Hard Starch

Problem 13.



Introduction

- Work devided in four steps
- Achiveing effect
- Necessary equipment construction
- Measurement
- Theoretical model development

What is corn starch ?





- Average particle radius is 3 *10^{-4} m
- It is not a corn flower !!

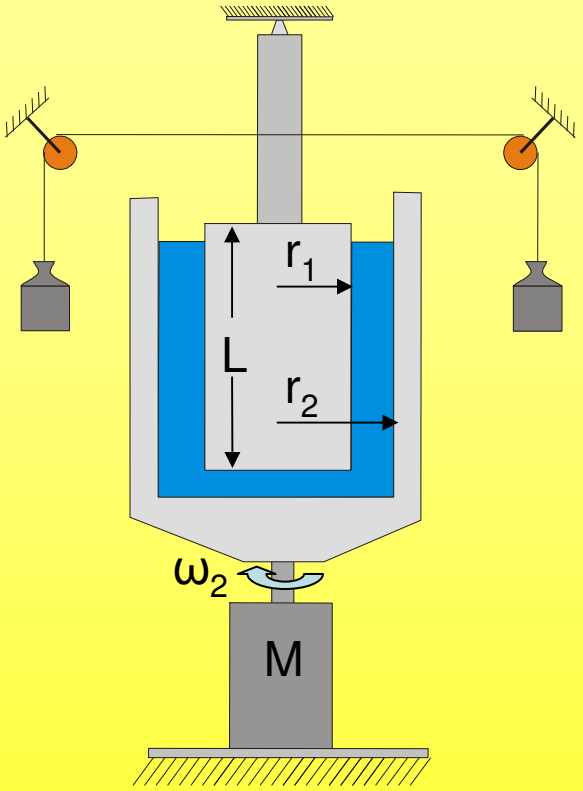
Achiveing effect “slowly”



Achiveing effect “fast”



Rotational viscometer



- For rotational viscometer we have :

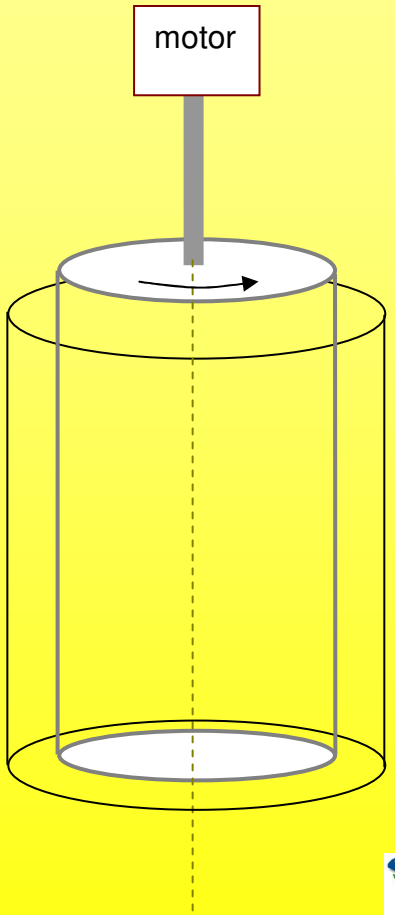
$$\eta = \frac{M}{4\pi\omega_2 L}\frac{r_2^2 - r_1^2}{(r_1 r_2)^2} \Rightarrow \eta \propto M$$

Breznišćak mjerenje i računanje 1966

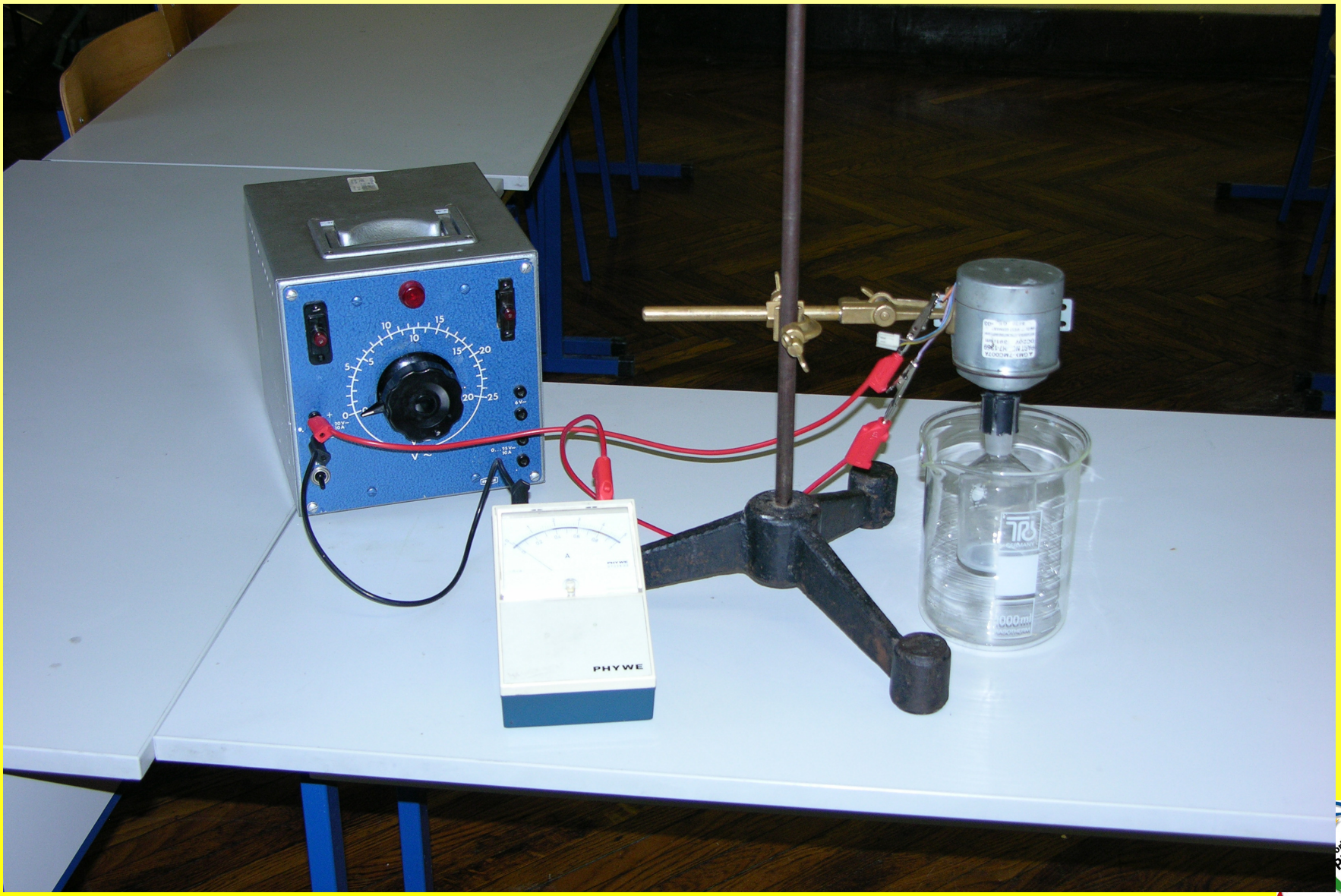
Our rotational viscosimeter

- It is different from standard
- Cylinder is rotating
- Current is linear to torque
- Measurement accuracy 10^{-2}A
- Max. Velocity 0.628 m/s

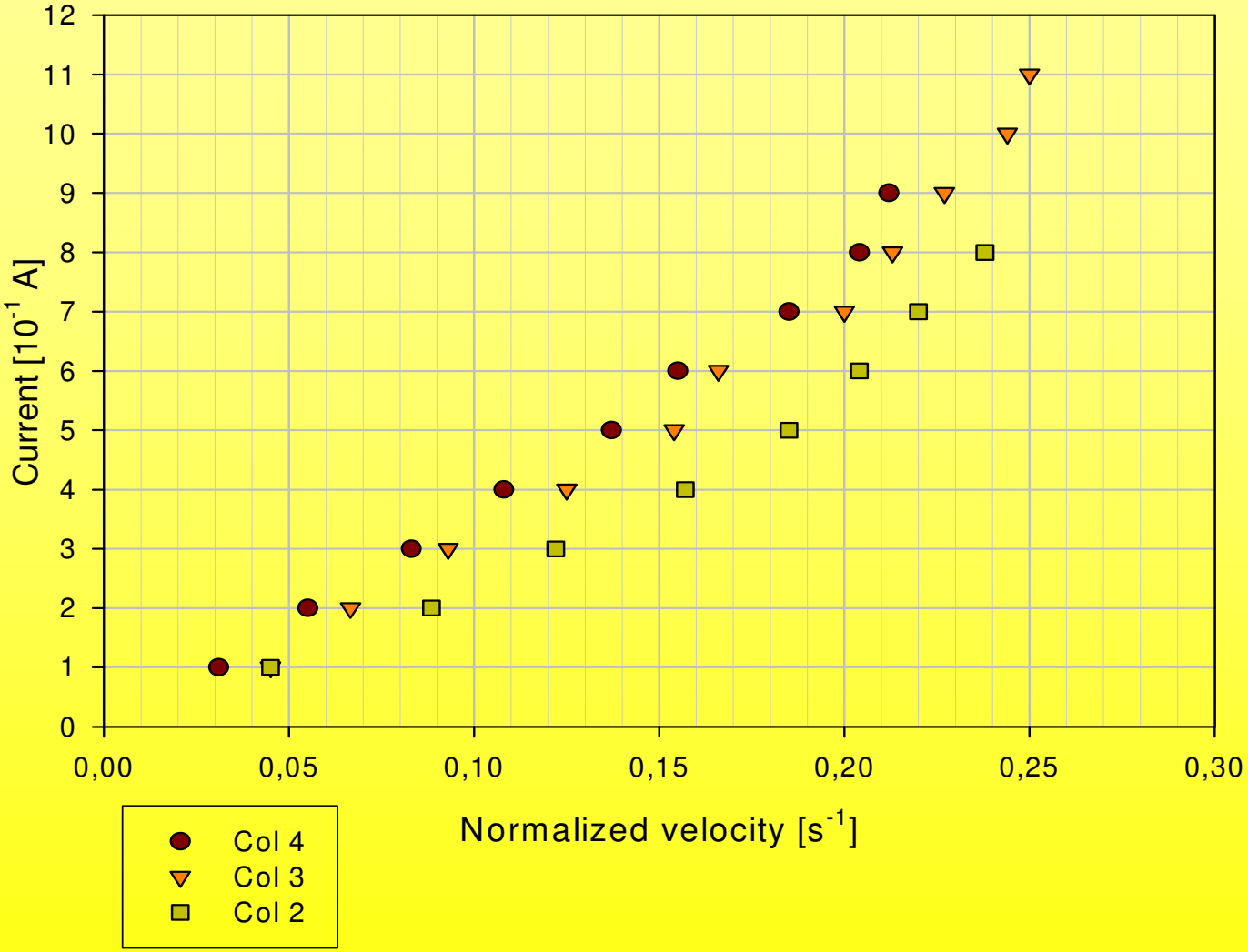
$$M \propto I \Rightarrow \eta \propto I$$



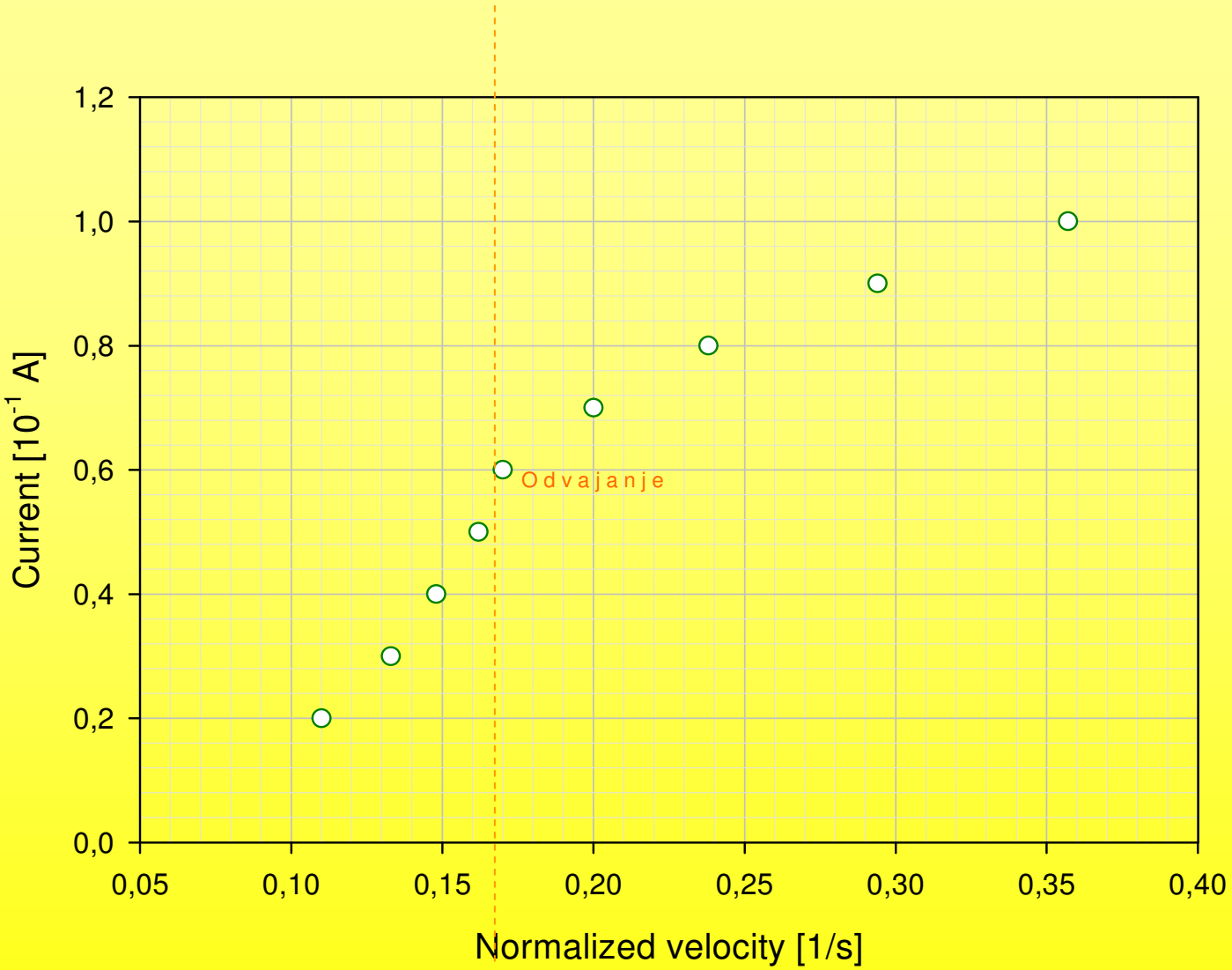
Rotational viscometer .cont



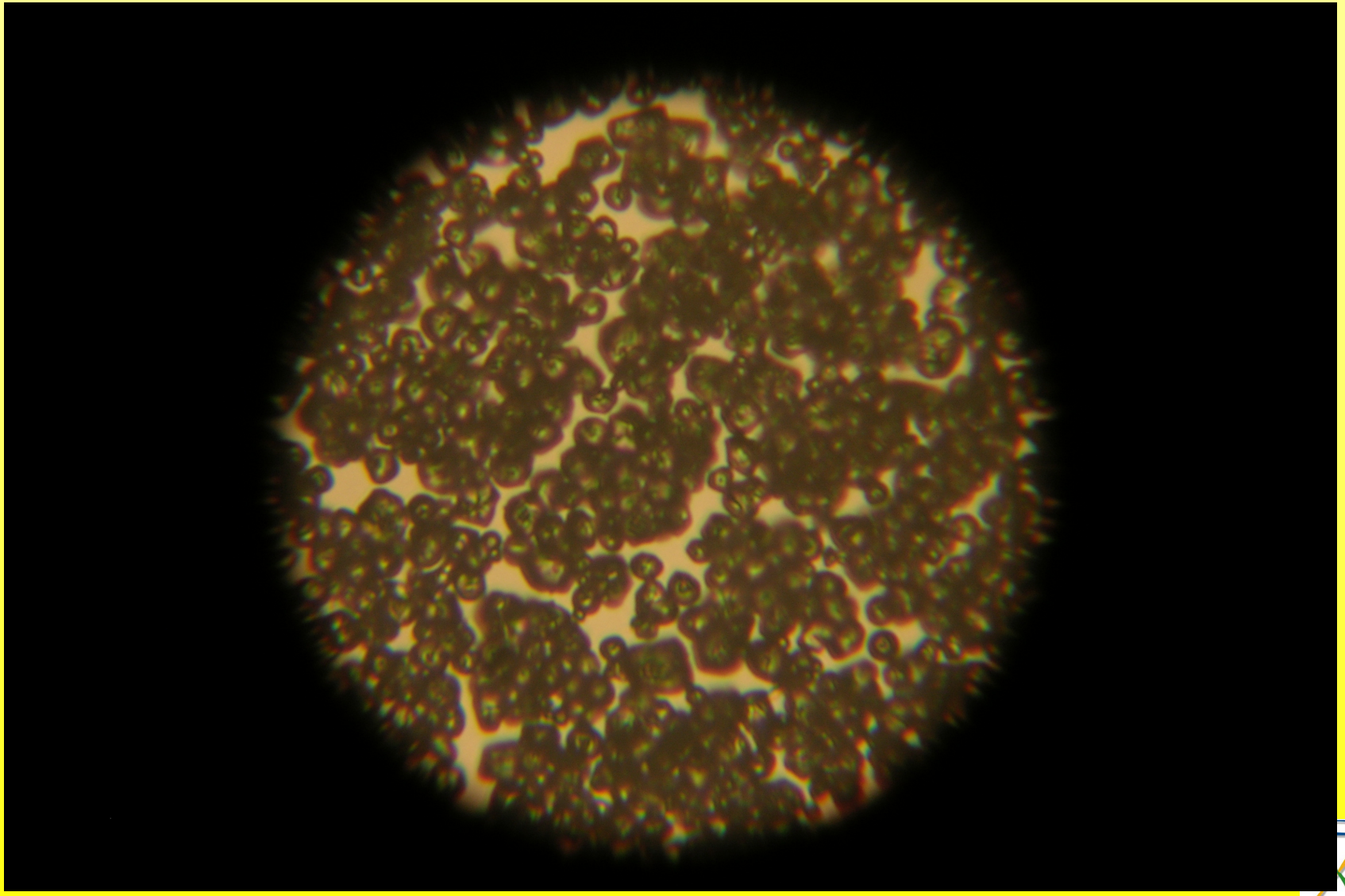
Measurements at different concentrations



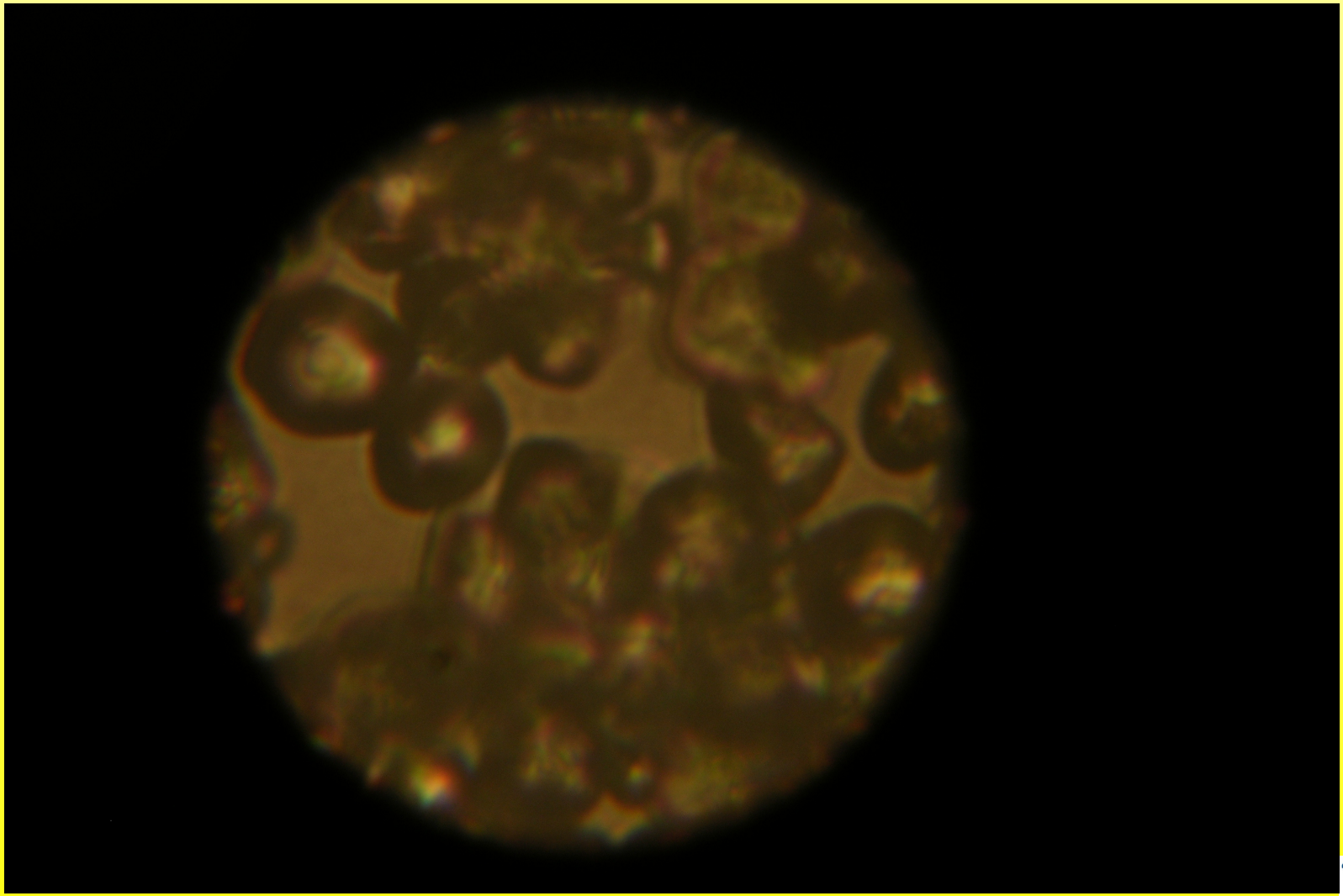
Separation


1,2
1,0
0,8
0,6
0,4
0,2
0,0
Current [10-1 A]
0,05
0,10
0,15
0,20
0,25
0,30
0,35
0,40
Normalized velocity [1/s]
Odvajanje

Structure under microscope



Structure under microscope



Explanation

- In state without stress – liquid phase
- There is a water layer between particles
- At low velocities water lubricates particles
- Pressure increase – displacement of water between particles => direct contact

  => Solution phase transition: liquid – quasisolid
- Particles rub each other – Significant friction

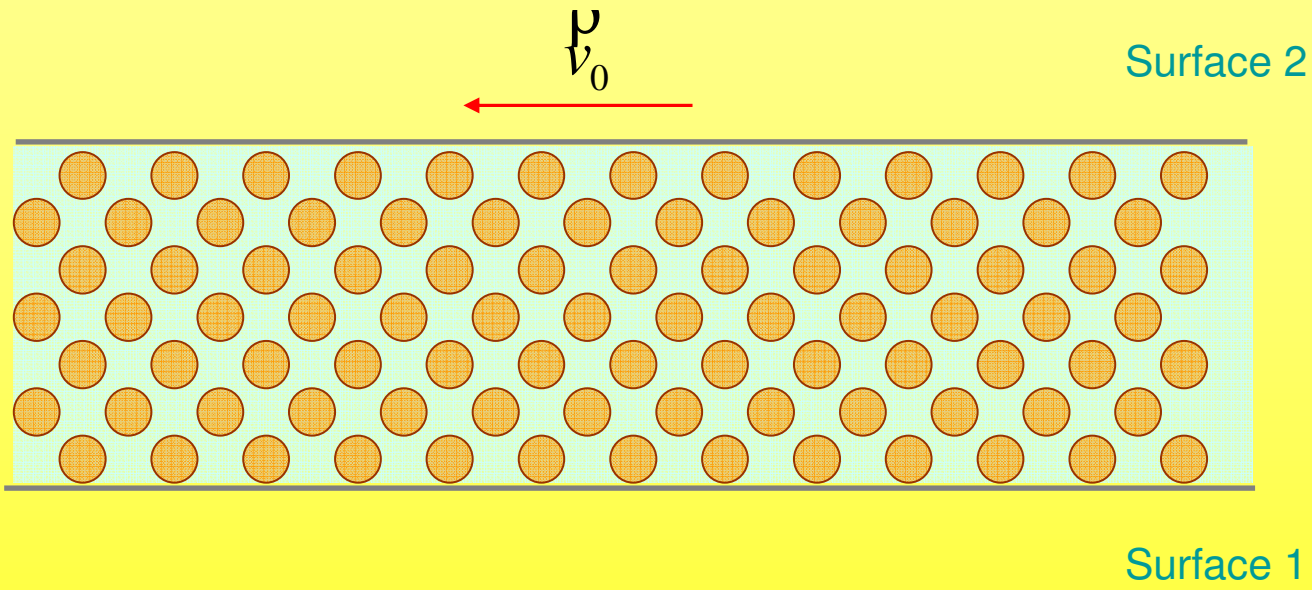
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Theoretical model

- Model goals:
  - Estimation of Phase transition condition
    - Density
    - Pressure (streaming velocity)
  - Determination of drag dependence of velocity
  - Explanation and determination of effect for other solutions

1. Transition conditions

- Model geometry:



- Layer structure is observed

1. Transition conditions

- Parameter which determine contact is average distance between particles :

$$\overline{d} = \frac{\Gamma}{\overline{N}}$$

Γ – coefficient

N – number of particles per volume

- Contact condition:

$$\overline{d_k} \approx 2\overline{r_i}$$

$\overline{d_k}$ – Critical distance

$\overline{r_i}$ – Average particle radius

- We have to determine Γ hydrodinamicaly!



1. Transition conditions cont.

- Hydrodynamical contact condition : Separation of water boundary layer from particles
- Criterion : Reynolds number

$$\mathrm{Re} = \frac{\Pi \rho v}{\eta}$$

Π – geometry coefficient $\approx \bar{d}$

ρ – Liquid density (water)

η – liquid viscosity

v – Characteristic velocity (In our case upper surface velocity)

- Separation at Re ~ 100 (In thin channel between particles)

1. Transition conditions

cont.

- Contact conditions combination:

$$\rho_k \approx \frac{\eta}{2 r_i \bar{v}} \mathrm{Re}_k$$

Re_k – Critical Re number

ρ_k – Critical density

- Comparation with measurement:

Water viscosity	~10^{-3} Pas
Average radius	~10^{-4} m
Re_k	~100
Theory	**~10^3 kg/m^3**
Measurement	**1216 kg/m^3**



2. Drag dependence on velocity

- Drag = Friction between particles + water viscosity
- Linear to (Number of particles in contact)*(Force between particles) – Force adding!

$$F = -CN_{ef}F_{ij}$$

C – Coefficient

N_{ef} – Number of particles in contact

F_{ij} – Force between particles

- N and F depends on pressure or $(\text{velocity})^2$



2. Drag dependence on velocity cont.

- Dependence of N on pressure is estimated through asimptotyc behaviour:
  - P = 0 N_{ef} =0 – every particle is surrounded with water
  - P $\rightarrow \infty$ N_{ef} $\rightarrow N$
- Simplest function:

$$N_{ef} = N_0\left(1 - e^{-\xi p}\right)$$

N – Number of particles

ξ - constant

p – pressure

2. Drag dependence on velocity cont.

- Friction in solid phase – linear to pressure

=> Dependence of drag on pressure :

$$F = -\Lambda\left(1 - e^{-\xi p}\right)p$$

Λ – linearity coeficient

p – Pressure

- Pressure becomes dynamical pressure

=> Dependence of drag on velocity :

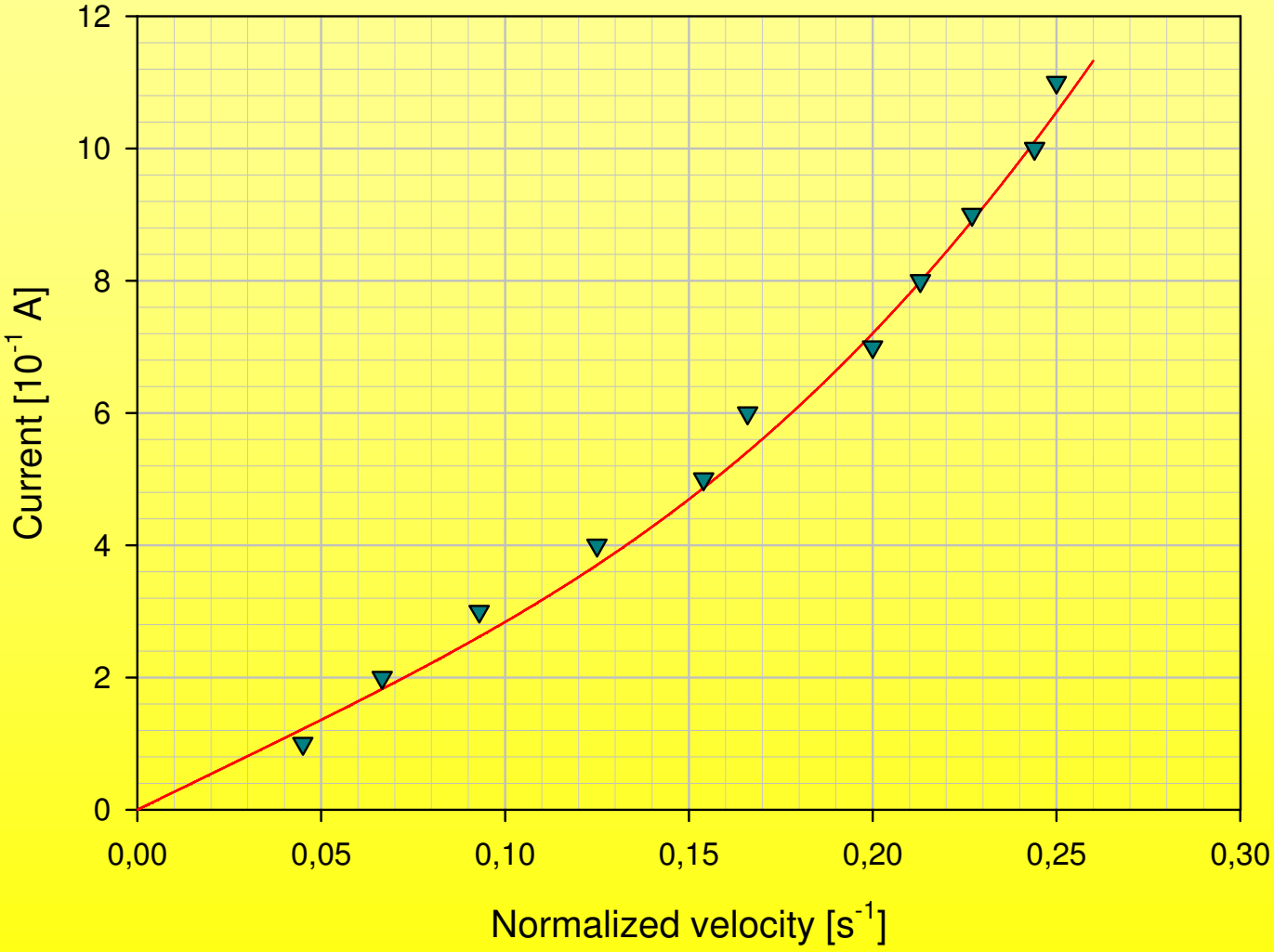
$$F = -\frac{1}{2}\rho\Gamma\left(1 - e^{-\frac{1}{2}\xi\rho\bar{v}^2}\right)\bar{v}^2$$

ρ – solution density

v – average streaming velocity



Results comparation



Results comparation .cont

