.

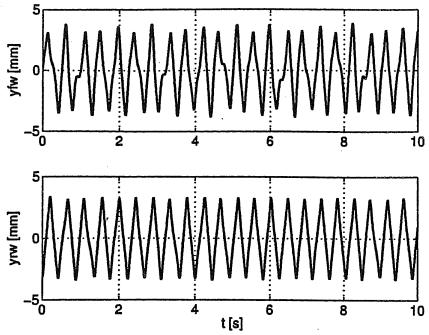
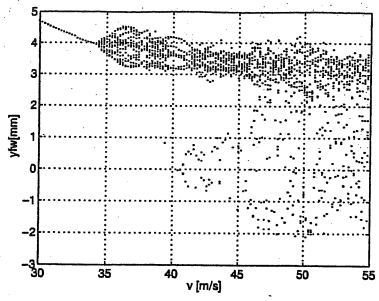
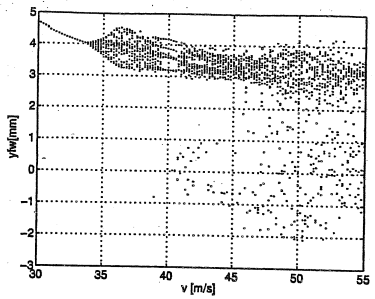


Figure 5.28: Wheelset behaviour at 43 m/s.

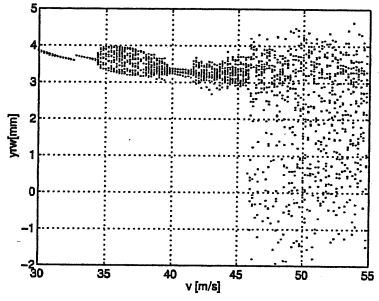


Increasing speed.

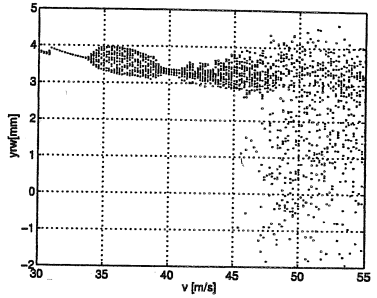


Decreasing speed.

Figure 5.29: Bifurcation diagram of the front wheelset. Kbps (empty, SPP, 1/30).

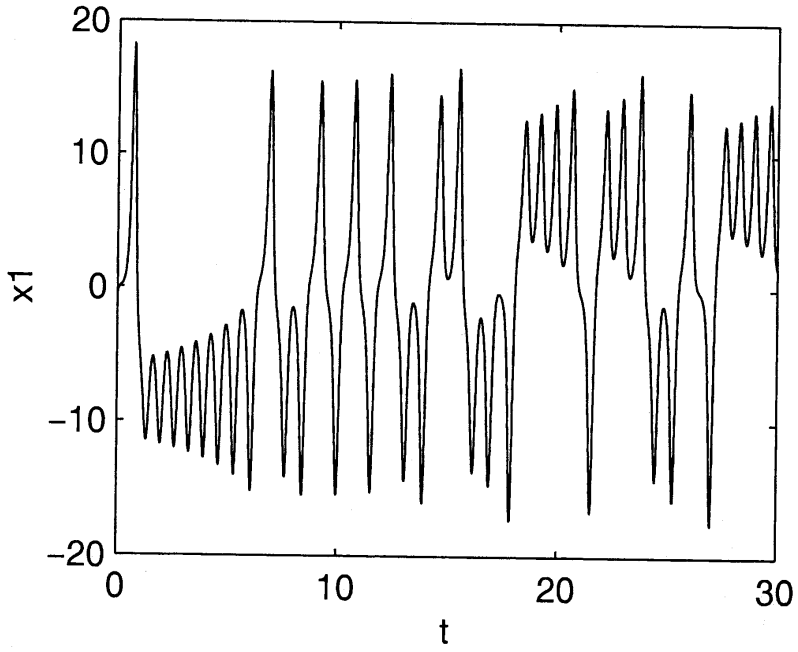


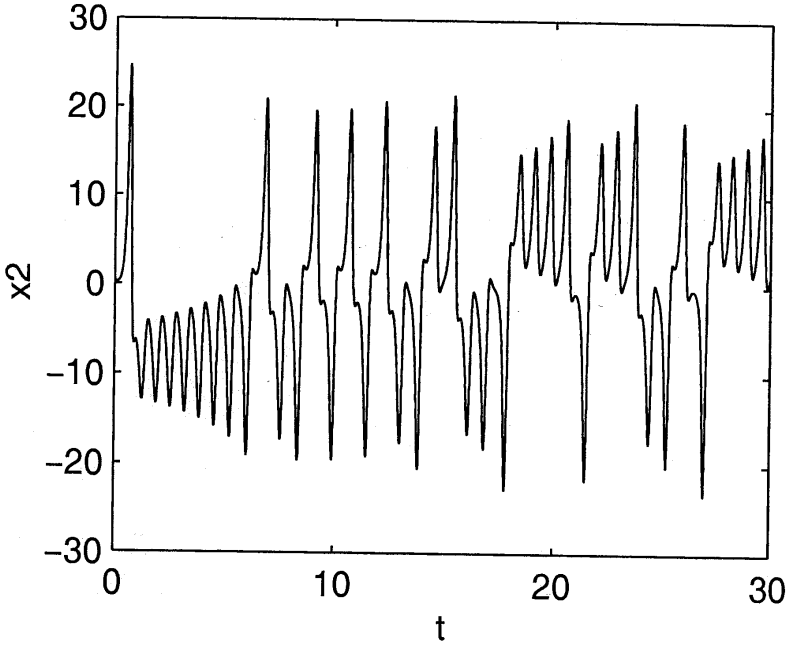
Increasing speed.

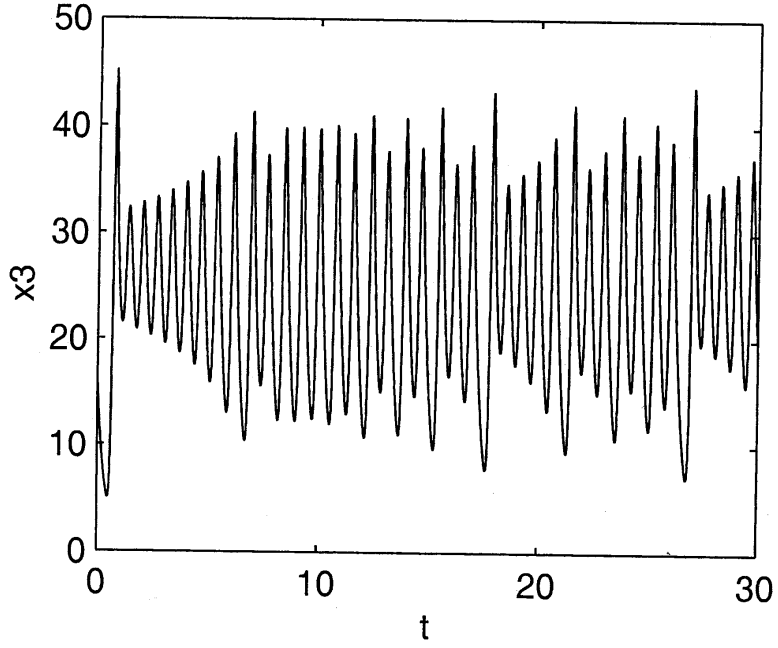


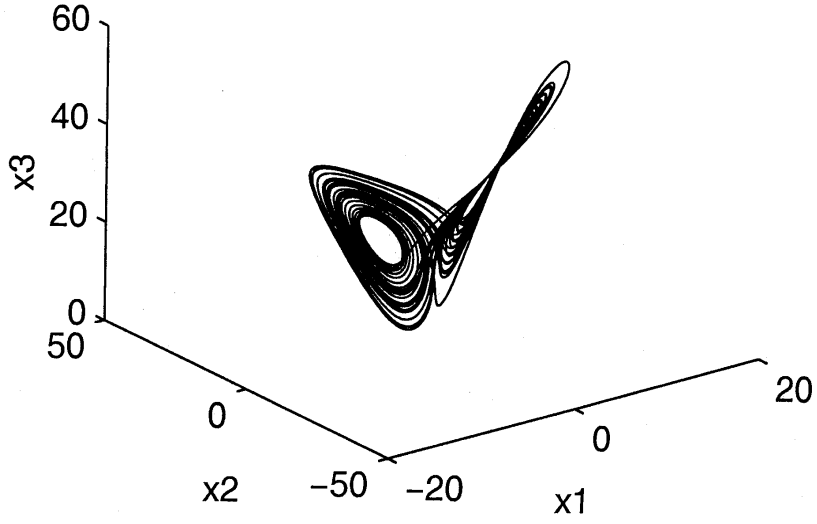
Decreasing speed.

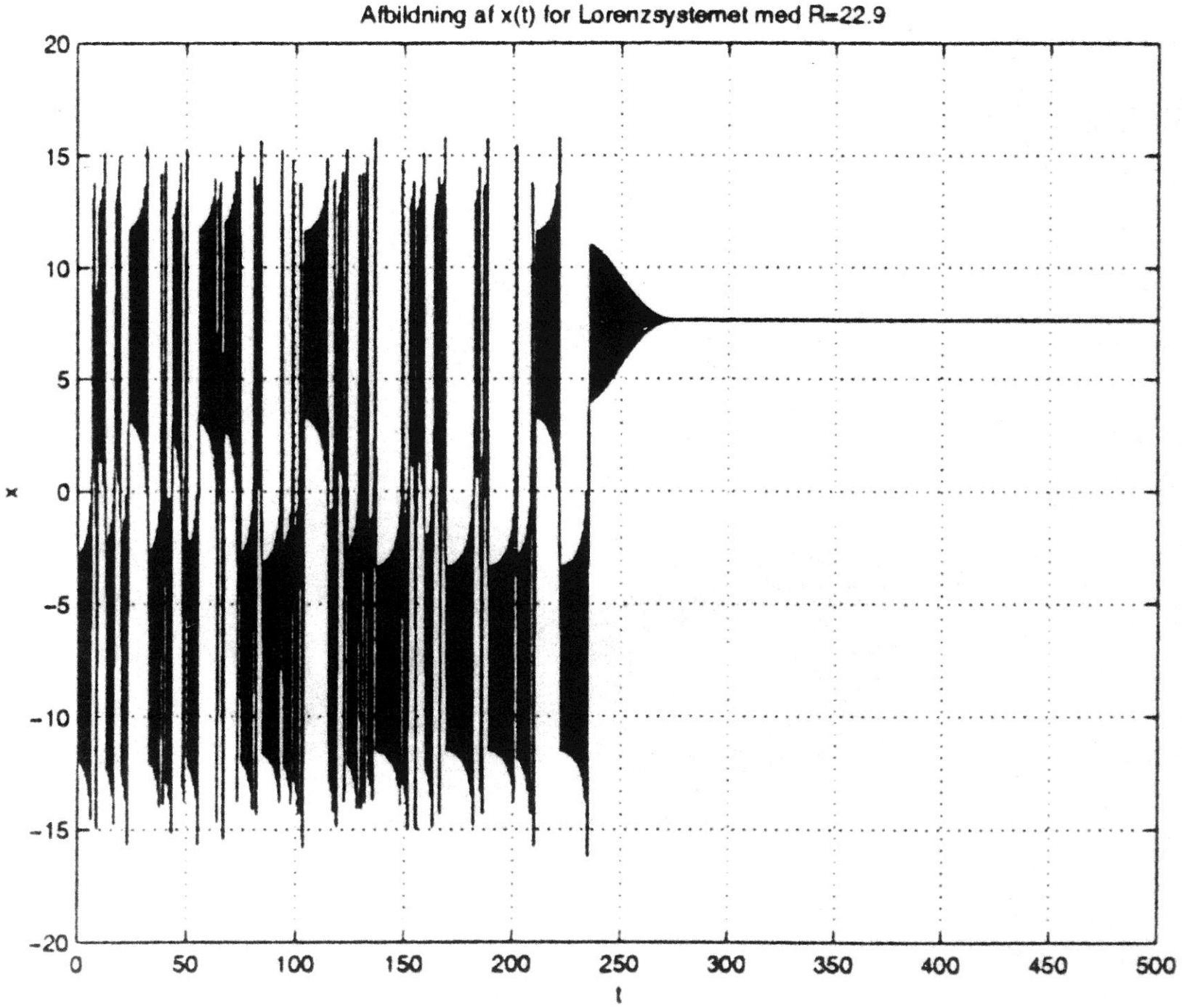
Figure 5.30: Bifurcation diagram of the rear wheelset. Kbps (empty, SPP, 1/30).


20
10
0
−10
−20
x1
0
10
20
30
t


30
20
10
0
−10
−20
−30
x2
0
10
20
30
t


50
40
30
20
10
0
x3
0
10
20
30
t


60
40
20
0
x3
50
0
−50
x2
−20
0
20
x1


Afbildning af x(t) for Lorenzsystemet med R=22.9
20
15
10
5
0
-5
-10
-15
-20
x
0
50
100
150
200
250
300
350
400
450
500
t

Danke schön