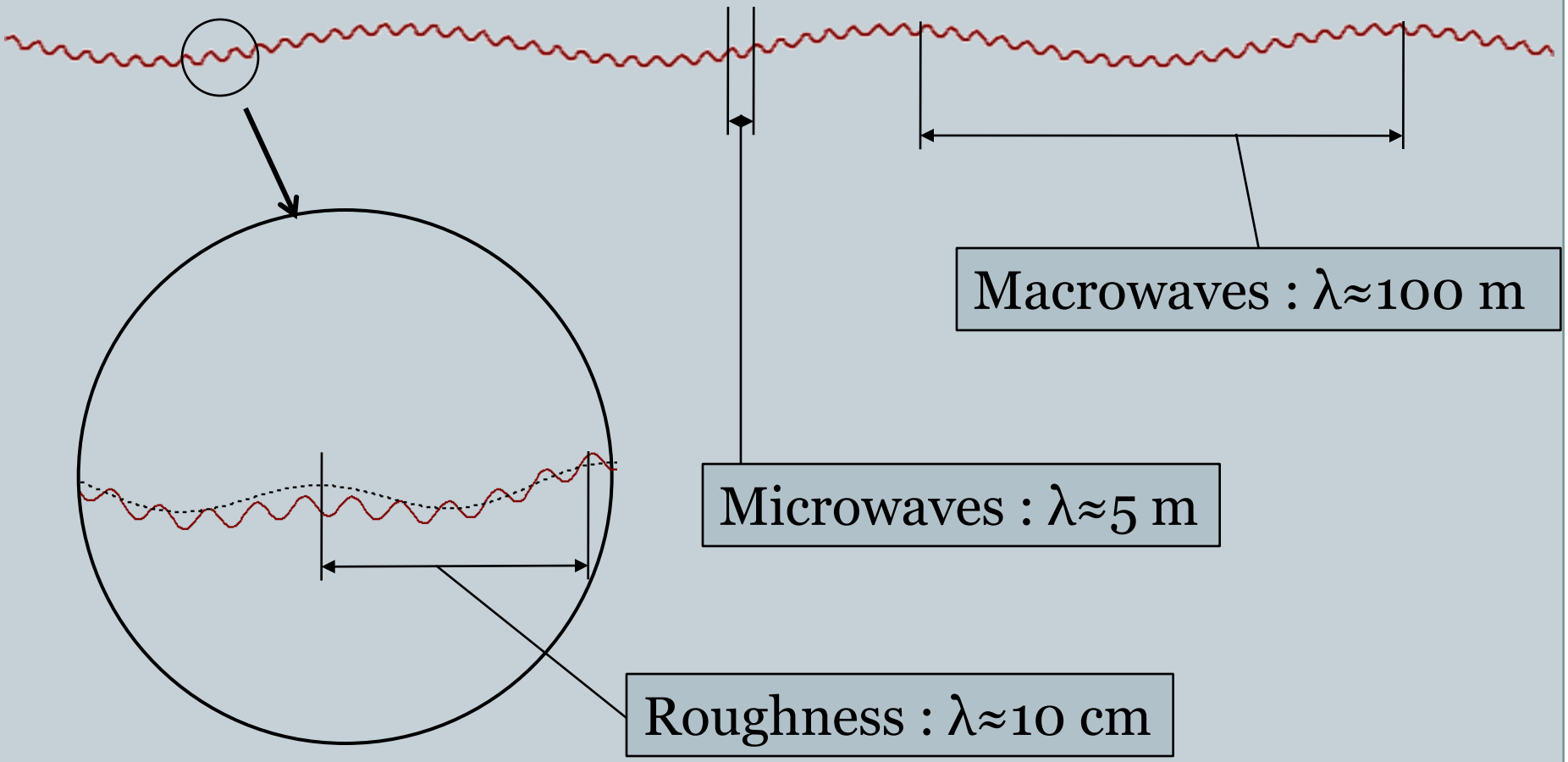
Corrugation

BY THE
BELARUS TEAM

The statement of the problem

- After traffic has used an unpaved road for some time the surface of the road gets a "wave" structure with a well defined wavelength. Investigate and explain this phenomenon.

Coating irregularities

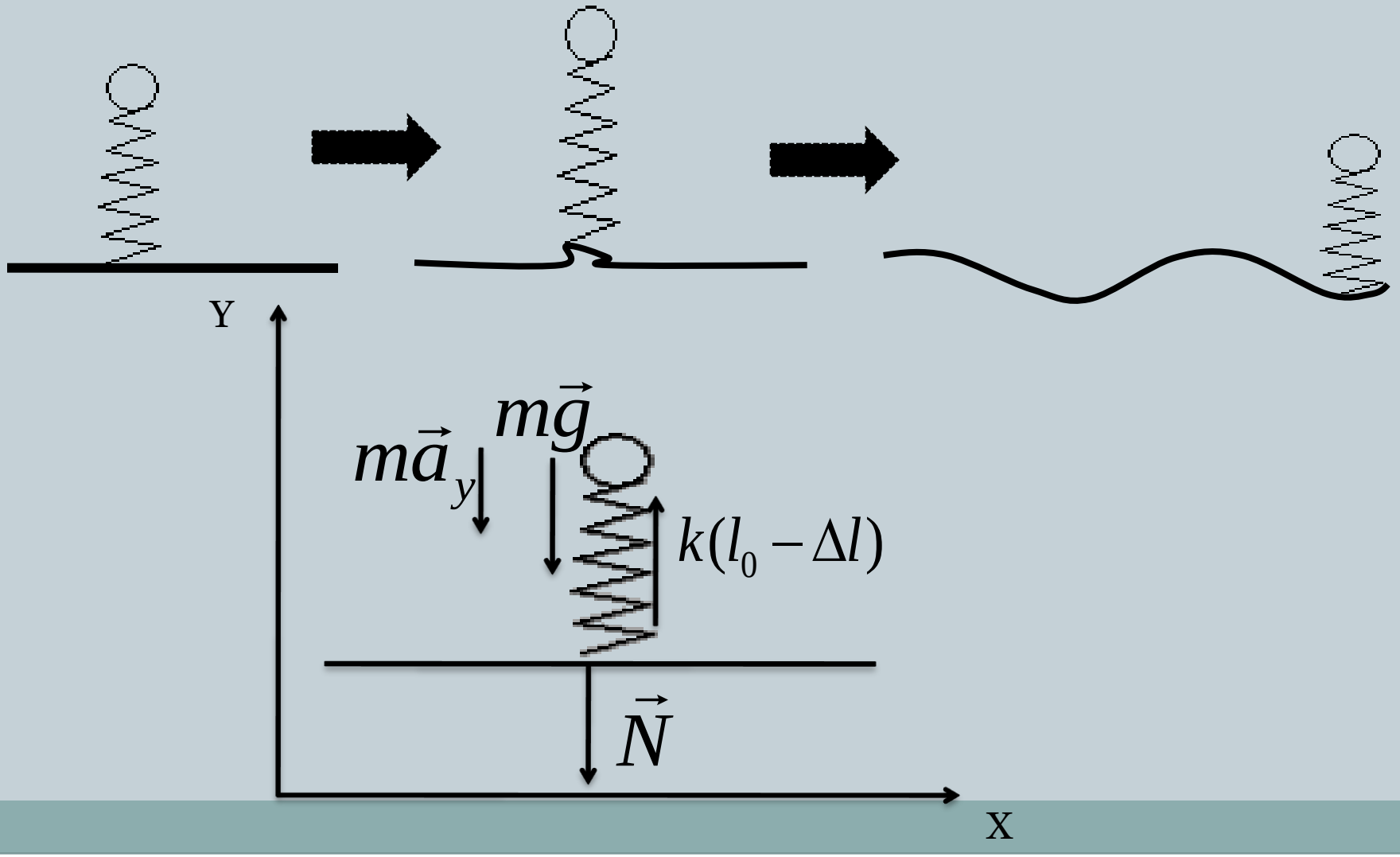


The reasons for the corrugation formation

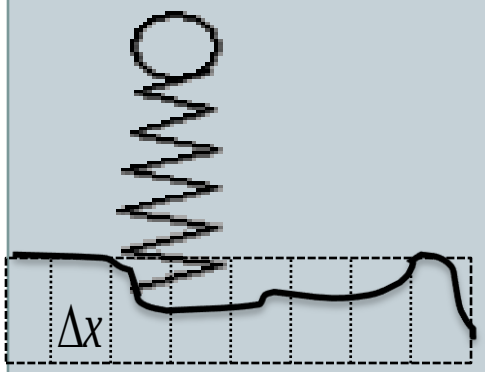
- 1) The fluctuations of the shock absorbers for road humps
- 2) Displacing of ground caused by cars' wheels
- 3) Irregularities which appear due to different temperature regimes and weather effects

Part 1

The process of the corrugation formation



Model. Process discretization



$$0 = -gm + k(l_0 - y) - (\beta V_y) + a'm$$

$$V_y = V_y + a'\partial t$$

$$y = y + V_y \partial t$$

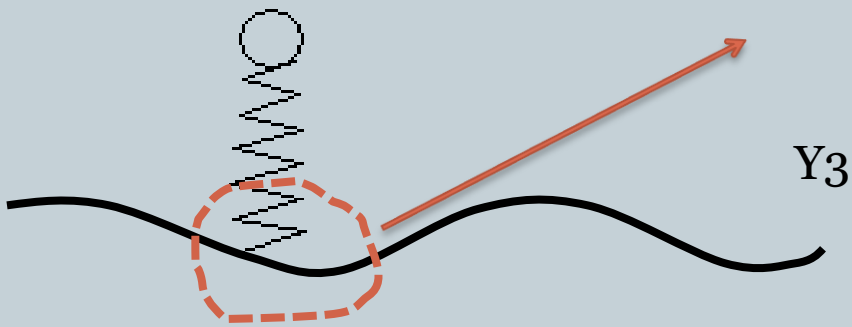
Force, that conditioned by damping

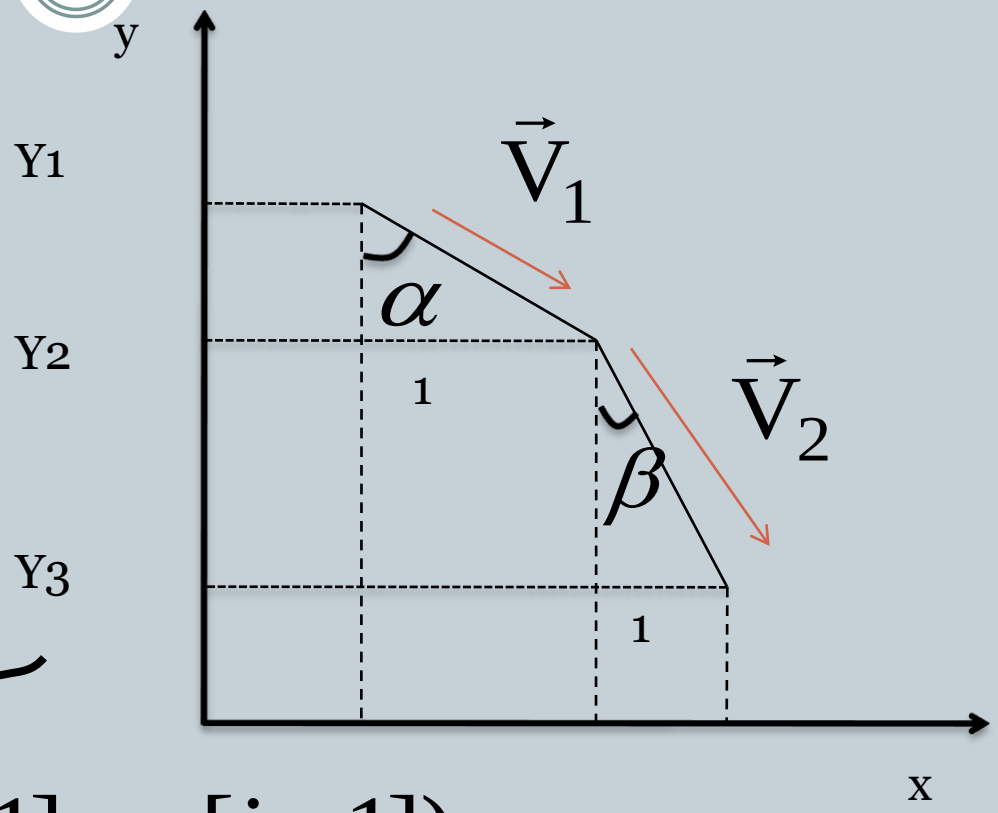
$$\Delta x = 1cm$$

For the discretization of the process the calculation of the period of time should be made so that the machine travel 1 cm in the projection on the vertical

$$\partial t = \frac{0{,}01}{\sqrt{1 + (y[i] - y[i+1])^2}}$$

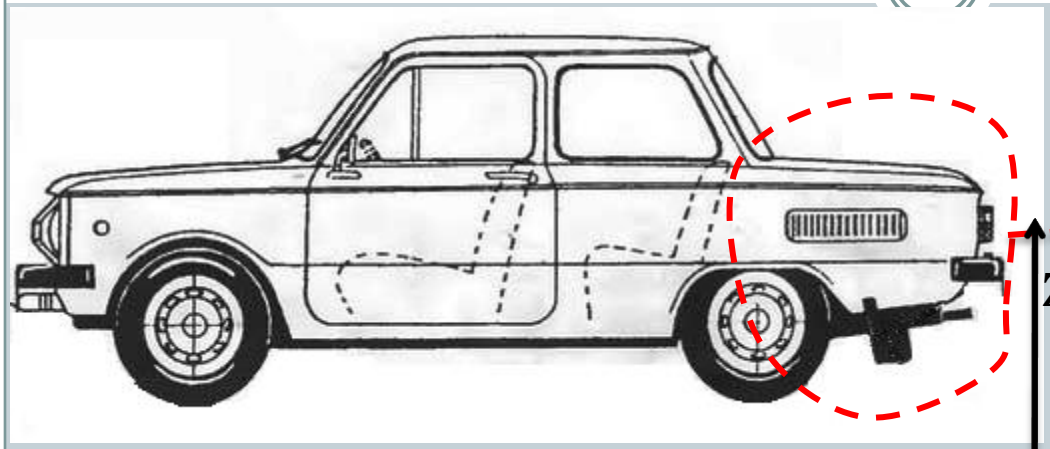
$$a' = \left| \frac{\vec{V}_1 - \vec{V}_2}{\partial t} \right|$$

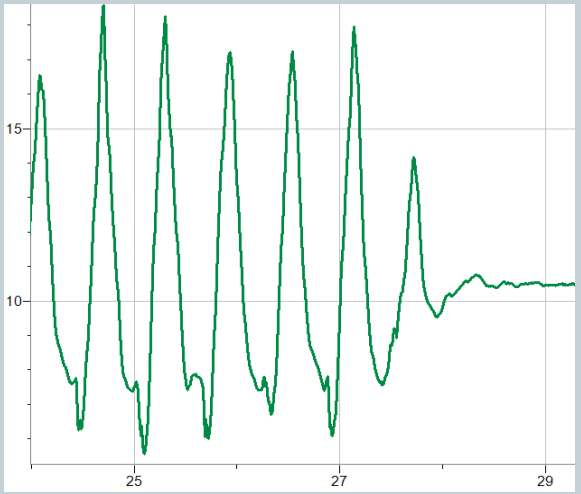


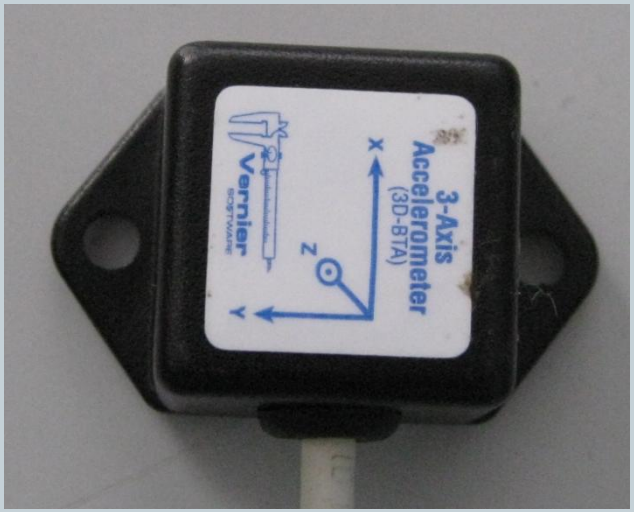


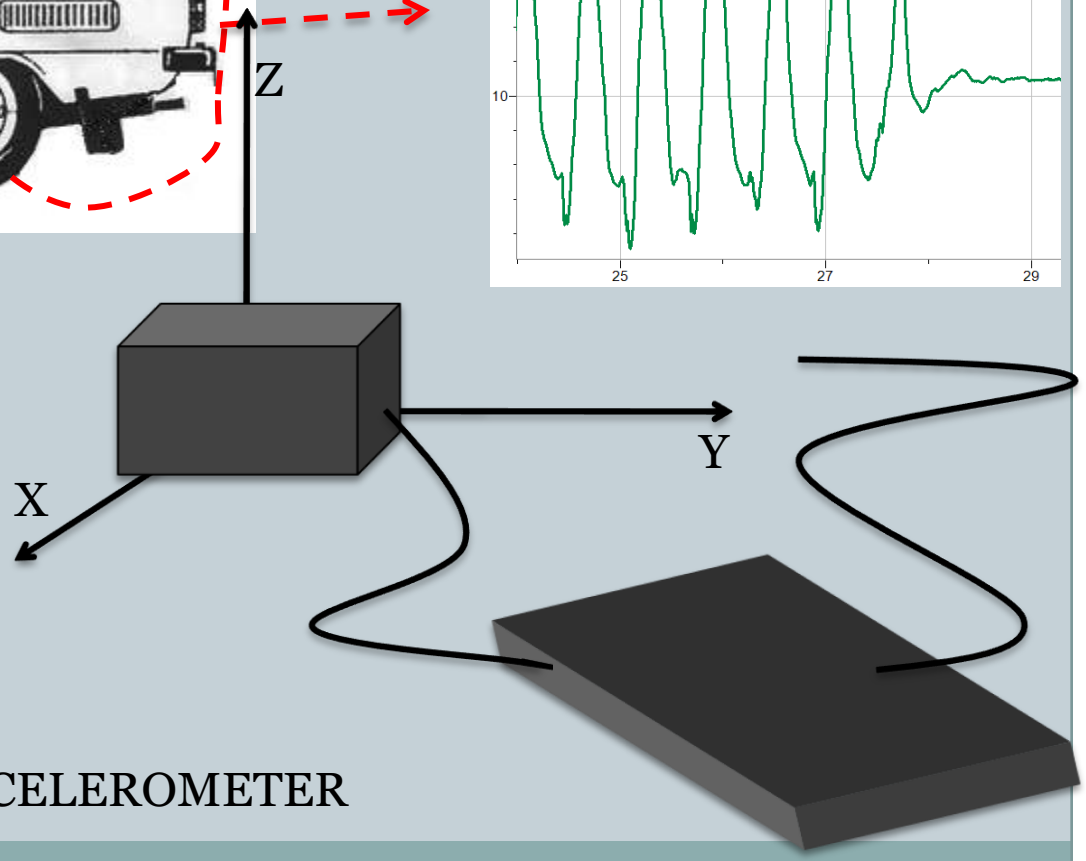
$$a' = \frac{V_0(2y[i] - y[i-1] - y[i+1])}{\partial t}$$

Oscillations damping



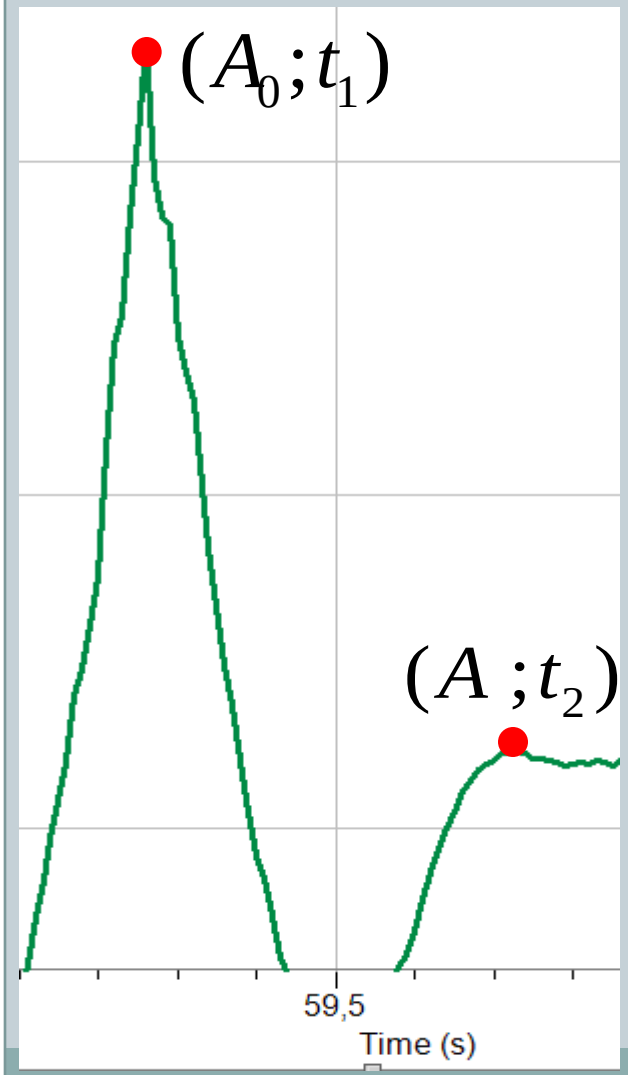






ACCELEROMETER

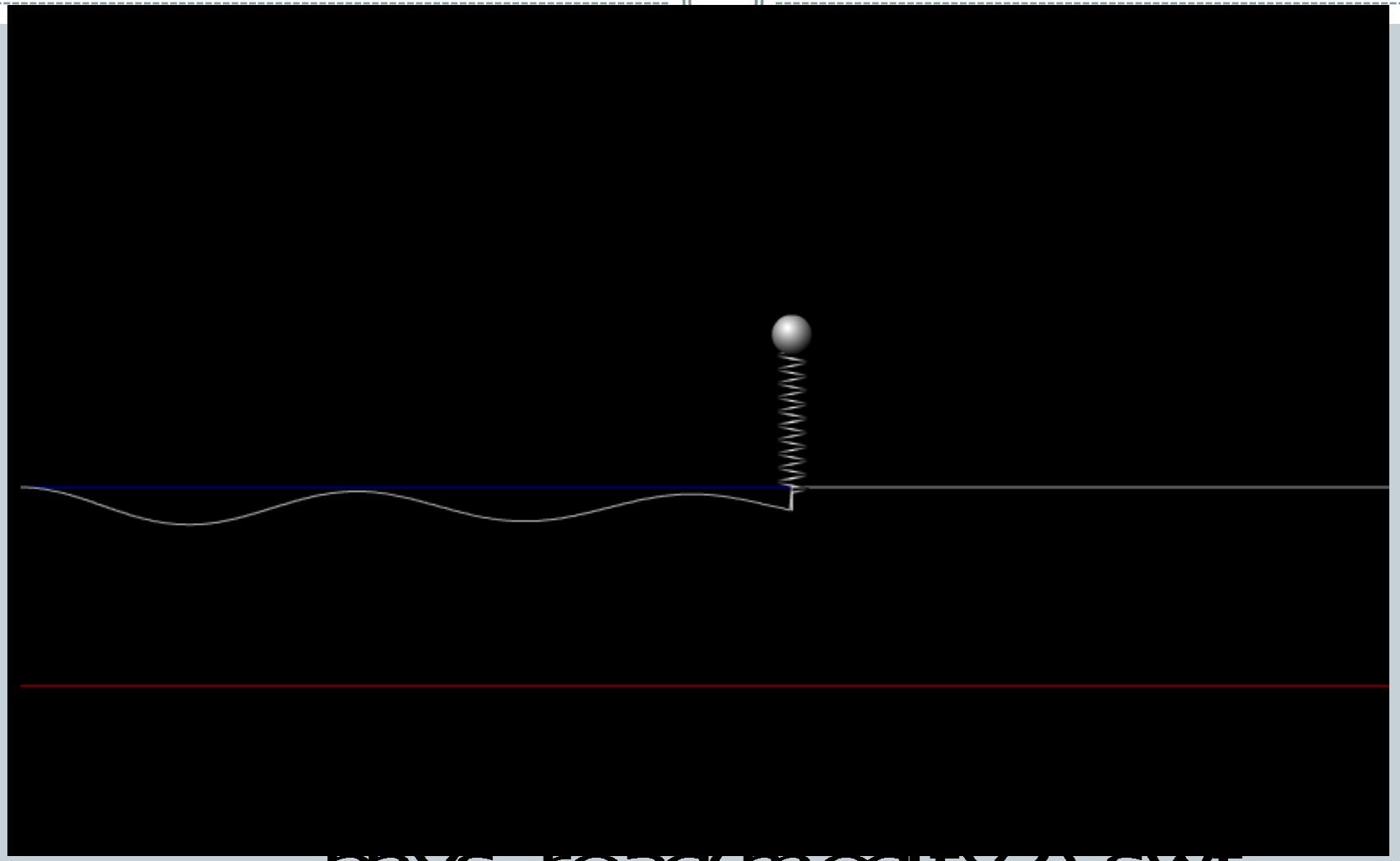
Oscillations damping

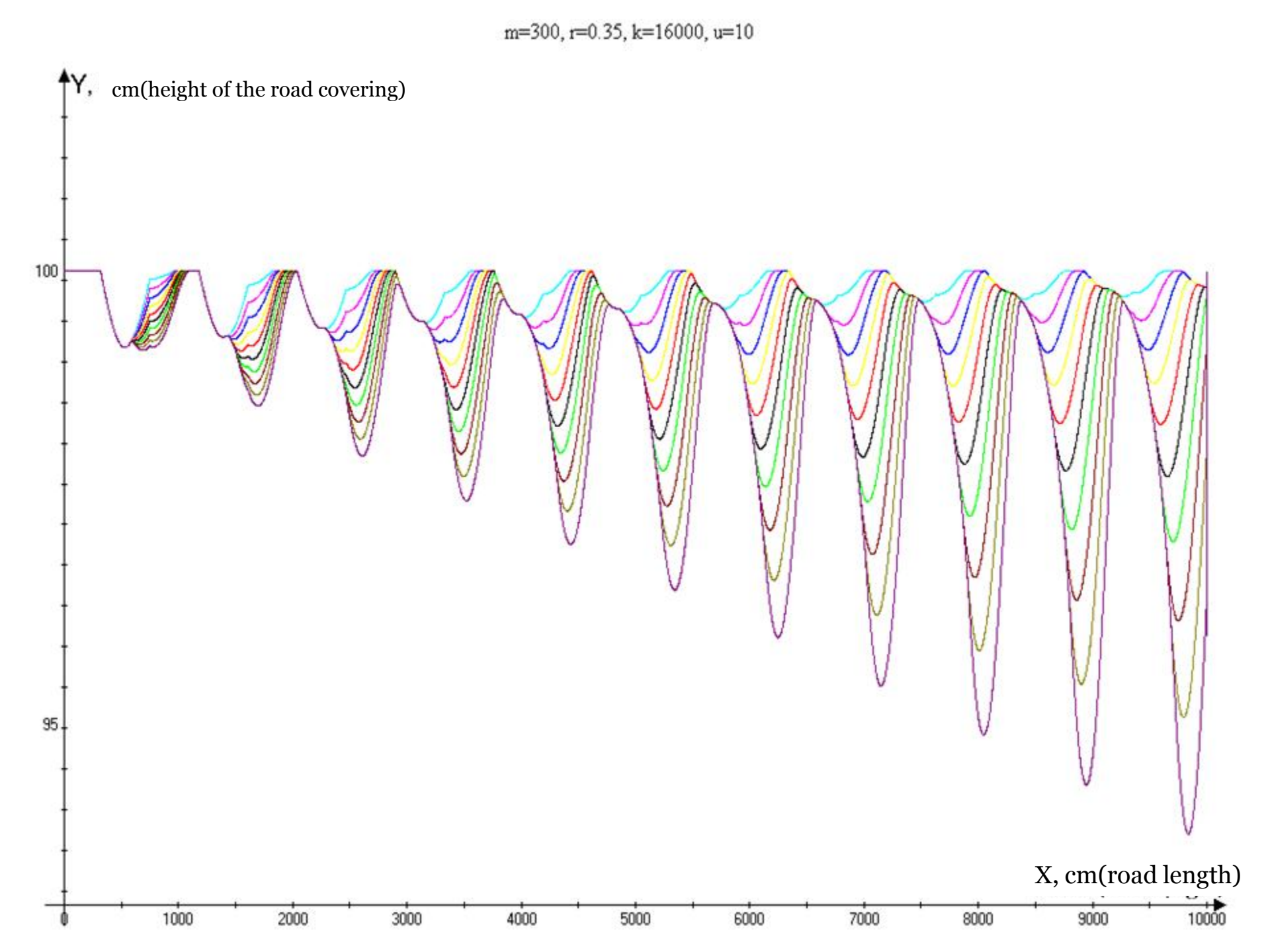


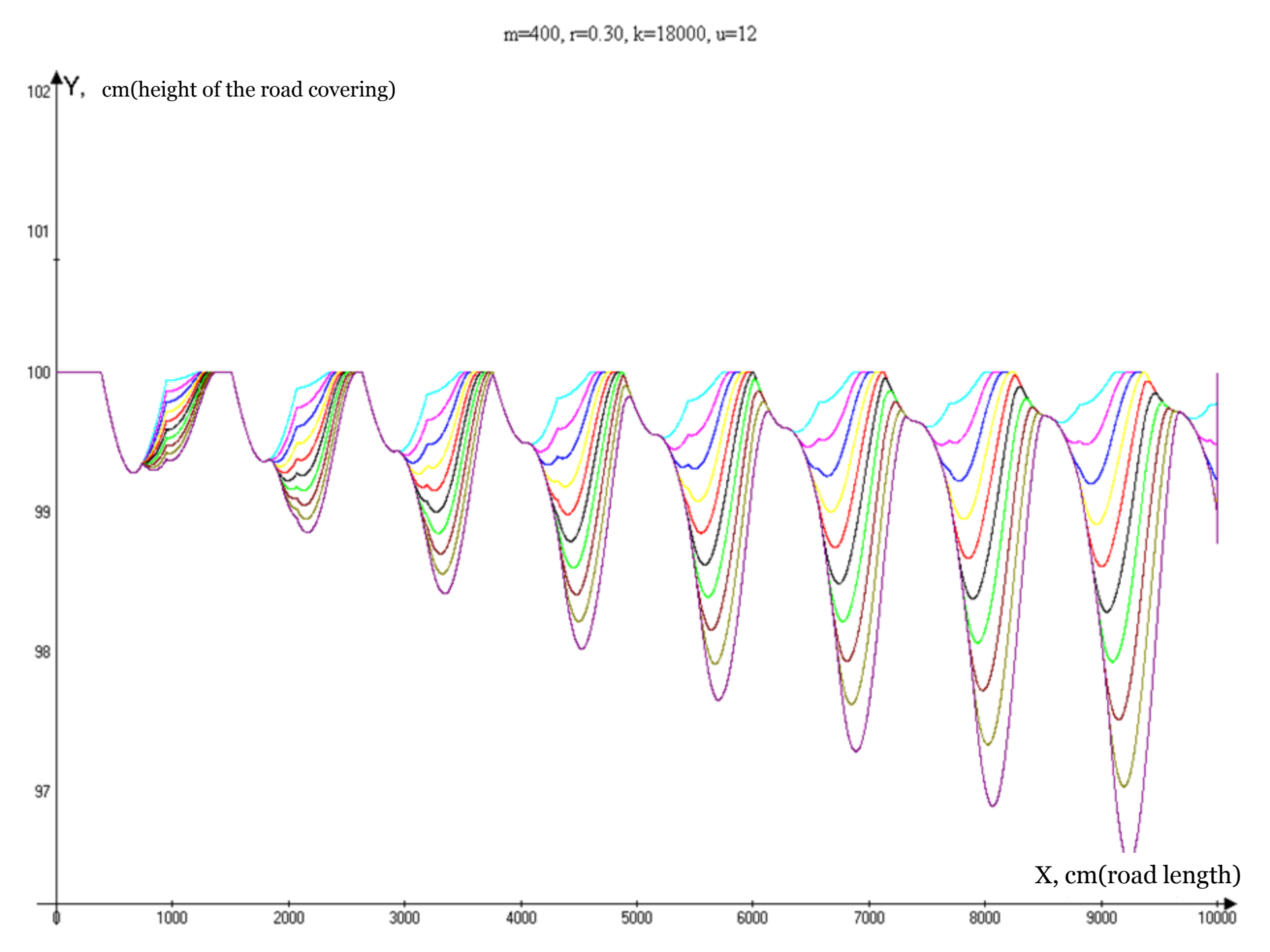
$$A - A_0 = A_0 e^{-\xi \Delta t} = A_0 e^{-\xi (t_2 - t_1)}$$

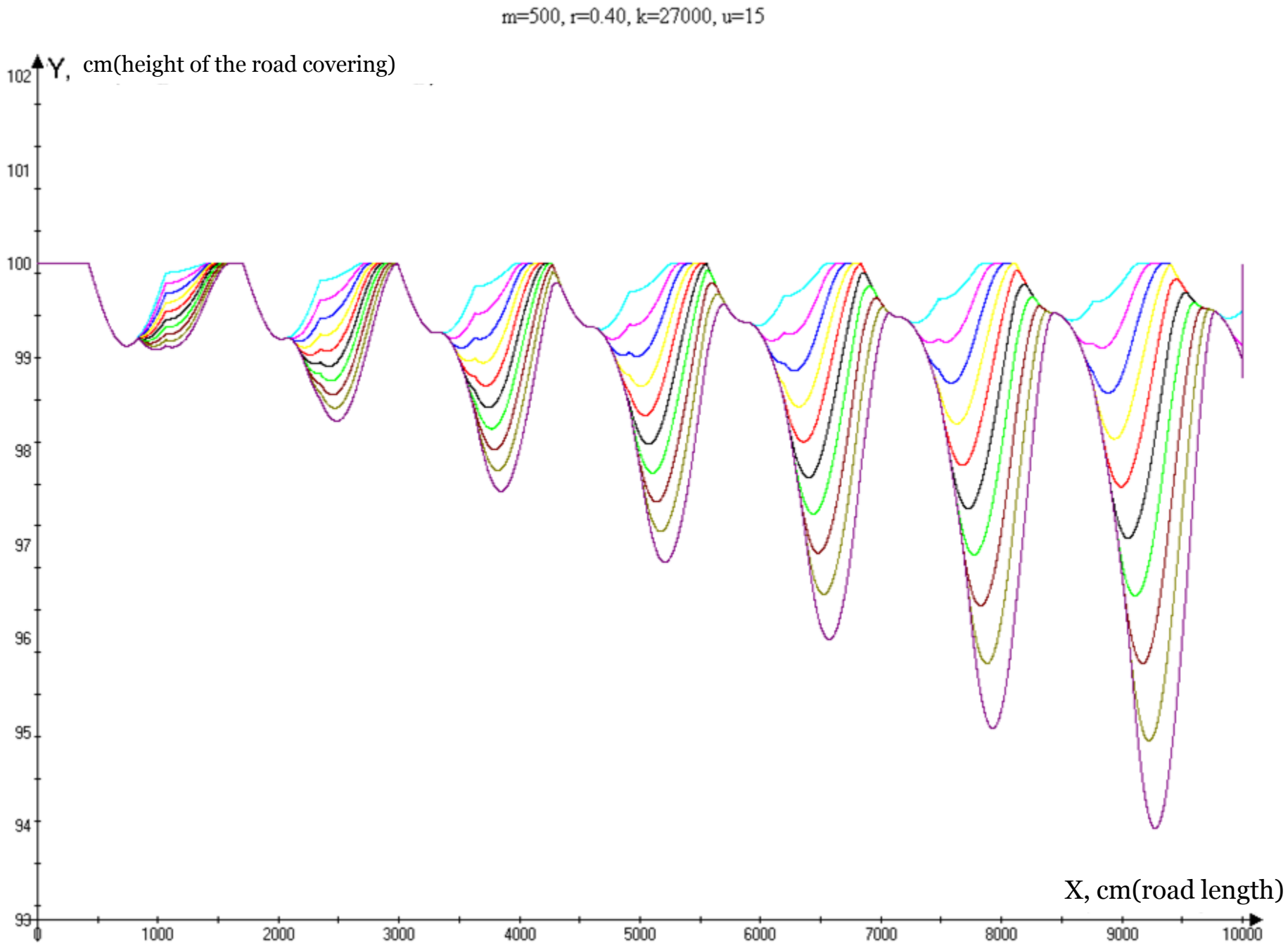
$$\beta = m\xi$$

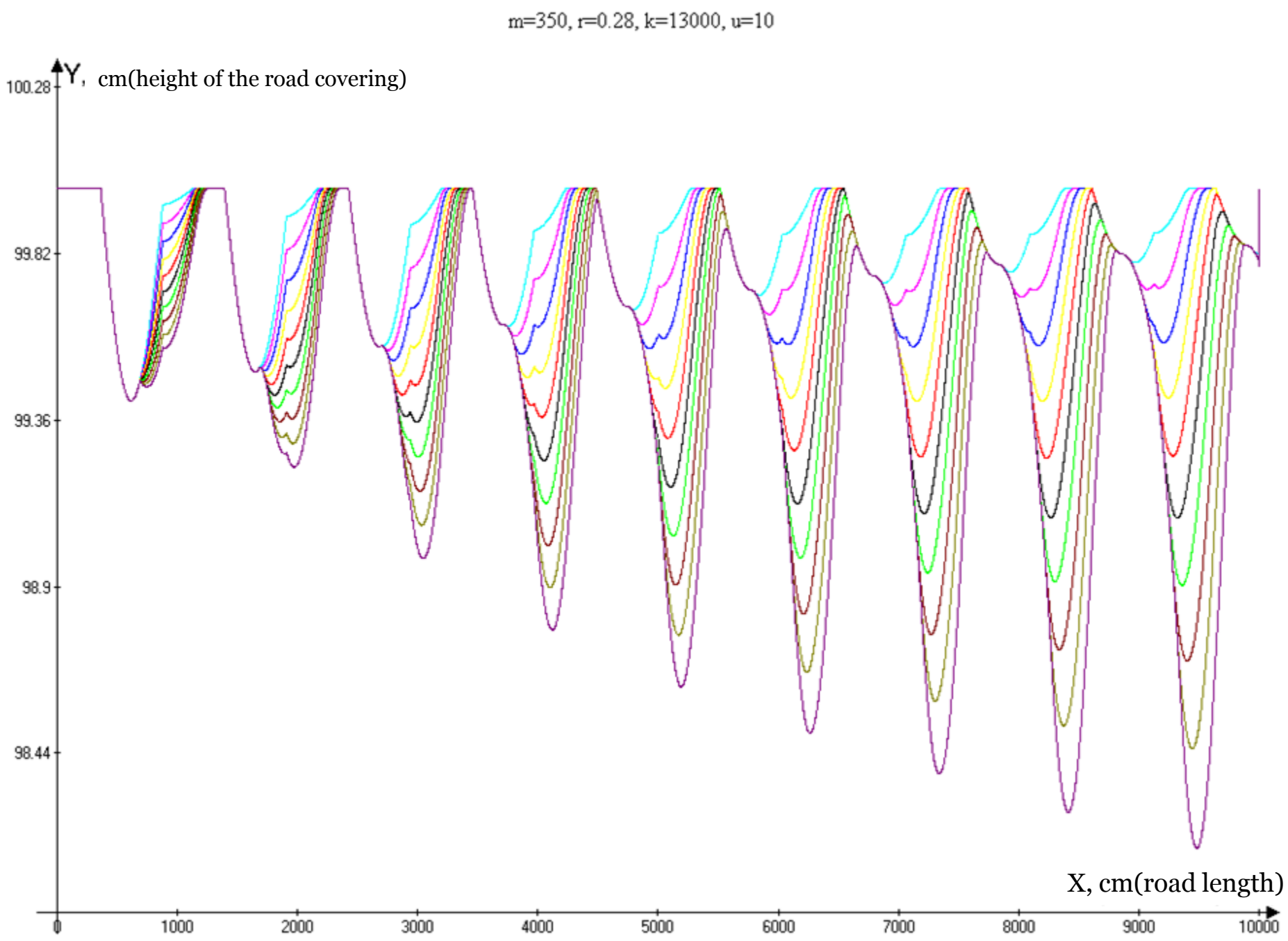
Program visualization



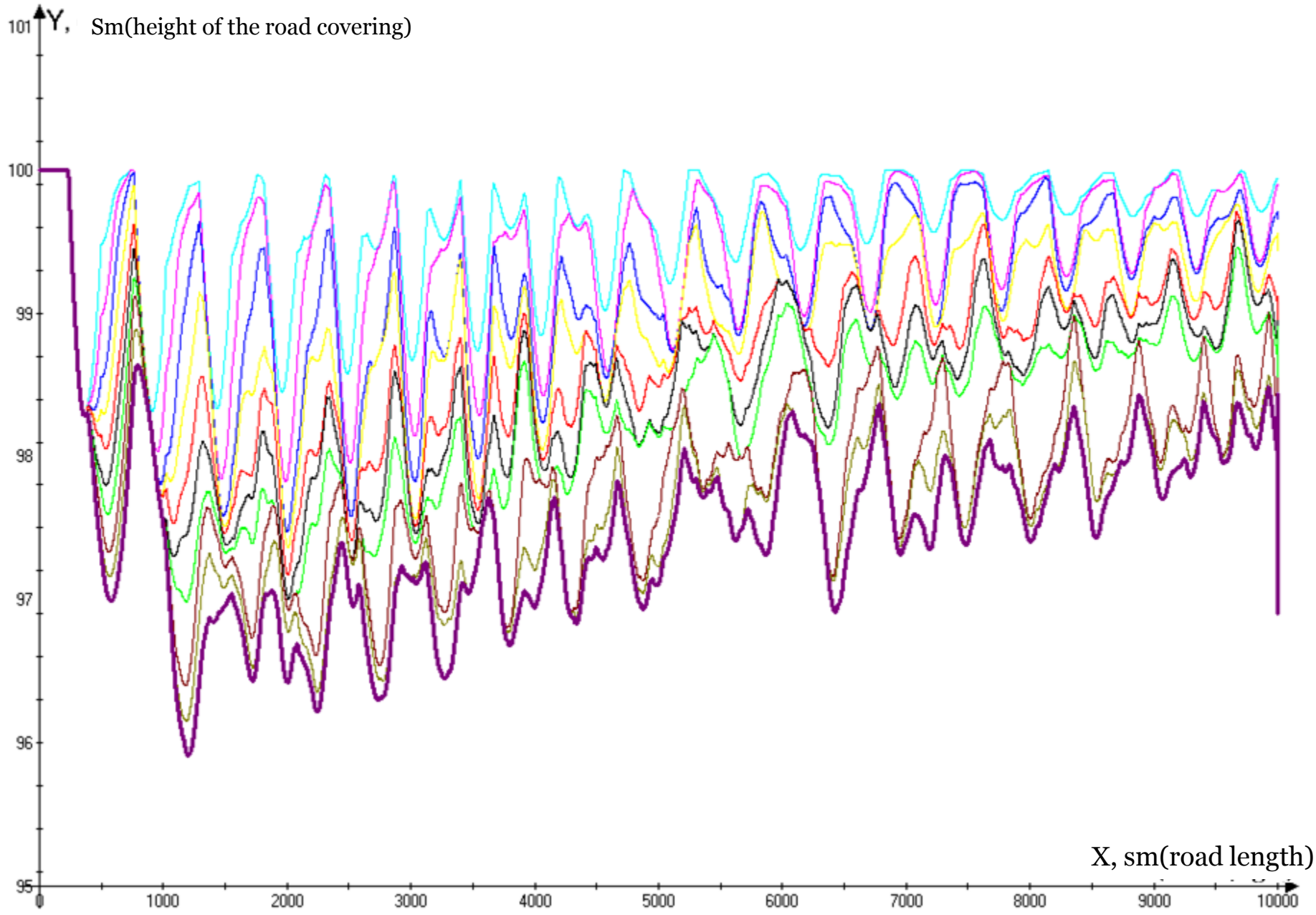

m=300, r=0.35, k=16000, u=10
Y, cm(height of the road covering)
100
95
X, cm(road length)
0
1000
2000
3000
4000
5000
6000
7000
8000
9000
10000


m=400, r=0.30, k=18000, u=12
Y, cm(height of the road covering)
102
101
100
99
98
97
X, cm(road length)
0
1000
2000
3000
4000
5000
6000
7000
8000
9000
10000

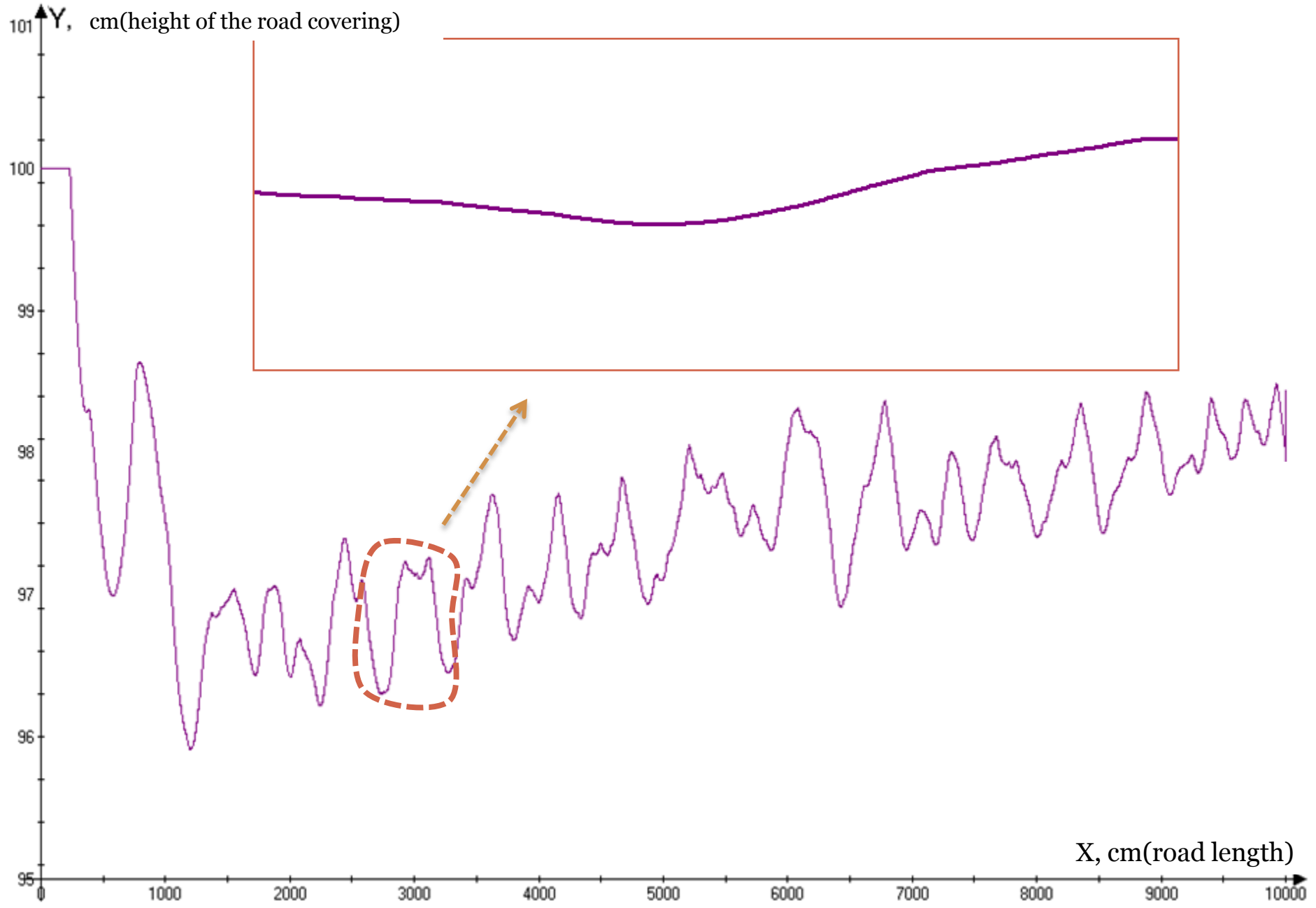

m=500, r=0.40, k=27000, u=15
Y, cm(height of the road covering)
102
101
100
99
98
97
96
95
94
93
0
1000
2000
3000
4000
5000
6000
7000
8000
9000
10000
X, cm(road length)


m=350, r=0.28, k=13000, u=10
Y, cm(height of the road covering)
100.28
99.82
99.36
98.9
98.44
X, cm(road length)
0
1000
2000
3000
4000
5000
6000
7000
8000
9000
10000

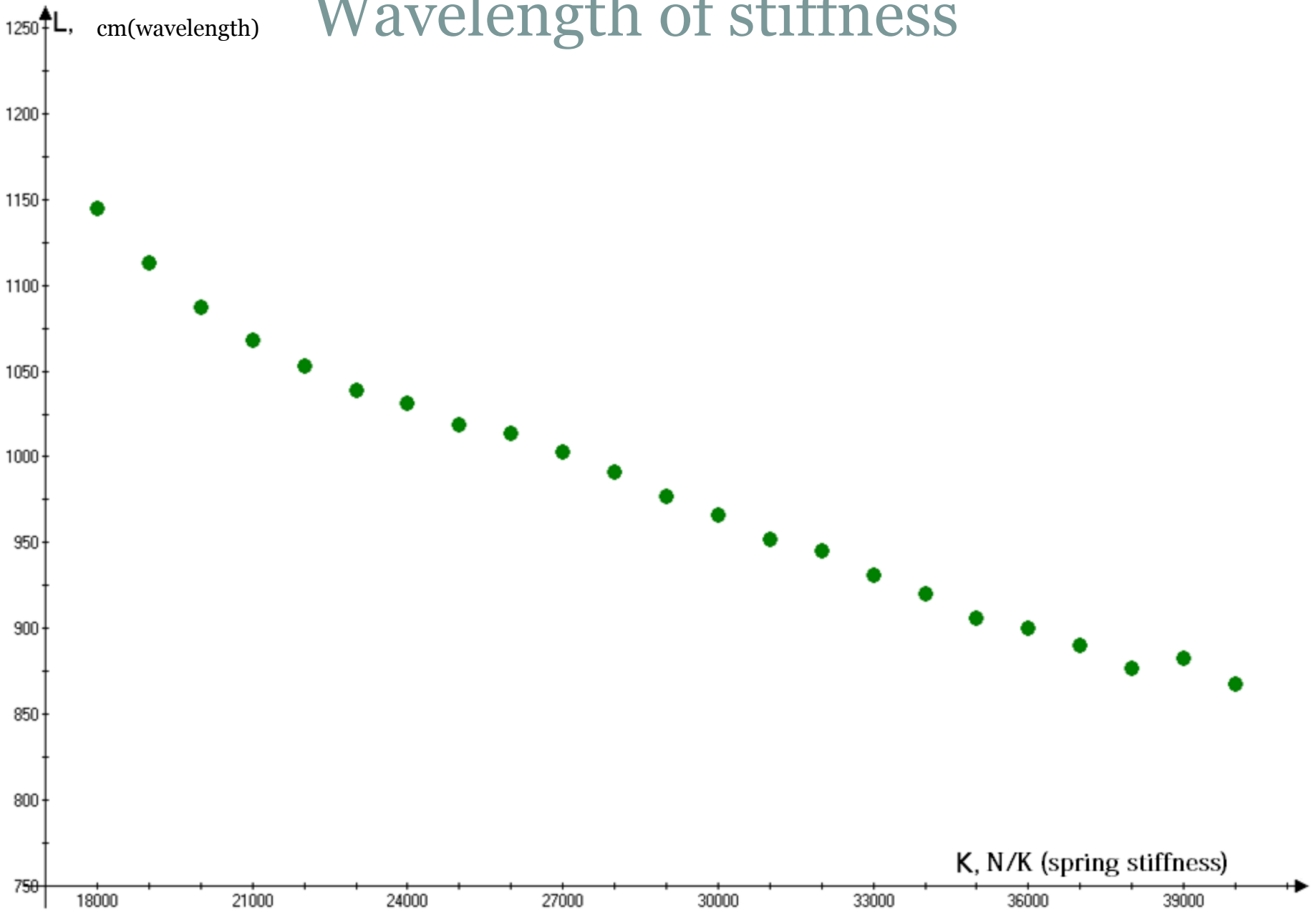
m=200-500, r=0.25-0.40, k=m*g/(0.1-0.05), u=7-15



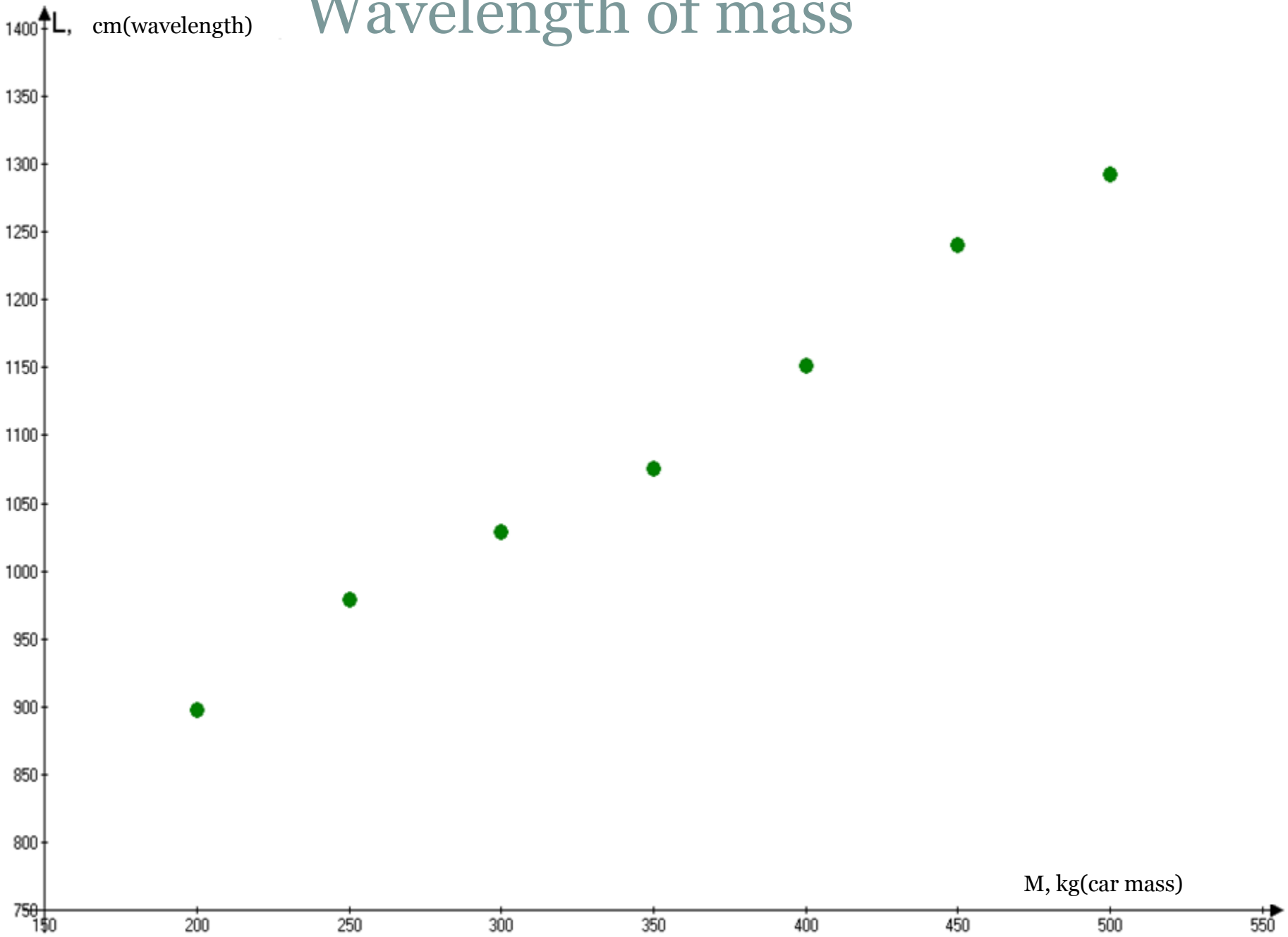
m=200-500, r=0.25-0.40, k=m*g/(0.1-0.05), u=7-15



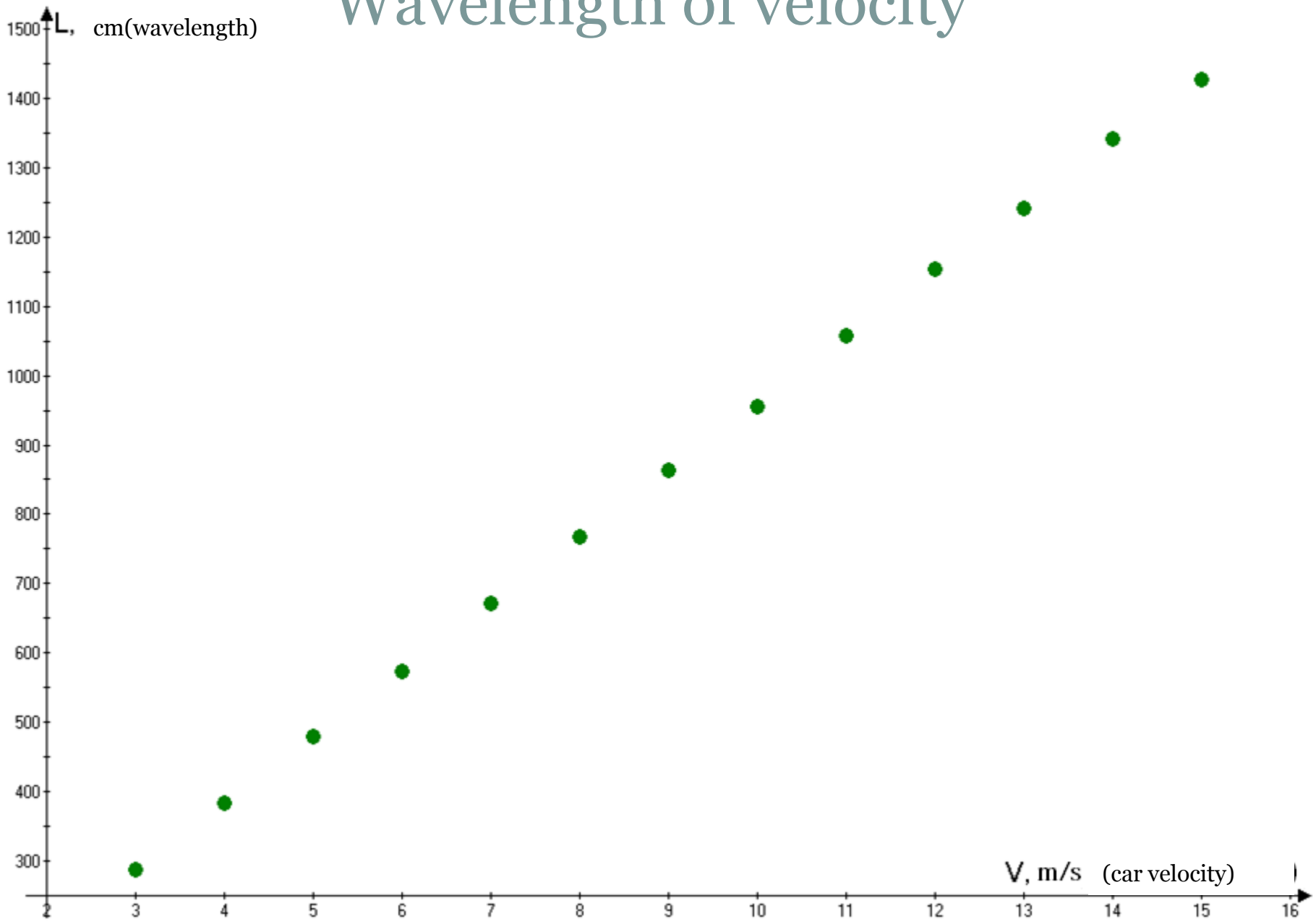
Wavelength of stiffness



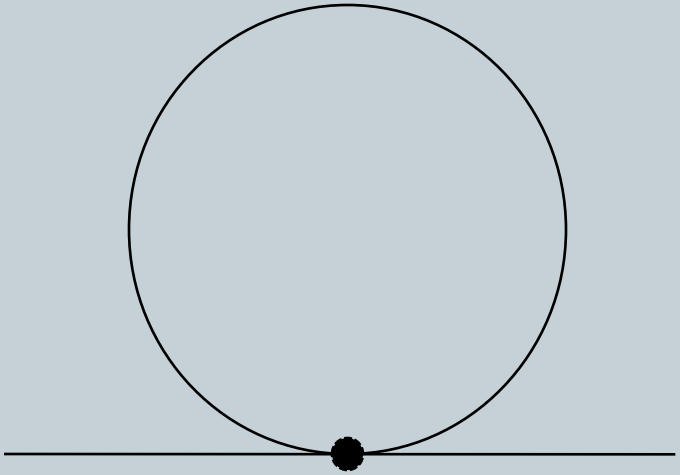
Wavelength of mass

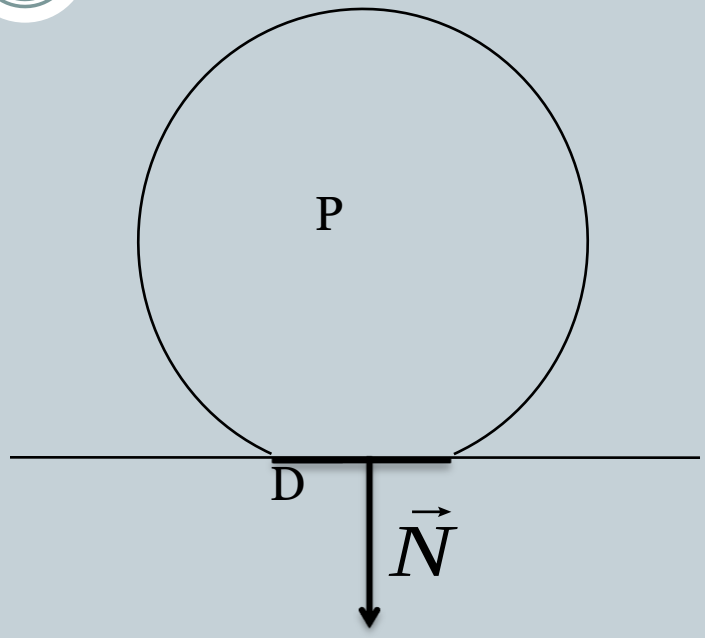


Wavelength of velocity



Spot of tangency





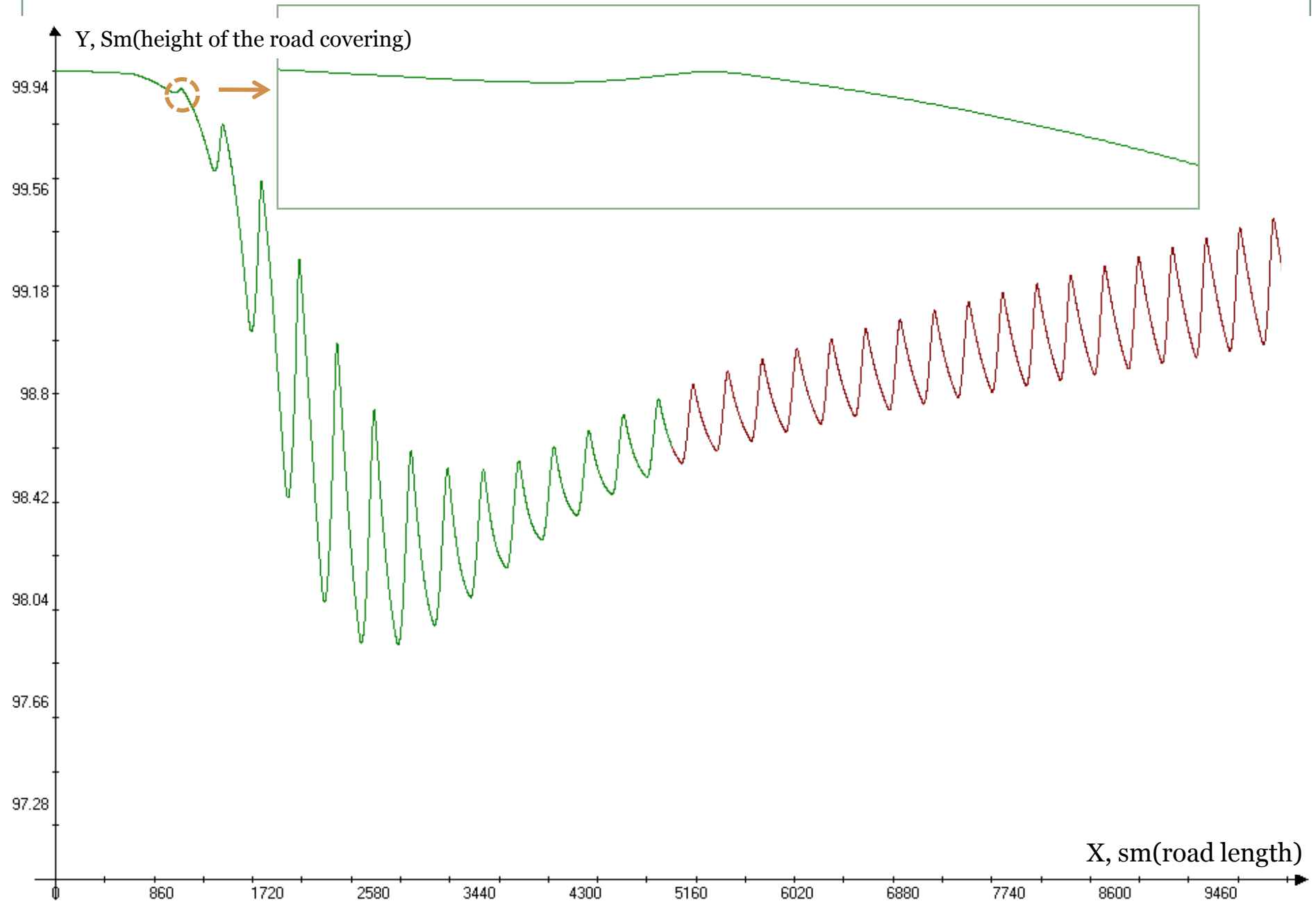
$$S = \frac{\pi D^2}{2}$$

$$D = 1{,}13\sqrt{\frac{mg}{1{,}2p}}$$

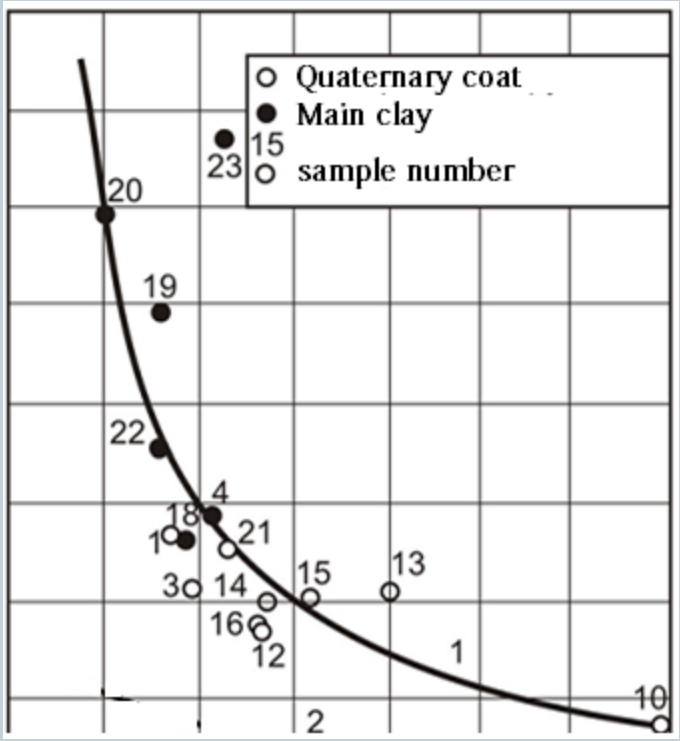
Coefficient depends on elastic of tire

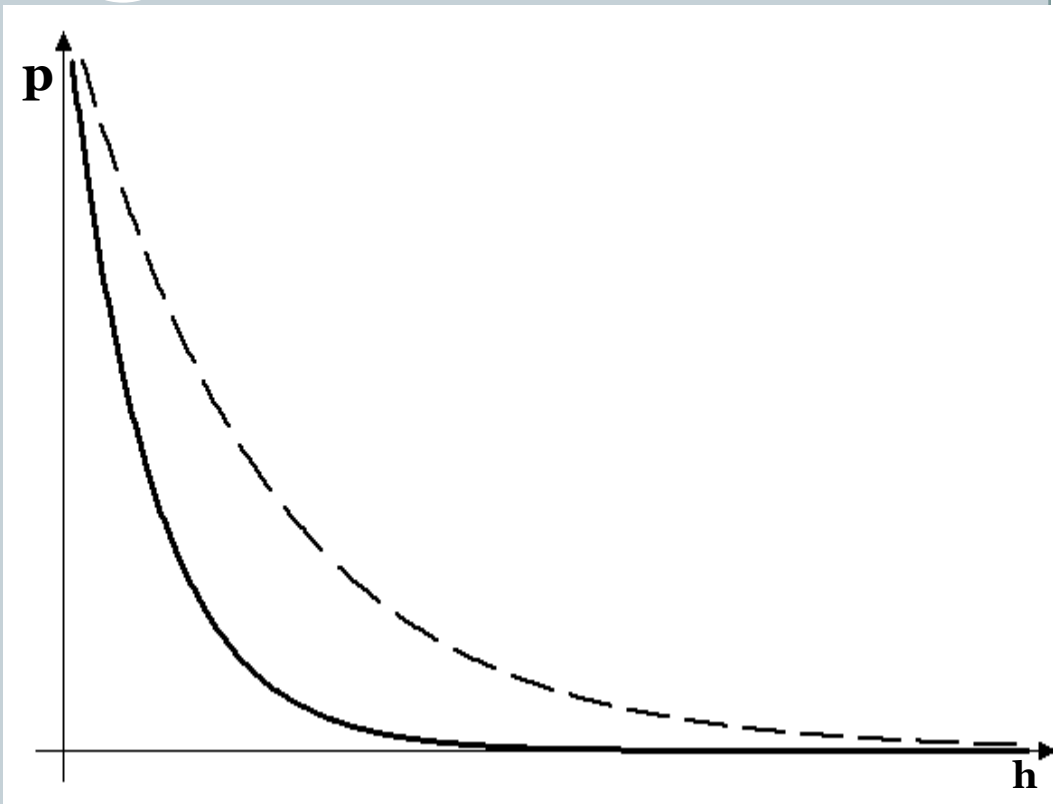
$$\vec{N}_i = \vec{P}_{\max} dS$$

P- pressure inside the tire


Y, Sm(height of the road covering)
99.94
99.56
99.18
98.8
98.42
98.04
97.66
97.28
X, sm(road length)
0
860
1720
2580
3440
4300
5160
6020
6880
7740
8600
9460

Sand compressibility





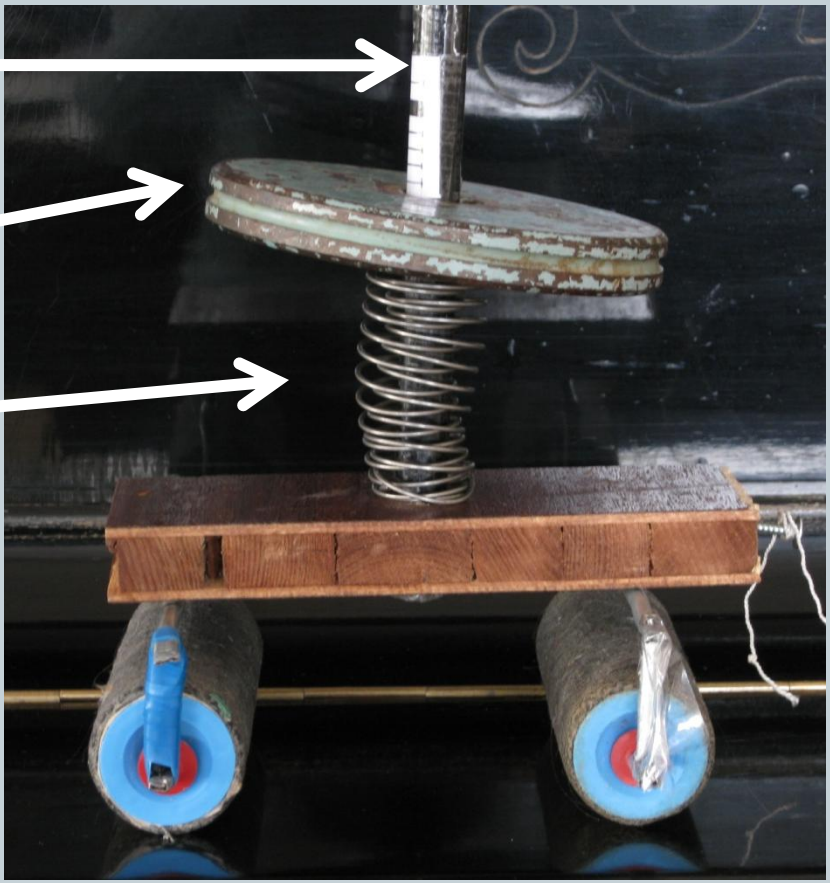
Life-model

Machine

Directrix

The cargo which weight exceeds the mass of all the other parts

Inflexible spring

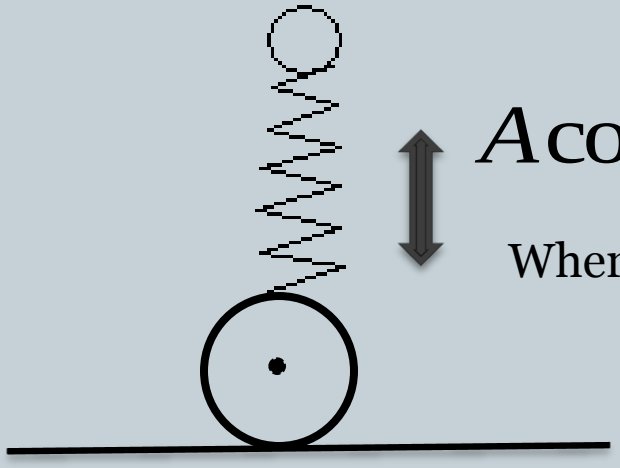


Corrugation received with the cargo with its wavelength corresponded to the results of the model

$$\lambda_{th} = 15{,}8sm$$

$$\lambda_{ex} = 16sm$$

Motor oscillations

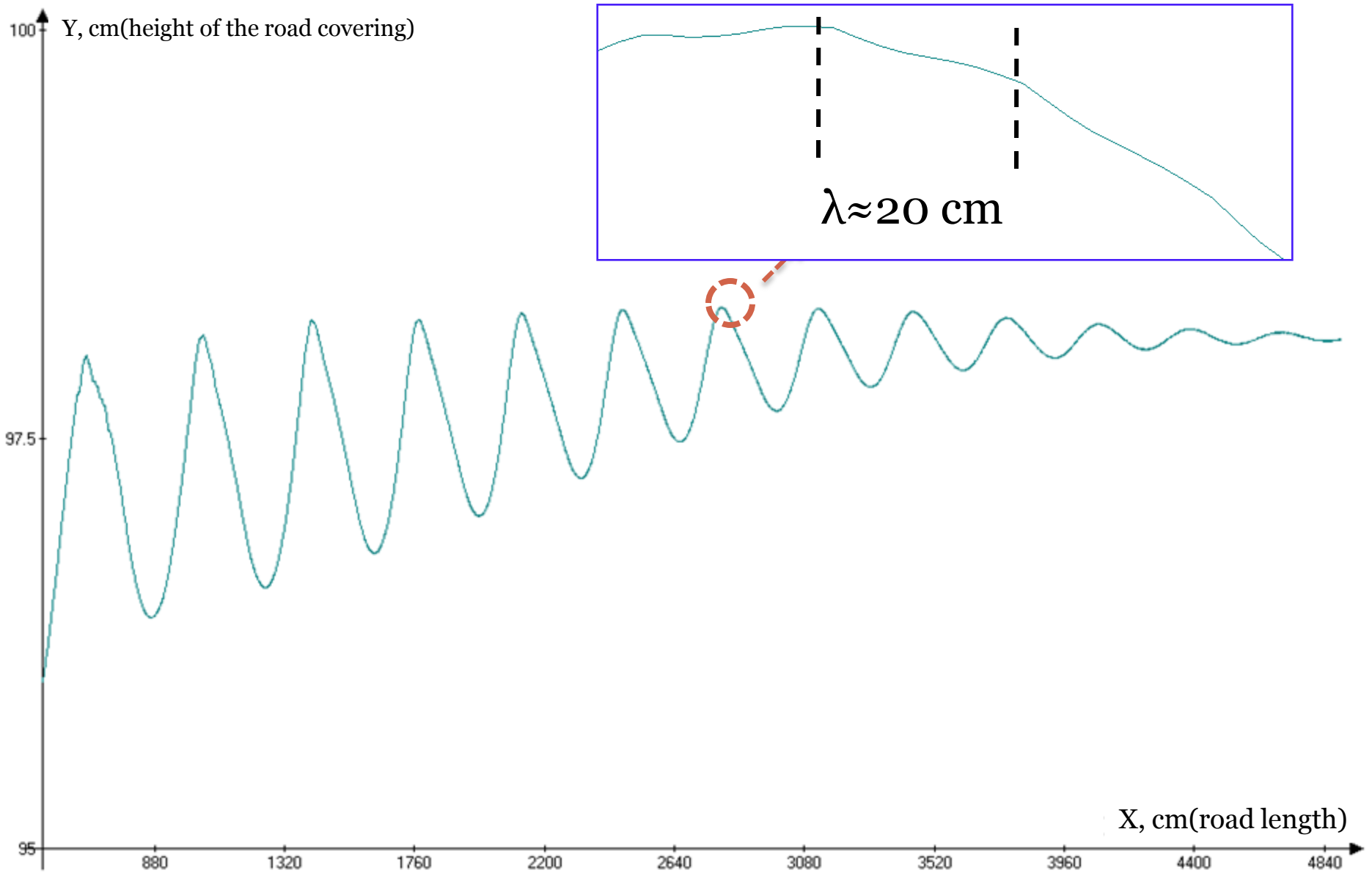


$$A\cos(wt) = A\cos(2\pi nt)$$

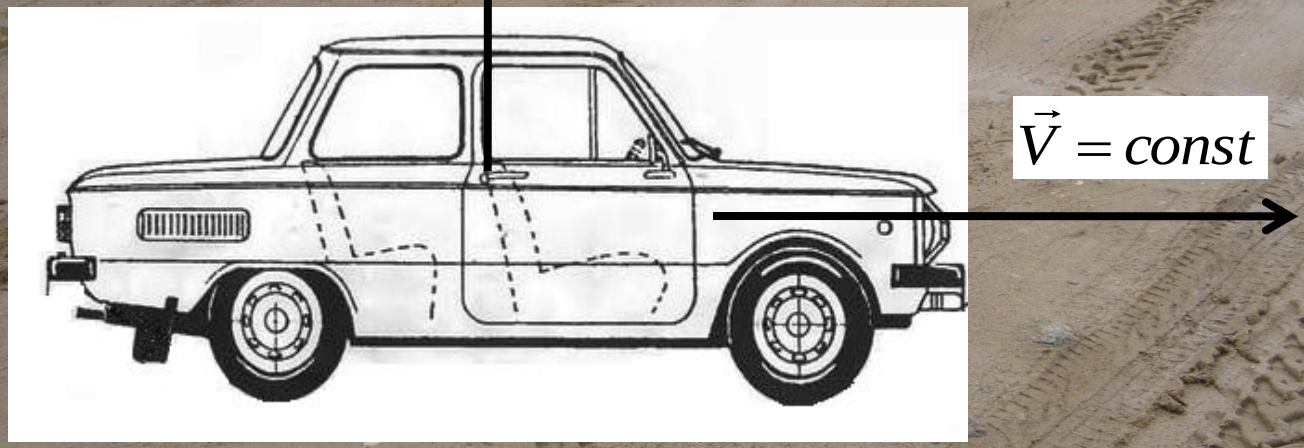
Where **n** - quantity of revolutions per second

$$N = k(l_0 - y) - mg + A\cos(2\pi nt)$$

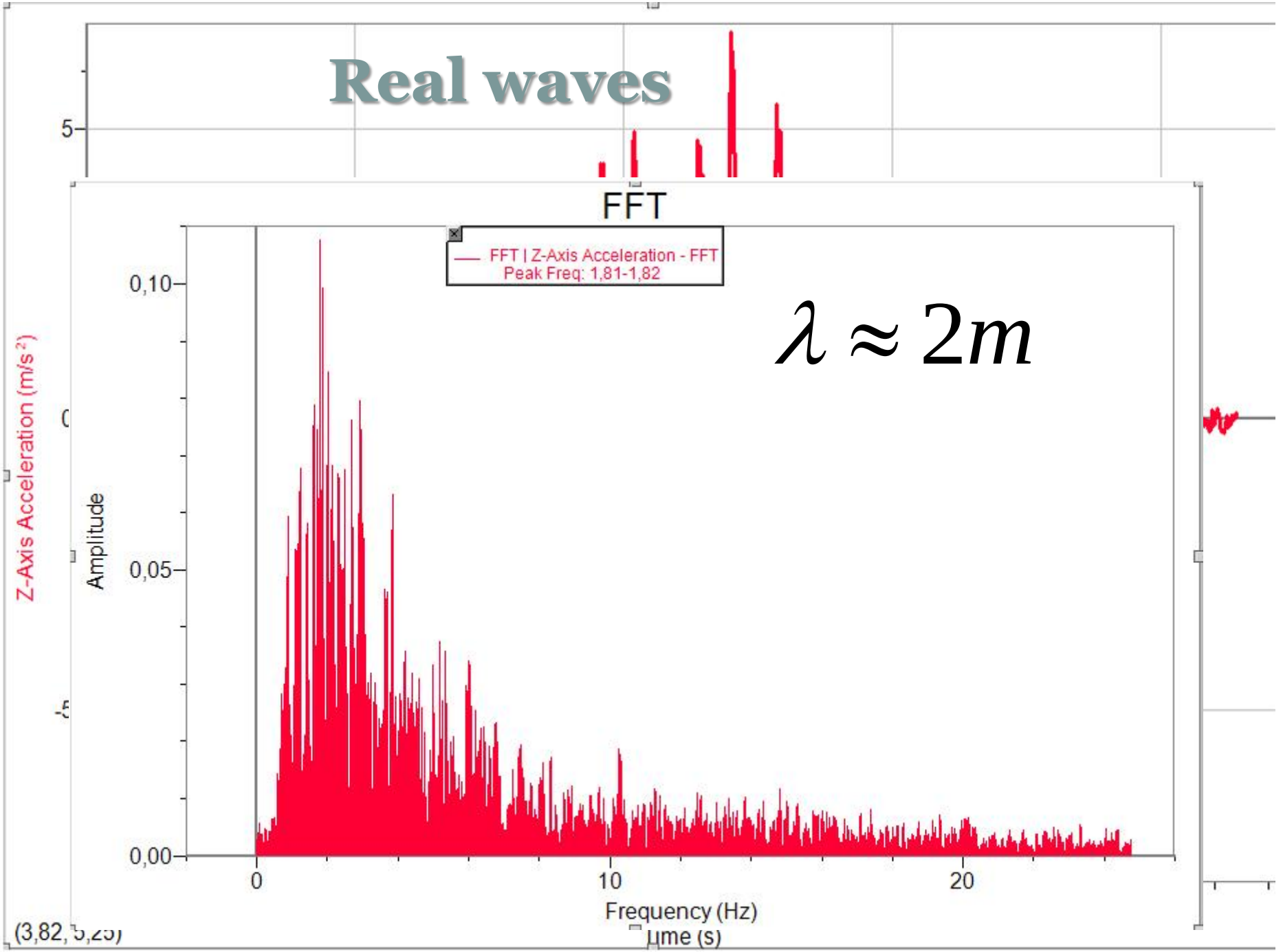
Motor oscillations



Real corrugation



Real waves

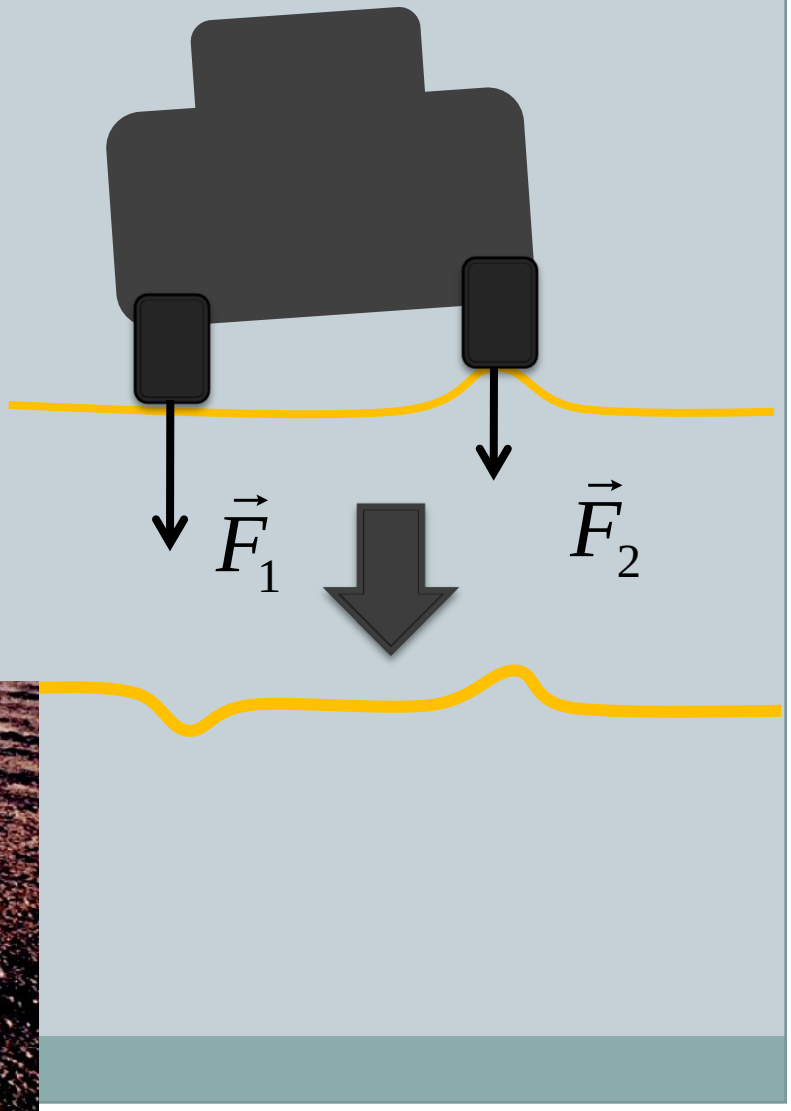


$$\lambda \approx 2m$$

Antiphase

$$\vec{F}_1 > \vec{F}_2; F_2 = \min \Rightarrow$$

$$h_1 = \max; h_2 = \min$$

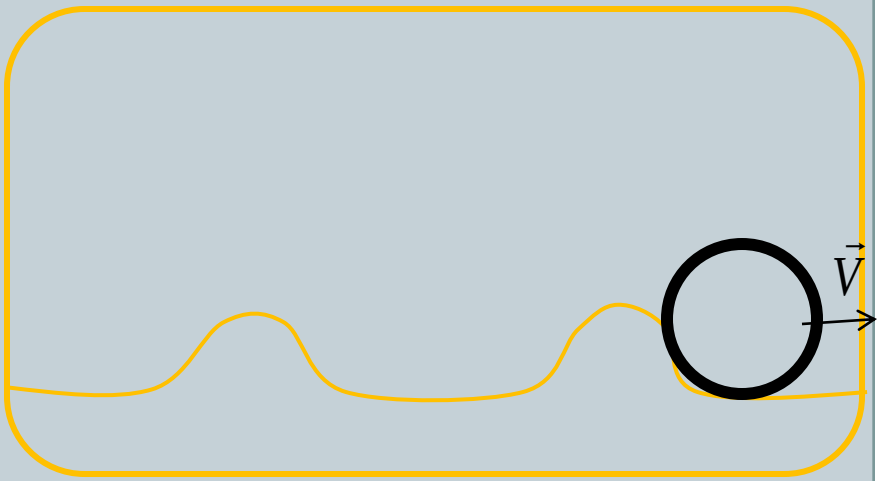


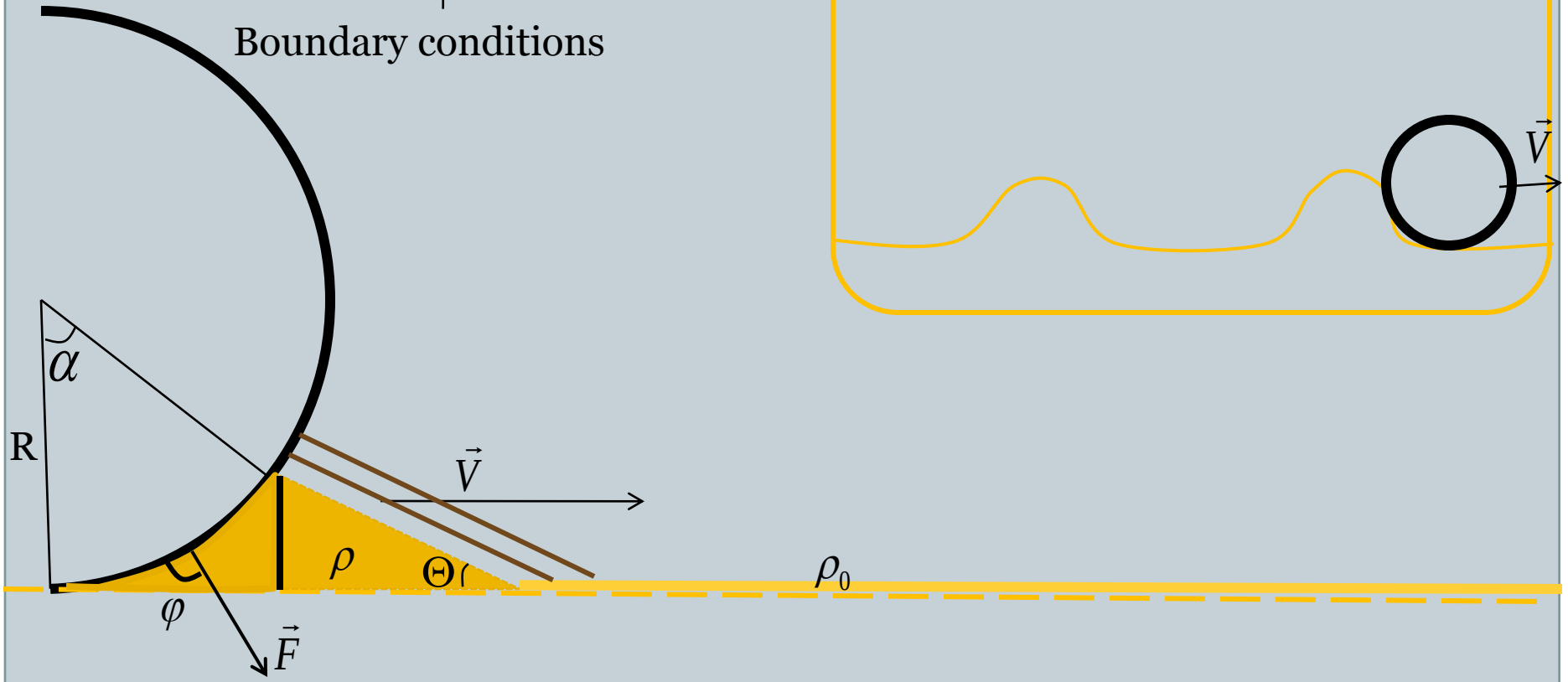
Part 2

Displacing theory

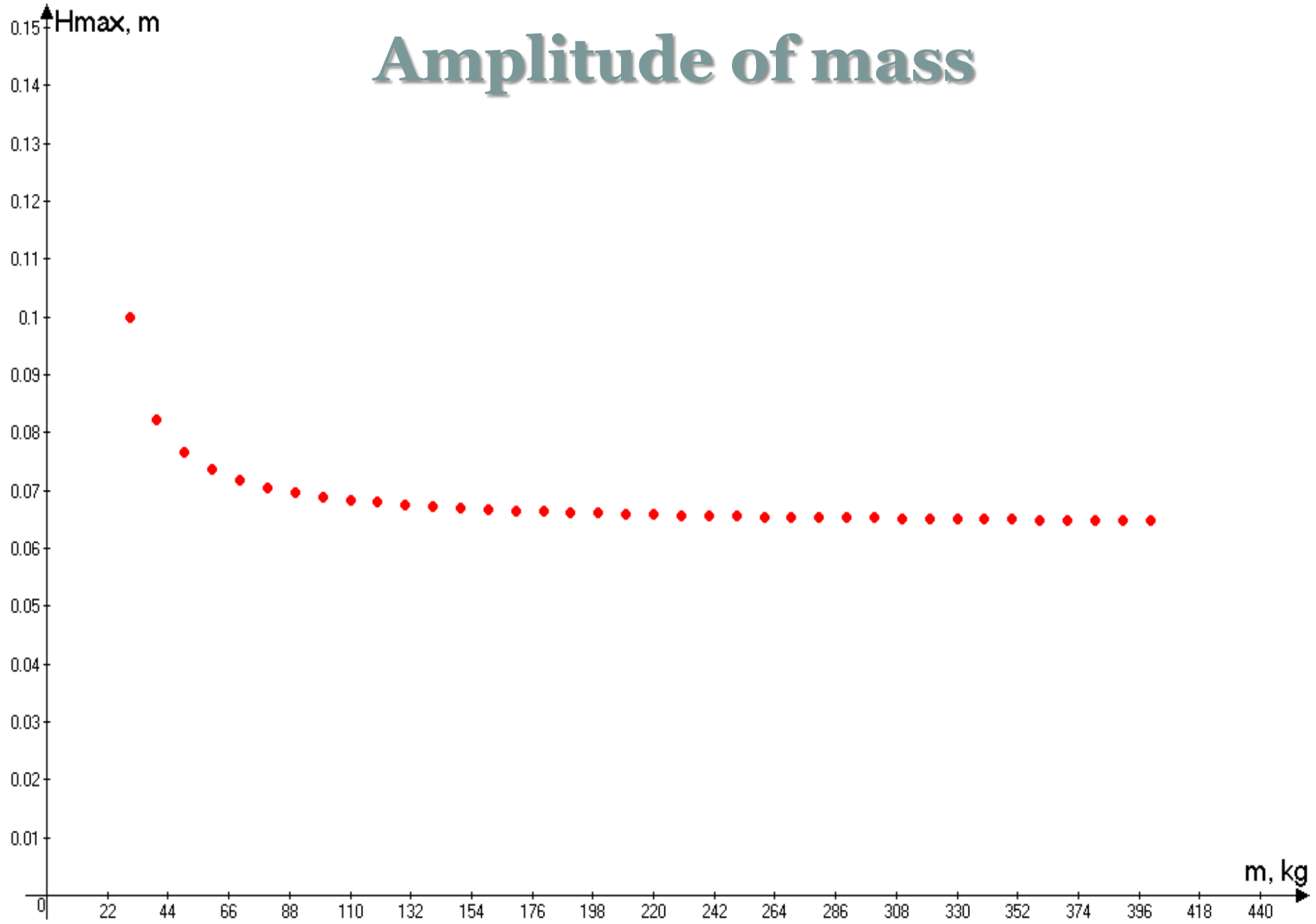
$$F \sin\varphi < \mu(M+m)g$$

Boundary conditions

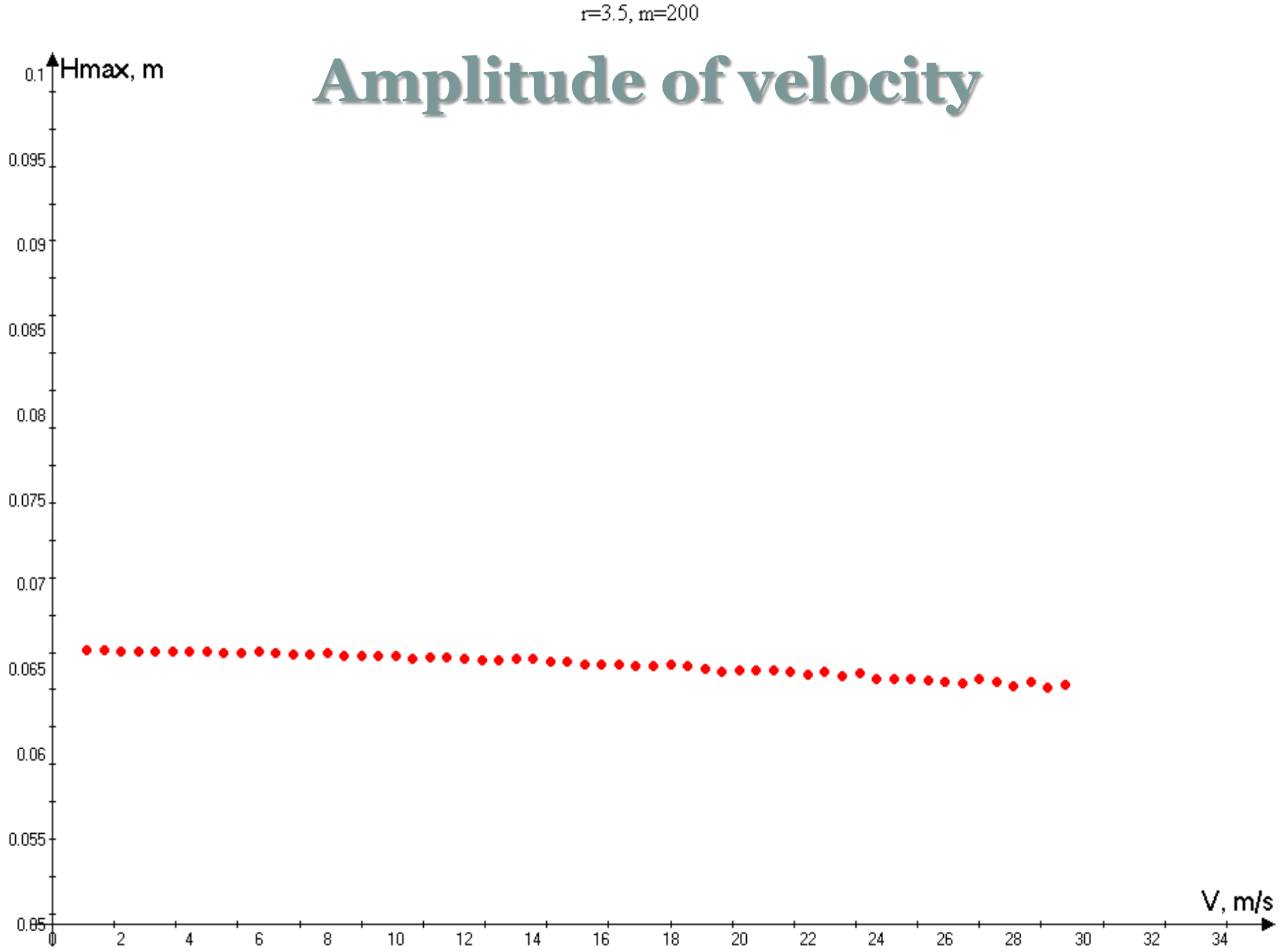




Amplitude of mass

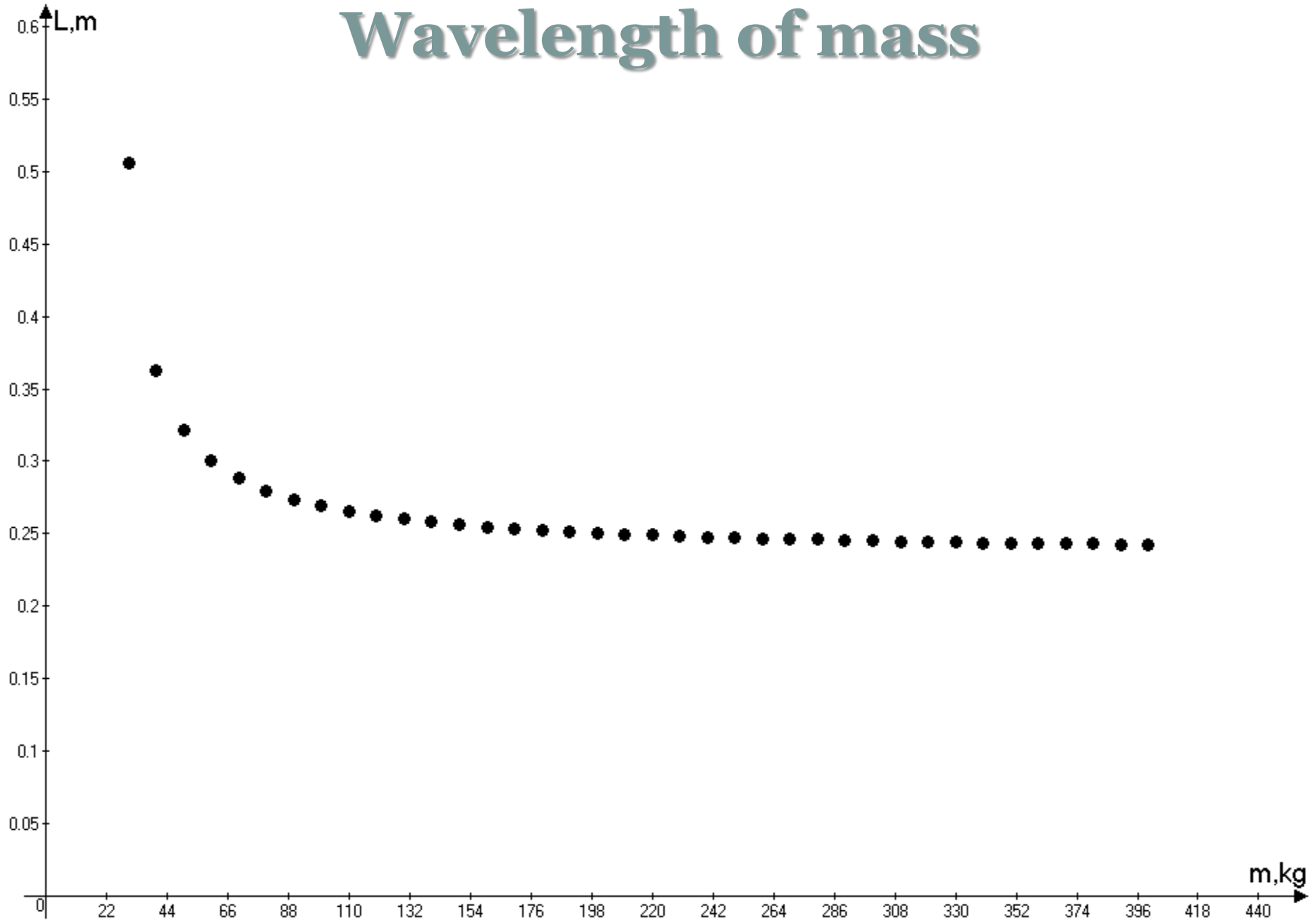


Amplitude of velocity

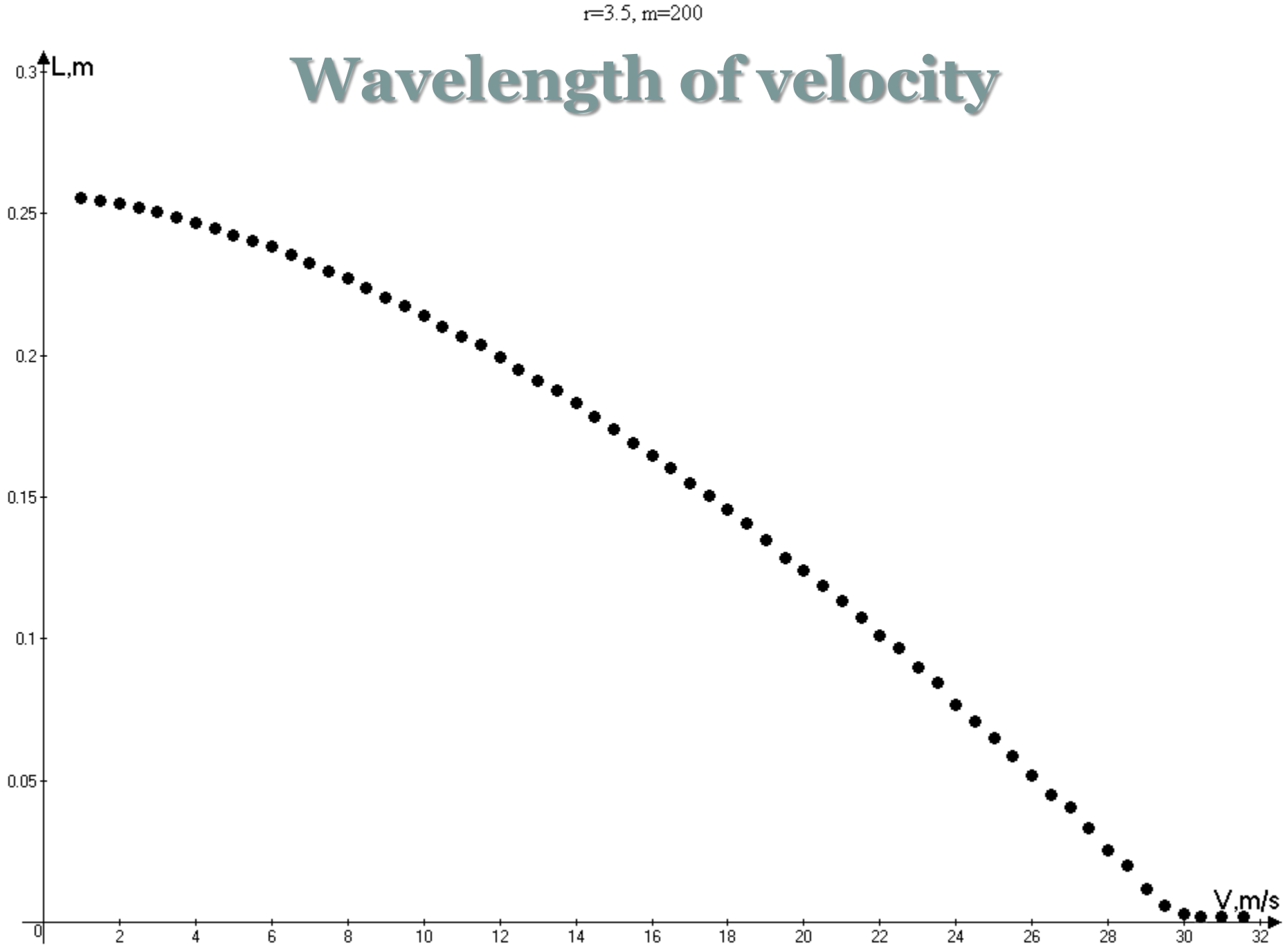


r=3.5, v=3

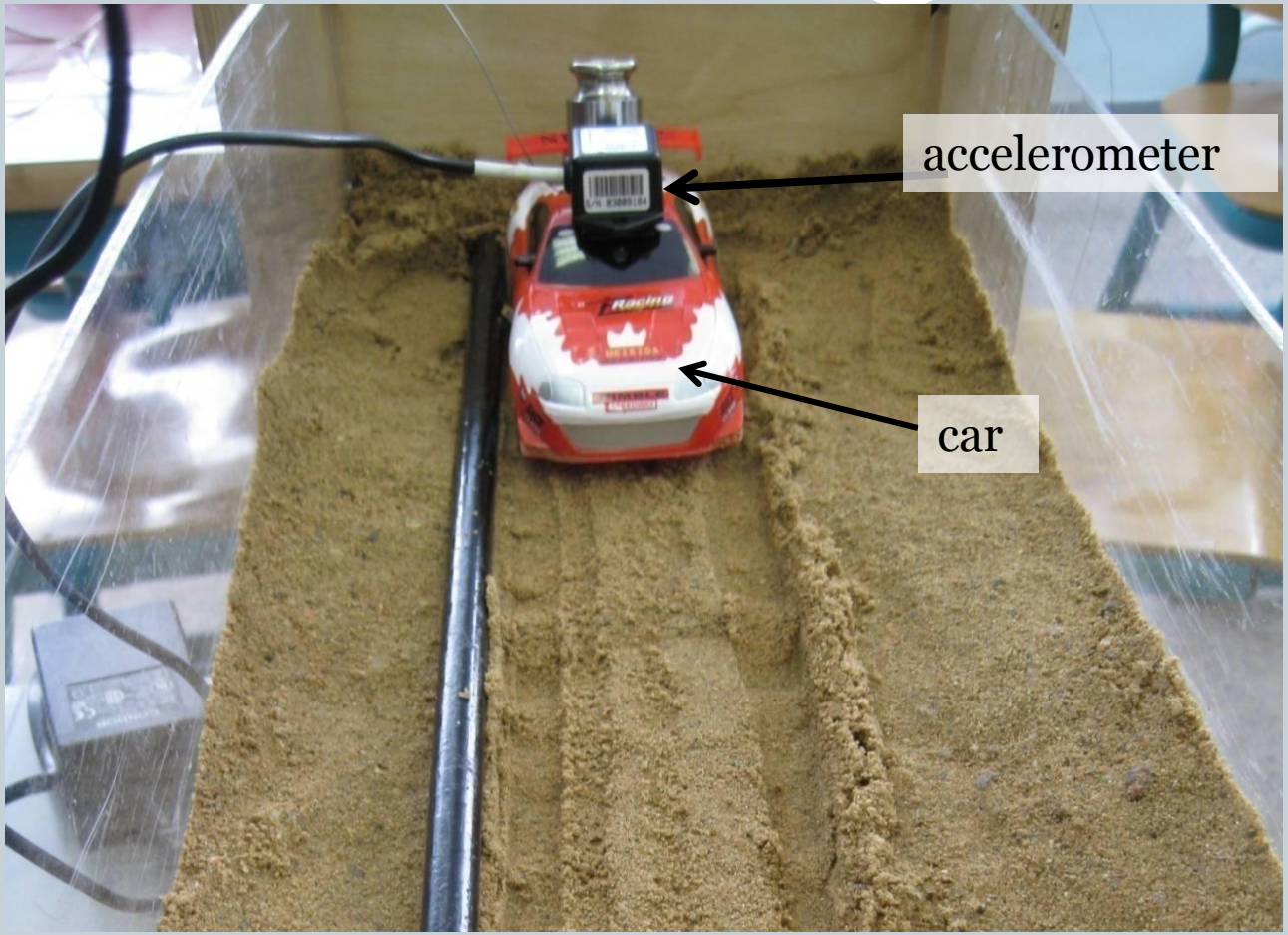
Wavelength of mass



Wavelength of velocity



Model



Car without fluctuations.

Its velocity is a constant.

$$\lambda_{th} = 36mm$$

$$\lambda_{ex} = 35mm$$

O

10

20

30

40

50

60

70

80

90

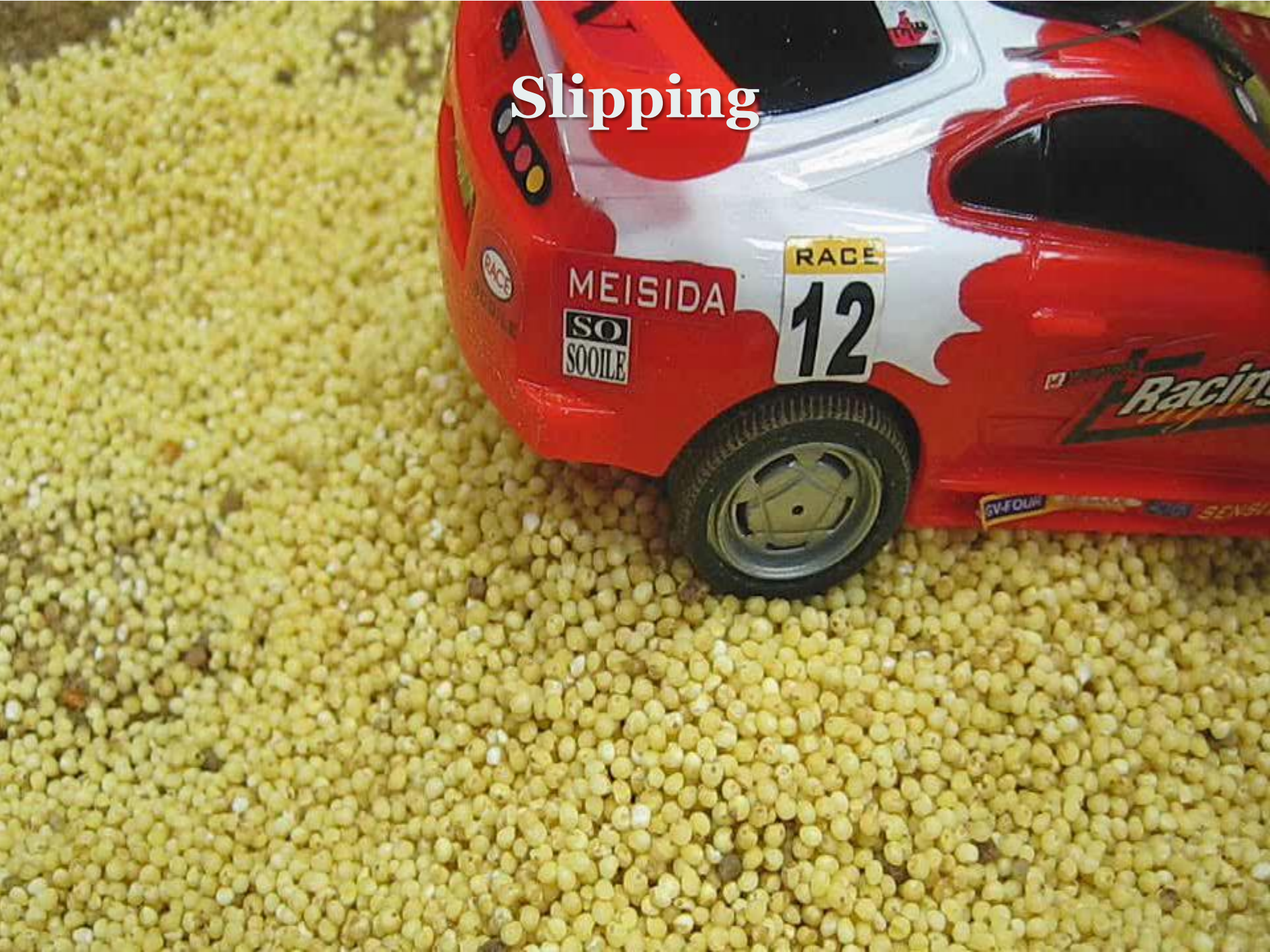
Theory prove

Part 3

Characteristics of the precoat

- Size of grains of precoat
- Precoat viscosity
- Constant of friction between grains and between grain and wheel

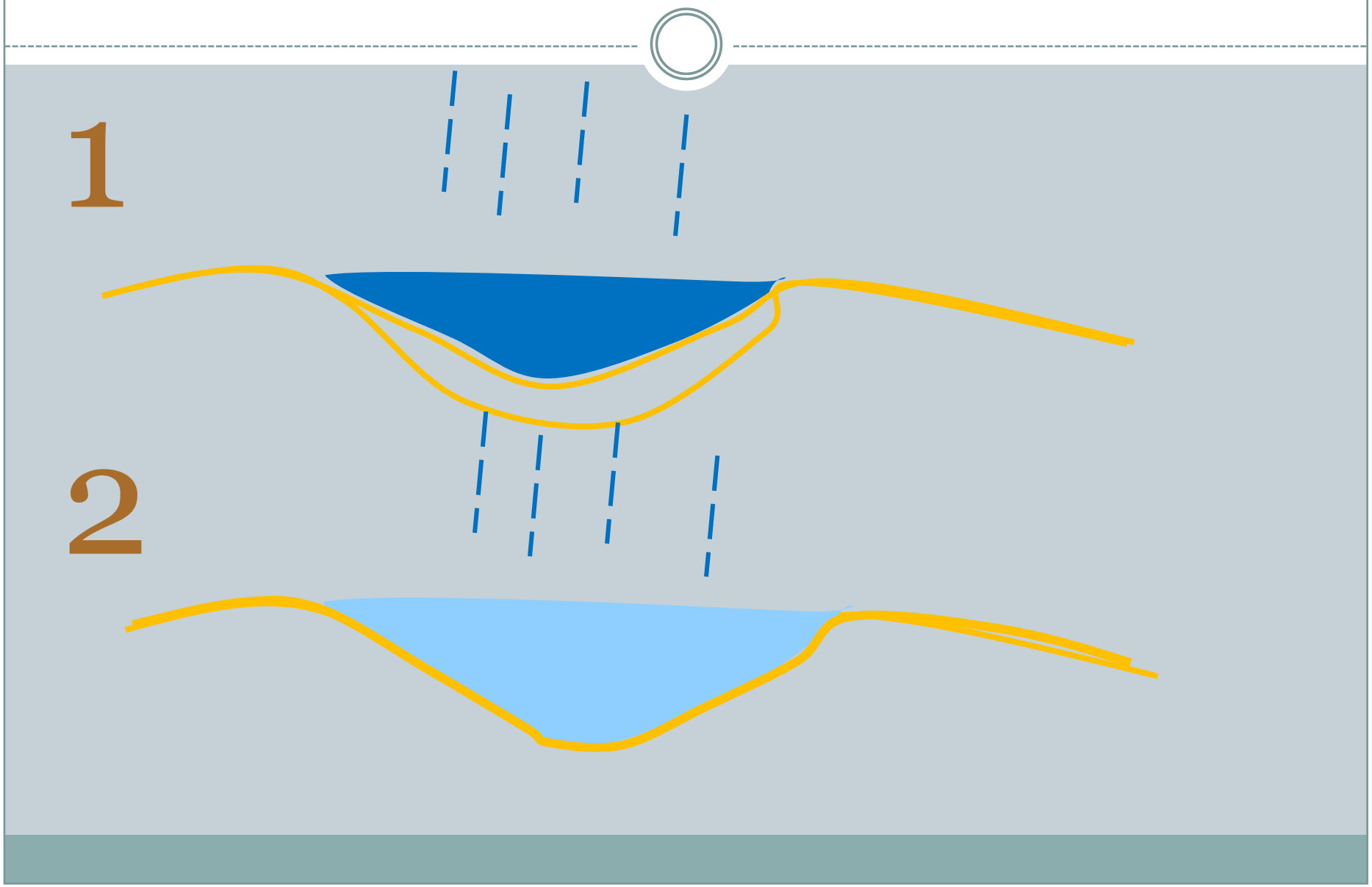
Slipping



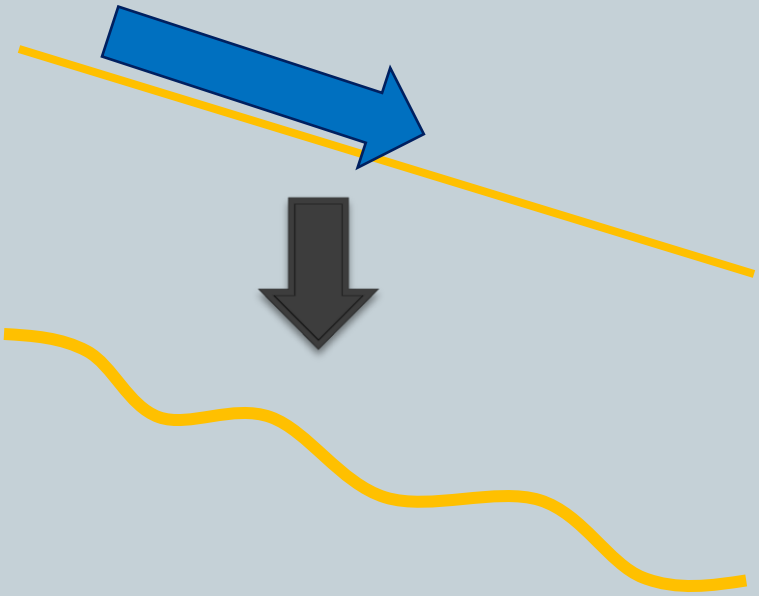
Part 4

Weather effects

- But the biggest part of roads consist both fluctuations effect and displacing of ground and there are no same periods and amplitudes because of weather effects.


1
2

Road blurring



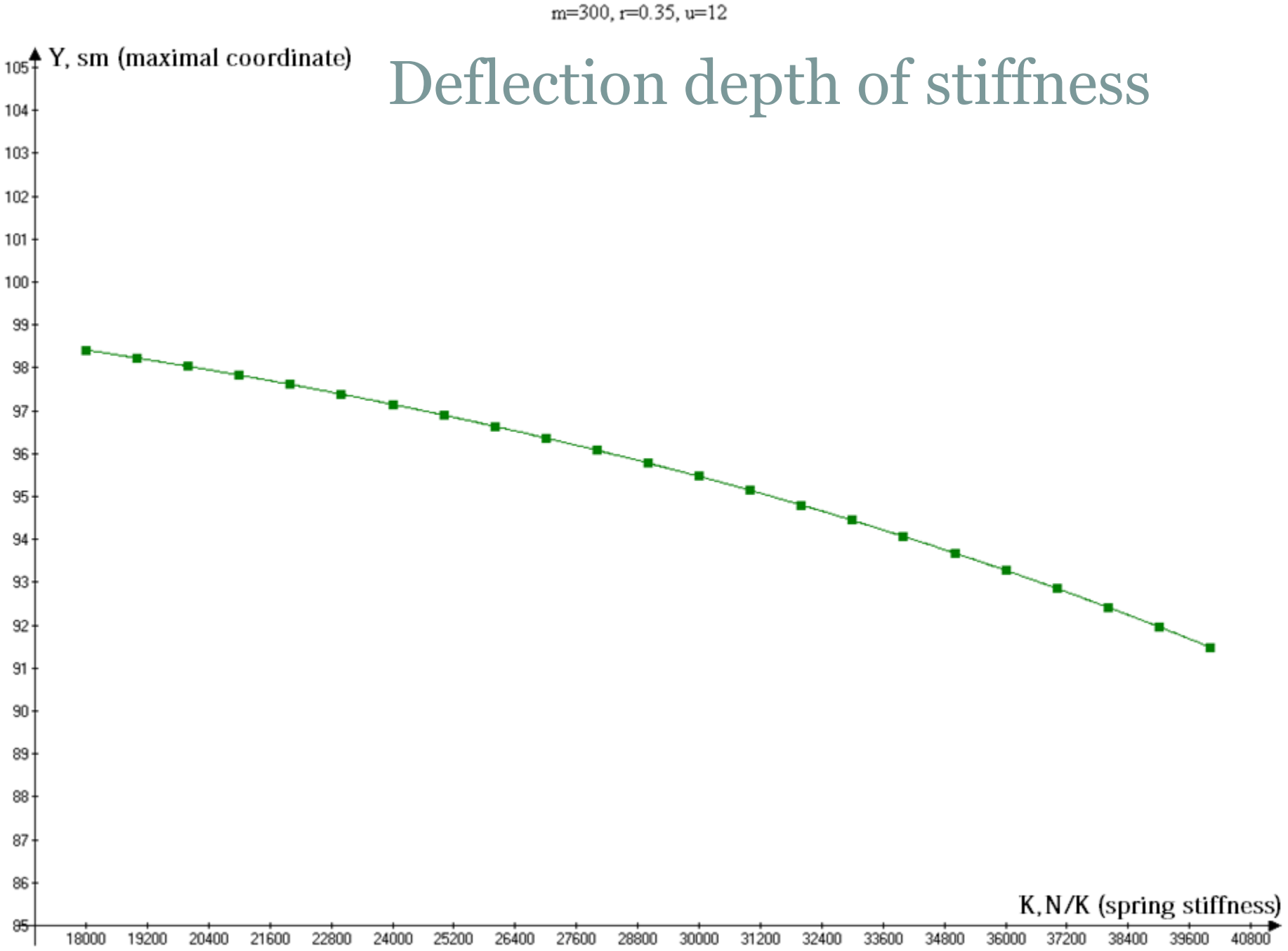
Conclusions

- The cars are capable to form irregularities such as roughness and microwaves.
- There are 3 main reasons of corrugation appearing on the road: oscillations of softener (2,5 – 4 m), precoat displacing by wheels (0,3 – 1,5 m), weather effects(increase both previous).
- The wavelength and amplitude of microwaves depend on inflexibility of the spring, mass of the car and its speed, geometrical parameters of the wheel and different parameters of precoat.
- Motor fluctuations of the car can also make corrugation with short length and amplitude: roughness length decreases with increasing oscillation frequency of the car motor and decreases with increasing speed of the car.
- Corrugation with wavelength is more than 100 m can not be explained by the influence of passing cars.

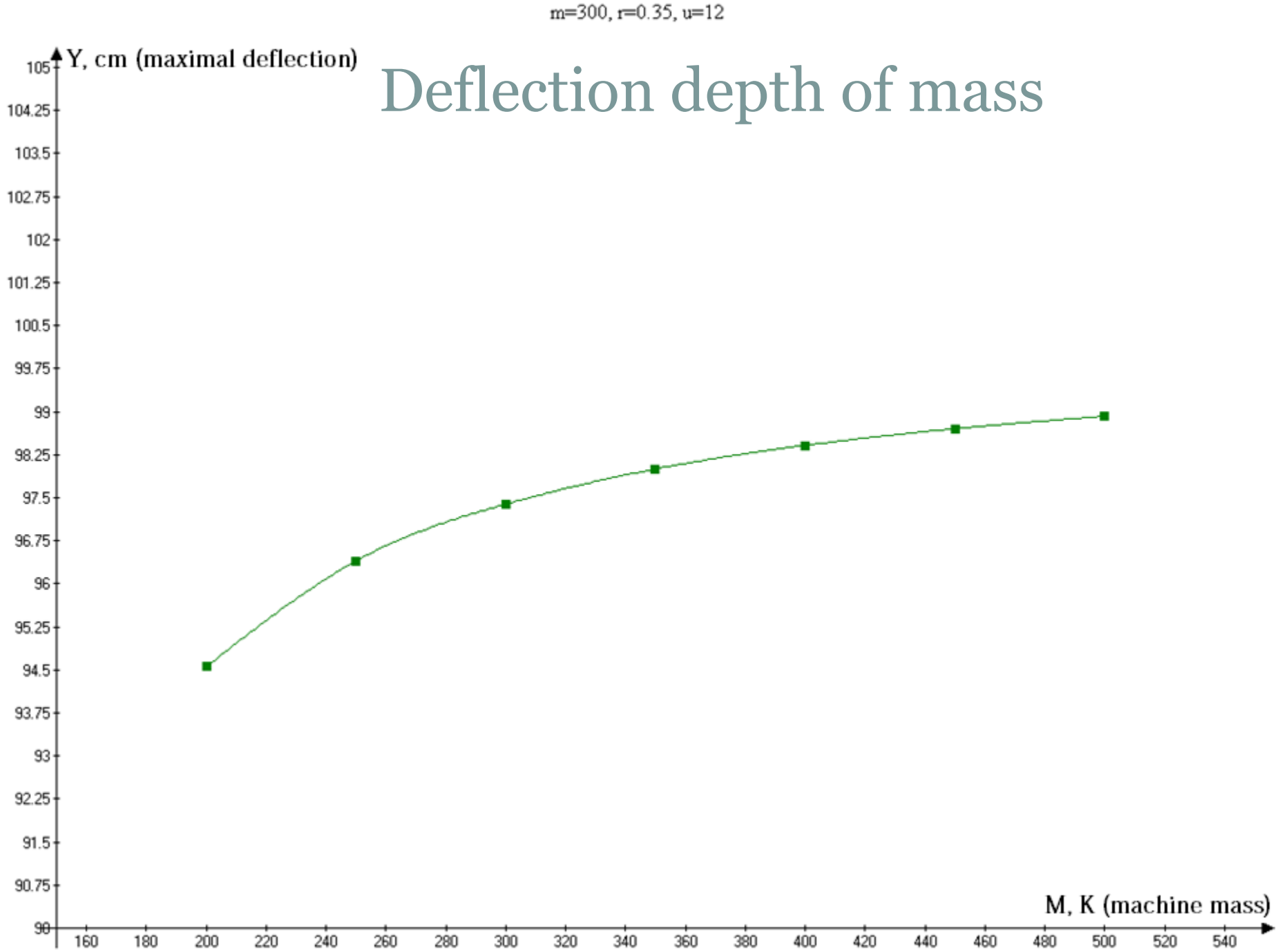
Thank you for your attention

BY THE
BELARUS TEAM

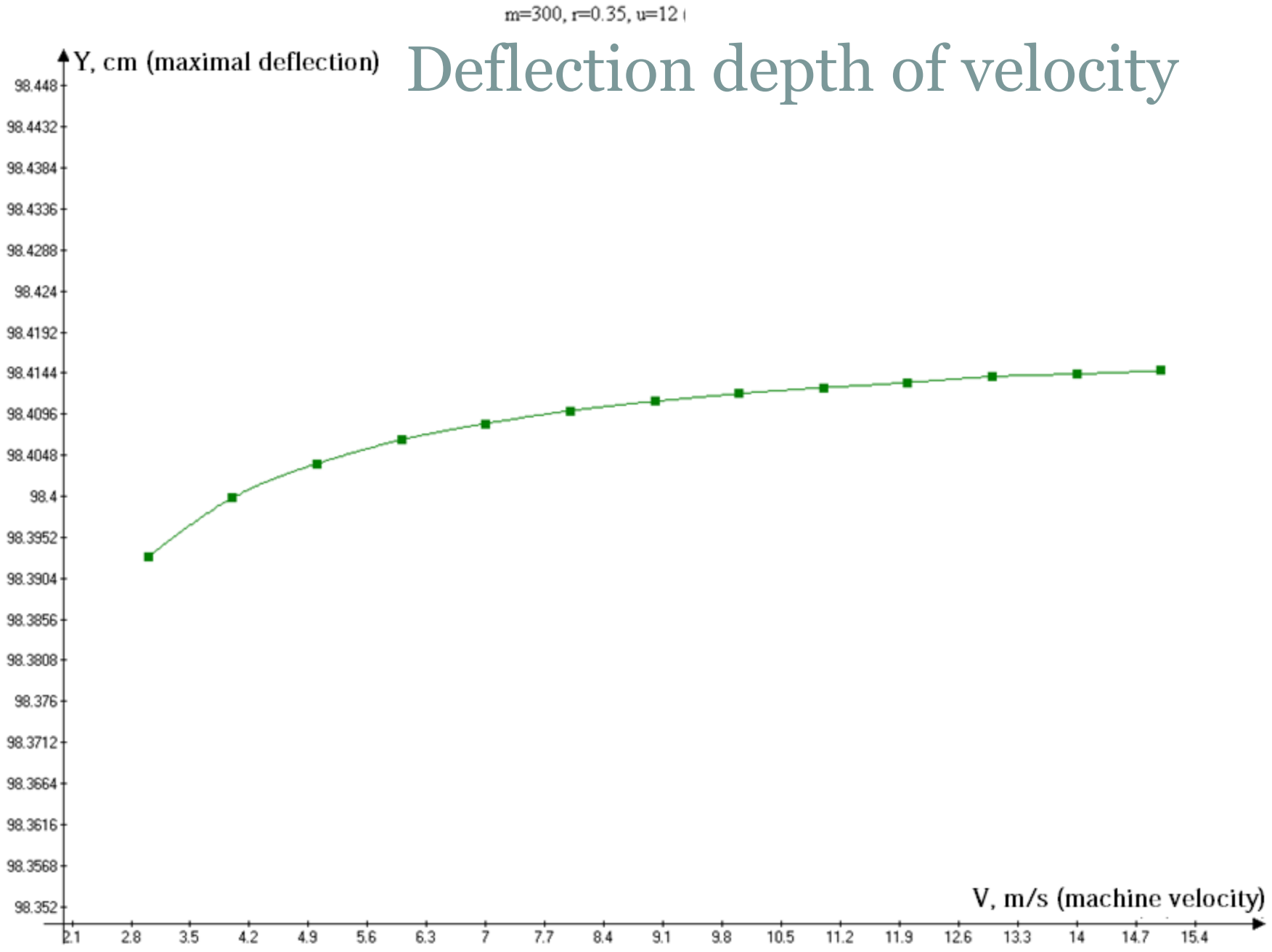
Deflection depth of stiffness



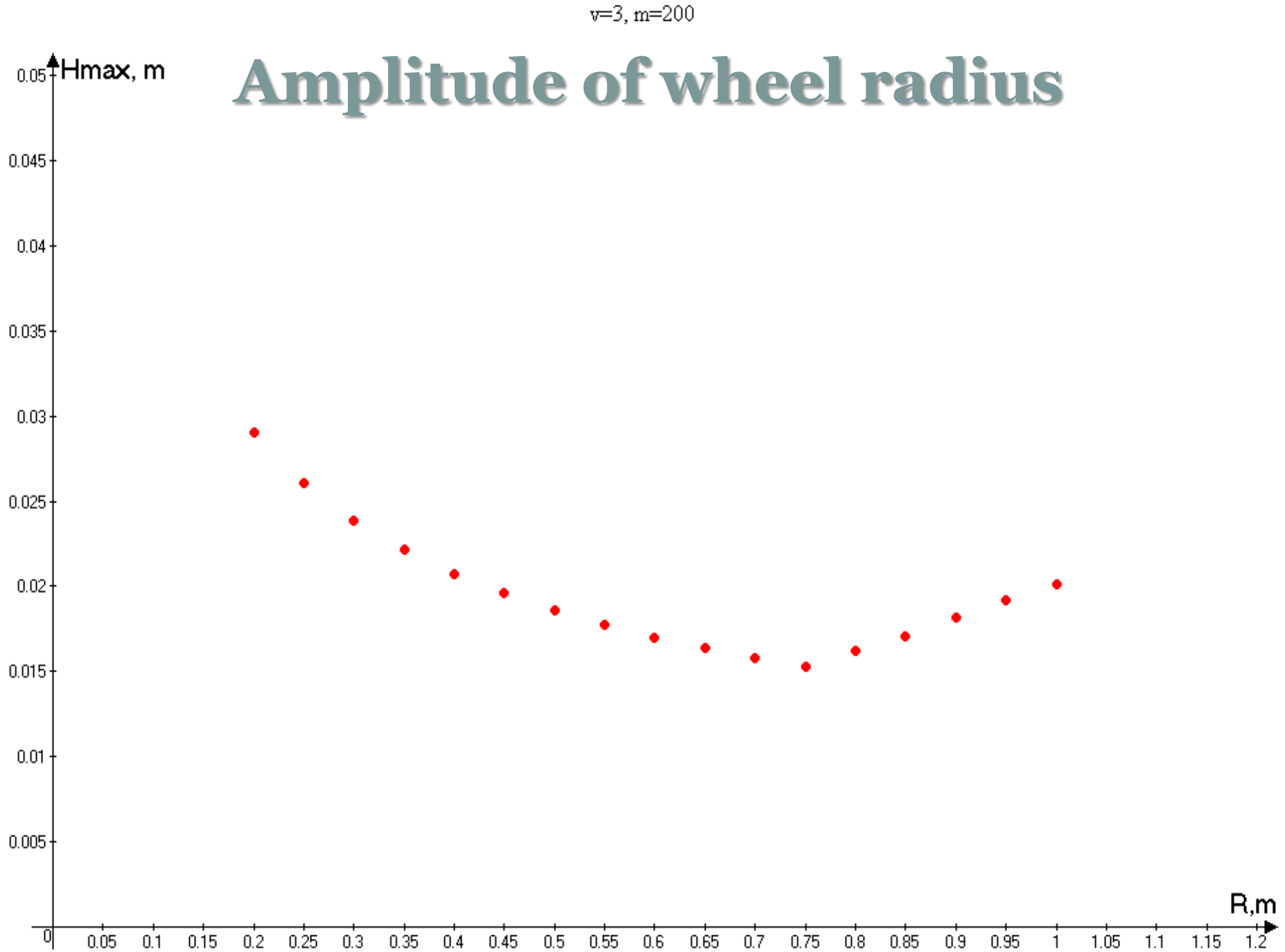
Deflection depth of mass



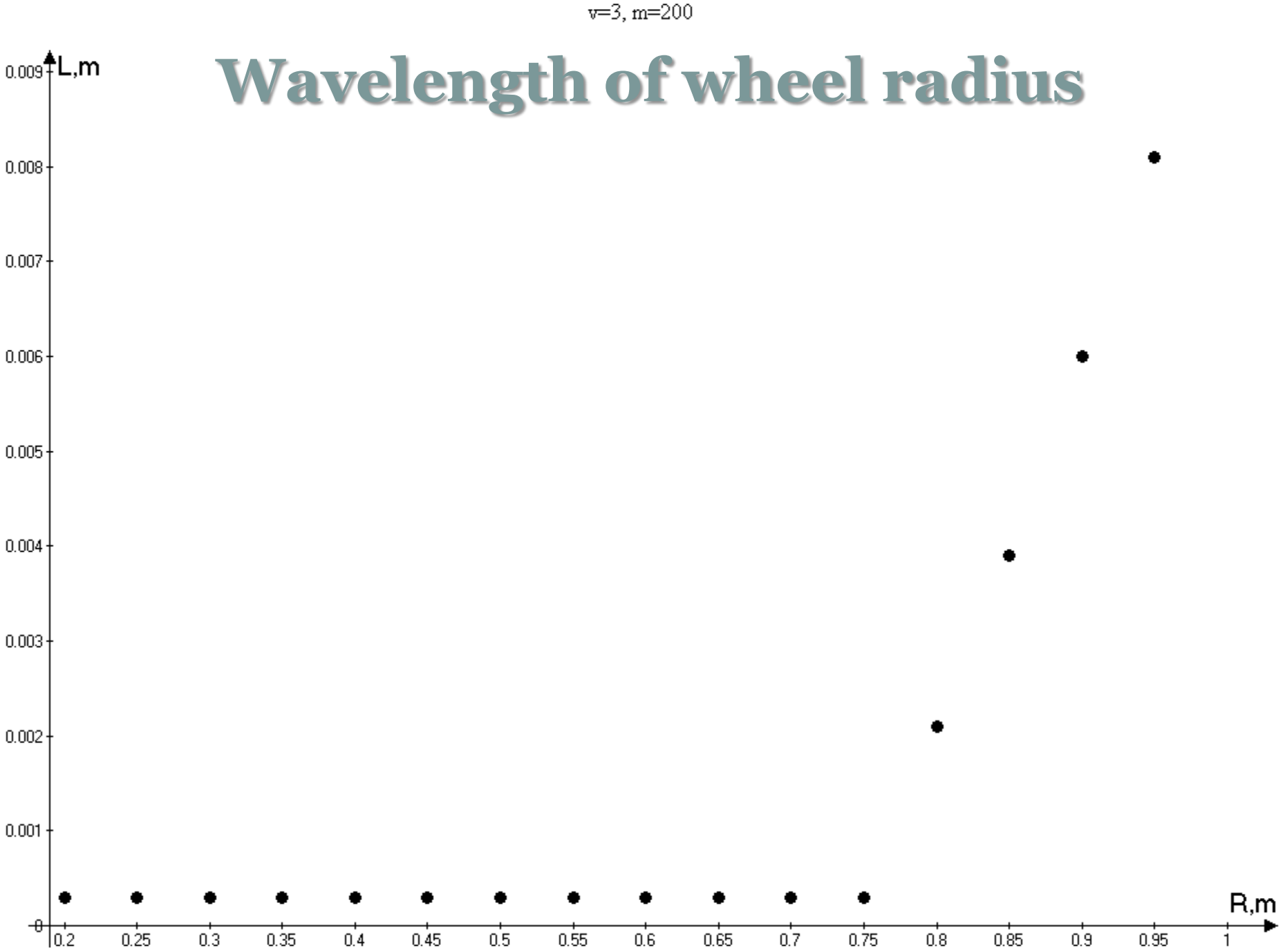
Deflection depth of velocity



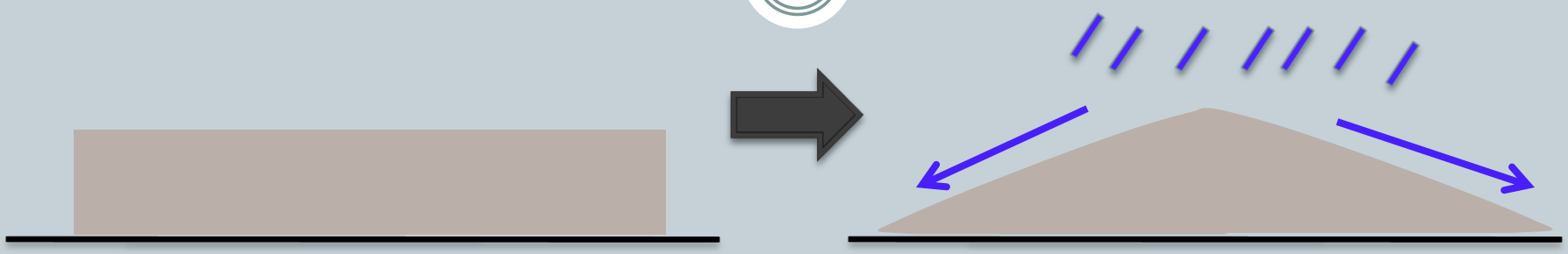
Amplitude of wheel radius

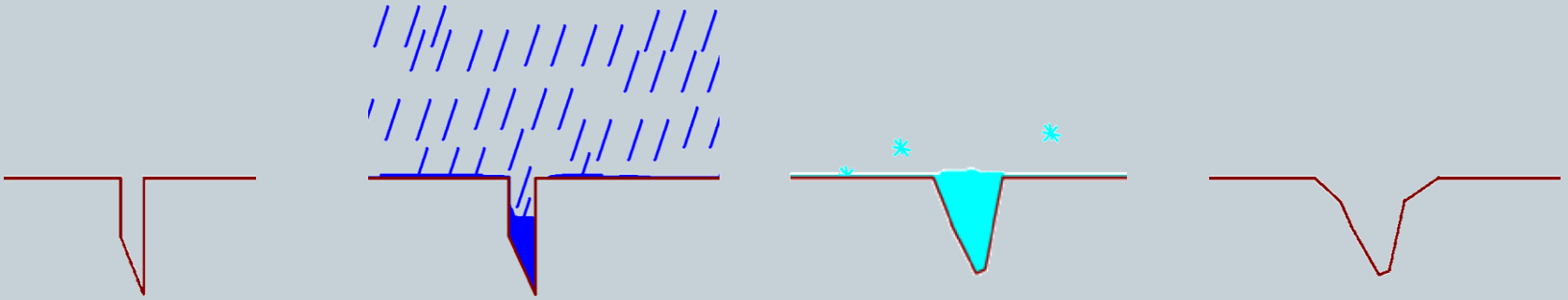


Wavelength of wheel radius



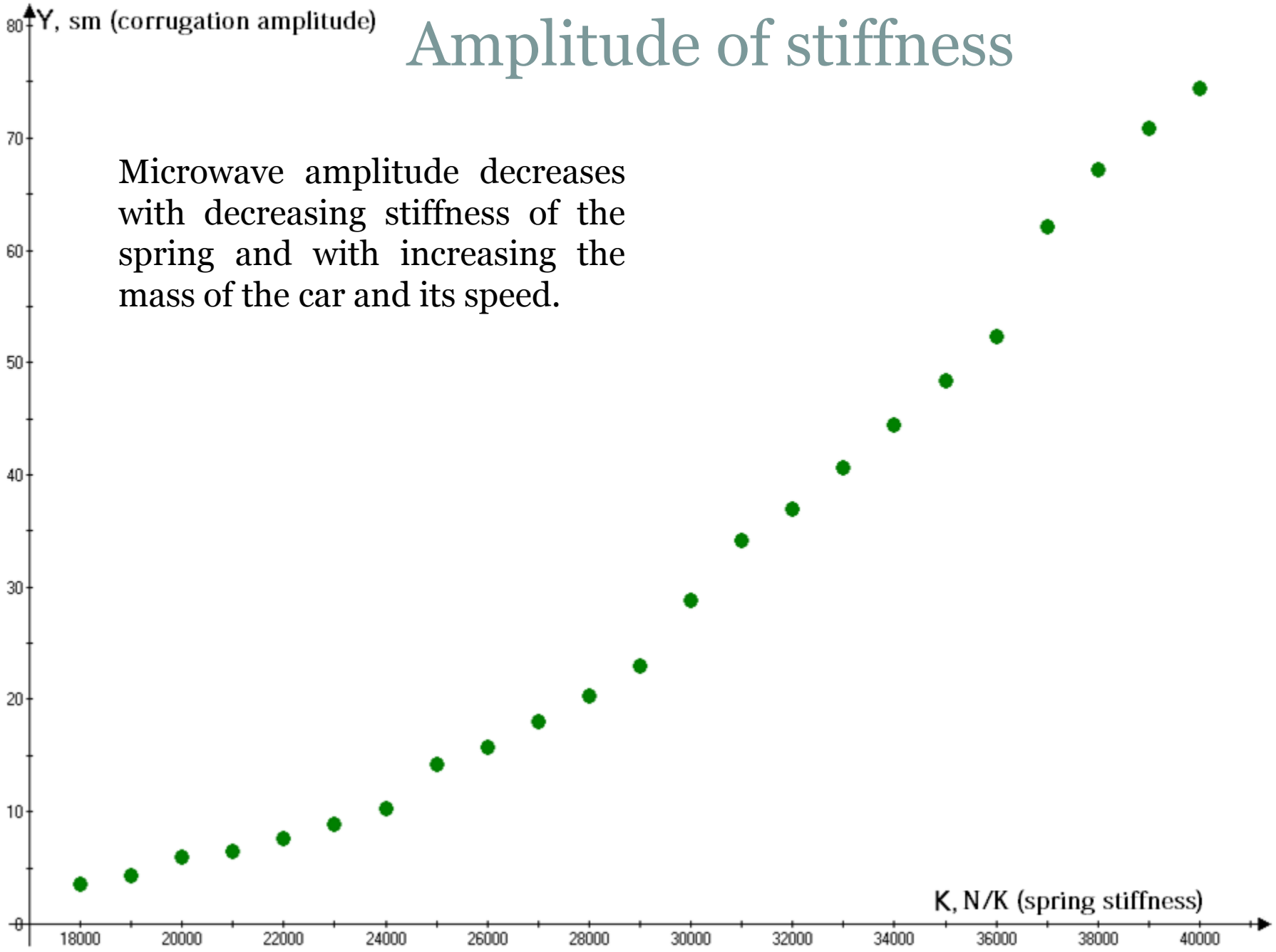
Road blurring



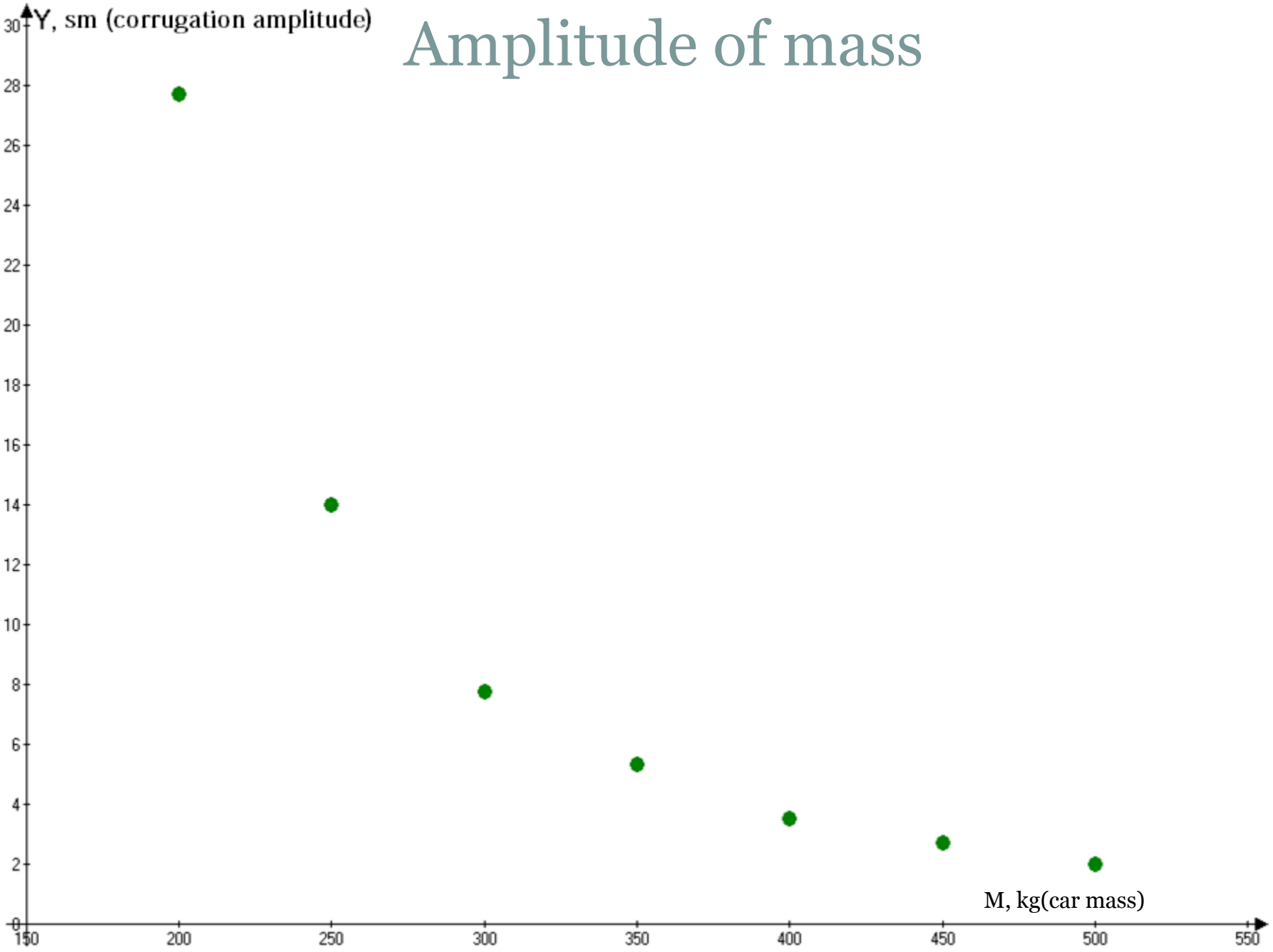


Amplitude of stiffness

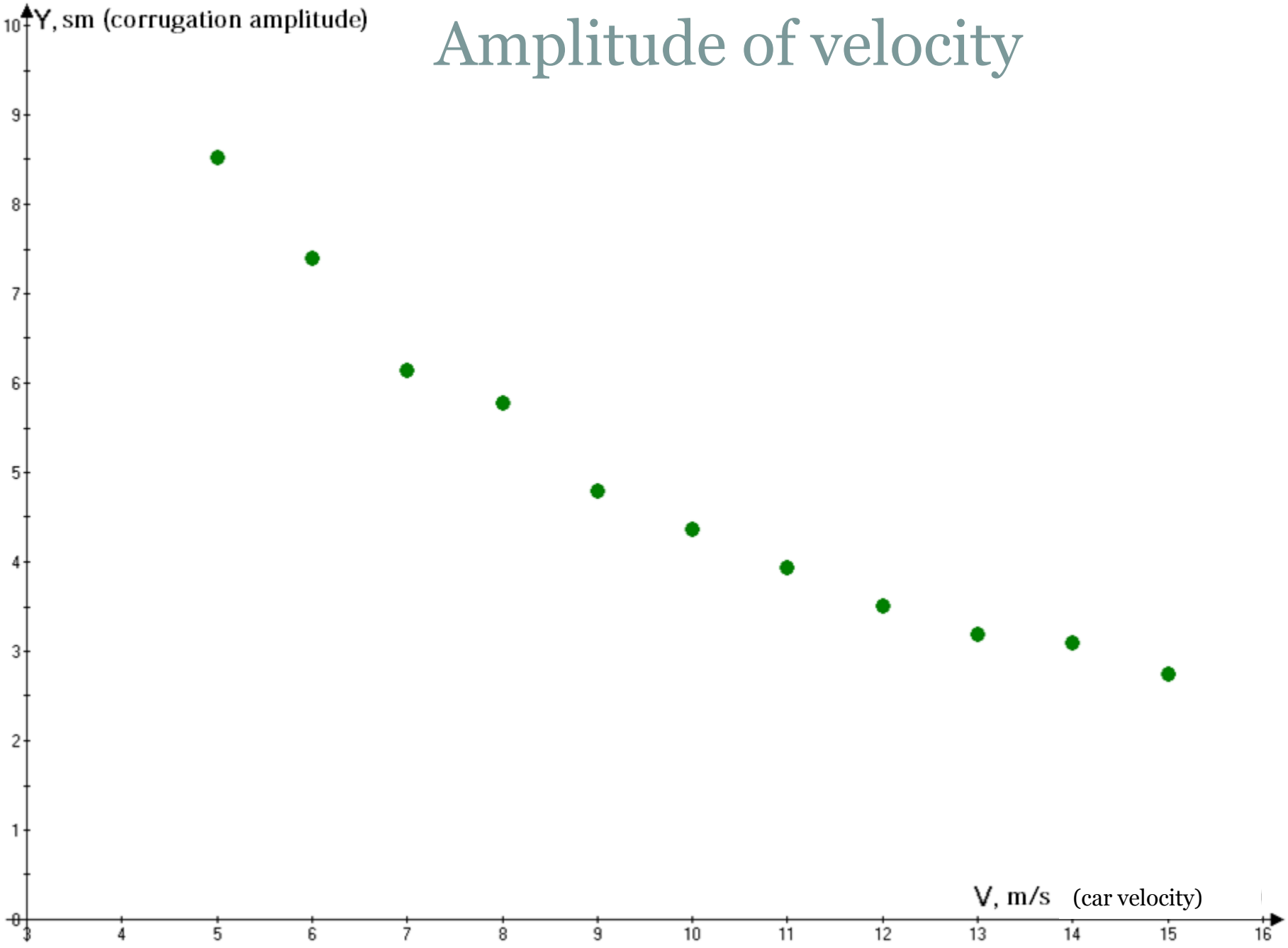
Microwave amplitude decreases with decreasing stiffness of the spring and with increasing the mass of the car and its speed.



Amplitude of mass



Amplitude of velocity



- The wavelength of microwaves increases with decreasing inflexibility of the spring and with increasing the mass of the car and its speed.