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IYPT
International Young Physicists' Tournament

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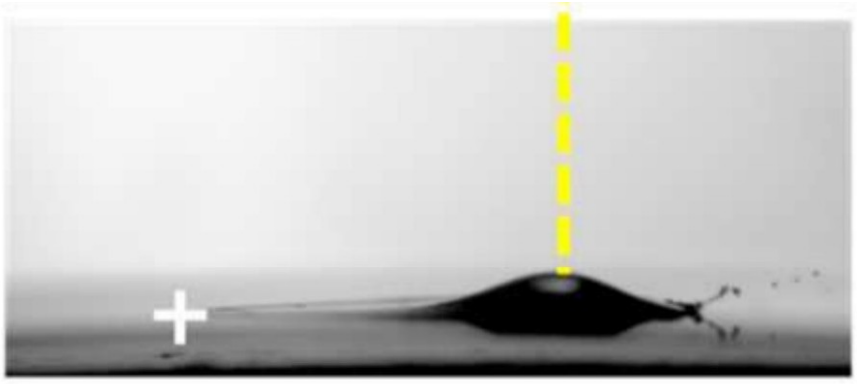
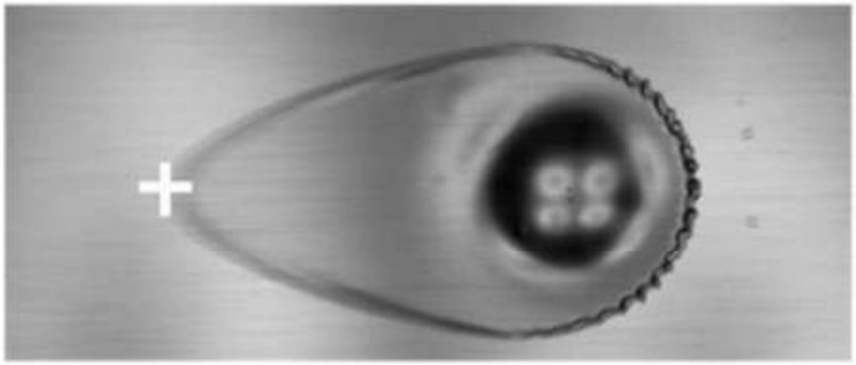
4

DYNAMIC HYDROPHOBICITY

When a drop of liquid impacts on a horizontally **moving surface**, the droplet **may be reflected or not**, depending on the **speed** of the surface. Investigate the interaction between a moving surface and a liquid drop.





BASIC UNDERSTANDING

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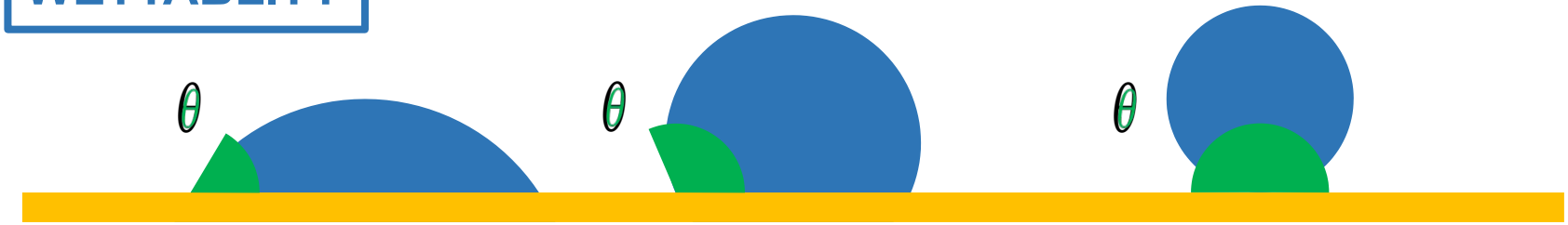
WETTABLITY



hydrophilic *hydrophobic* *superhydrophobic*

Should we expect similar behaviour?

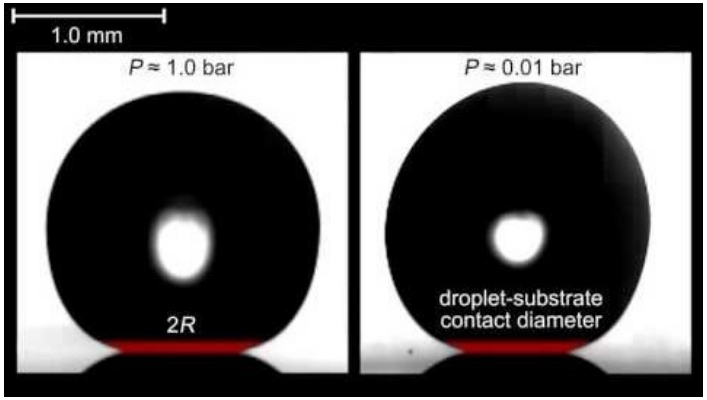
Maybe, but it will be rare…

Dependence on:

surface material

surface tension of the liquid

gas surrounding liquid and surface



$\theta > 150°$

θ – contact angle

BASIC EXPLANATION

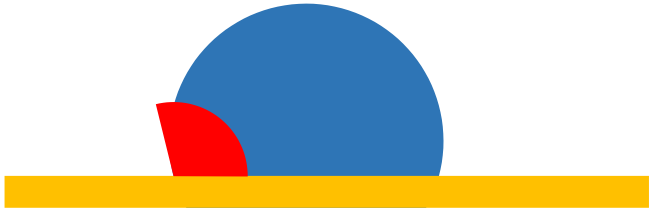
SPEED OF THE SURFACE

θ is close to 90°

stationary surface

Change of the contact angle will be velocity dependent

θ exceeds 90°



moving surface

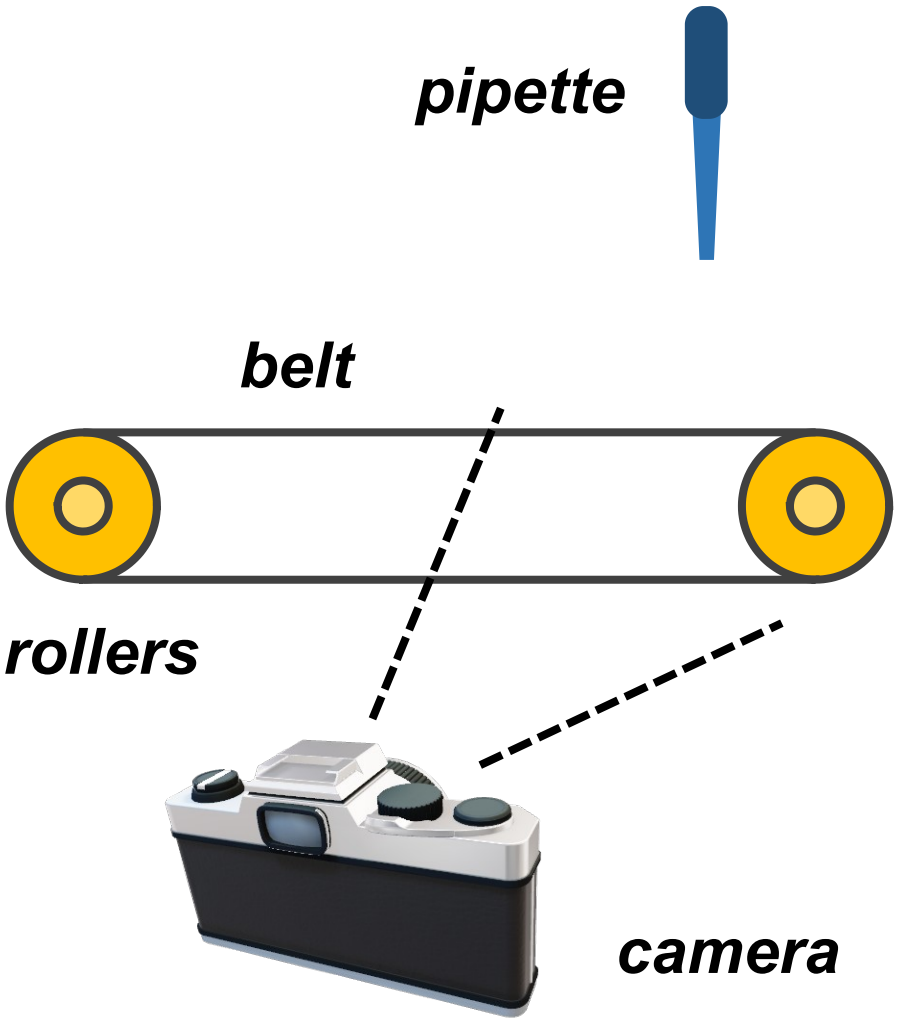
Might be reflected or splashed

APPARATUS

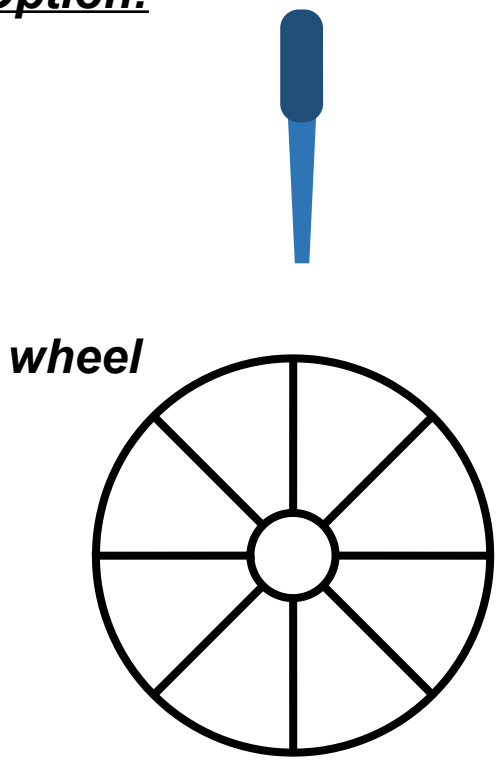
APPARATUS

Suggestion

You can reuse the old setup from Problem No.13 of IYPT 2020 (Friction Oscillator)



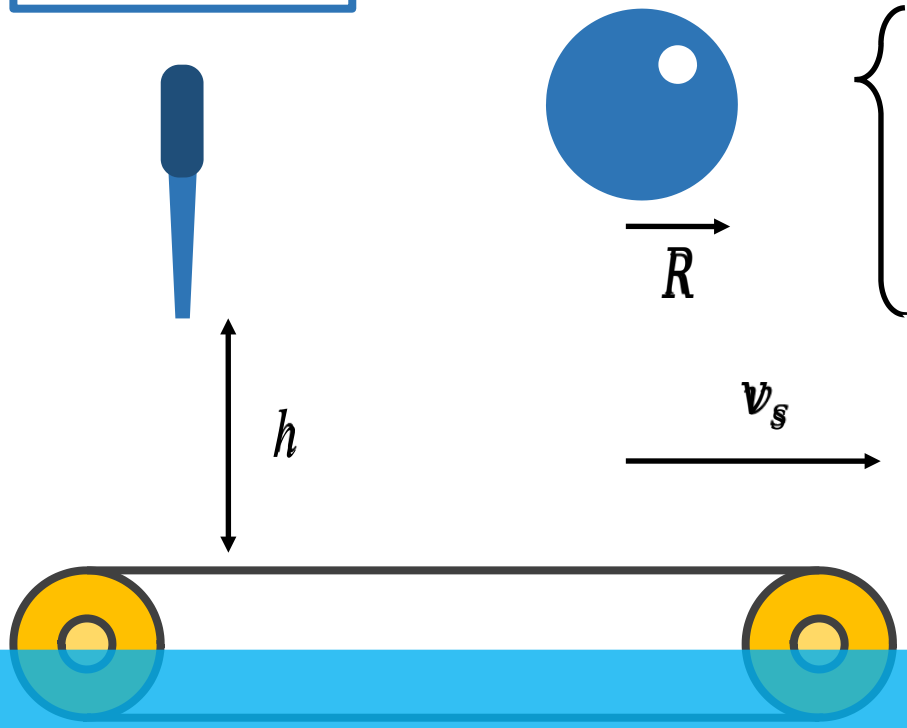
Second Option:



THEORY

THEORETICAL MODEL

Parameters



η = dynamic viscosity

γ = surface tension

ρ = density

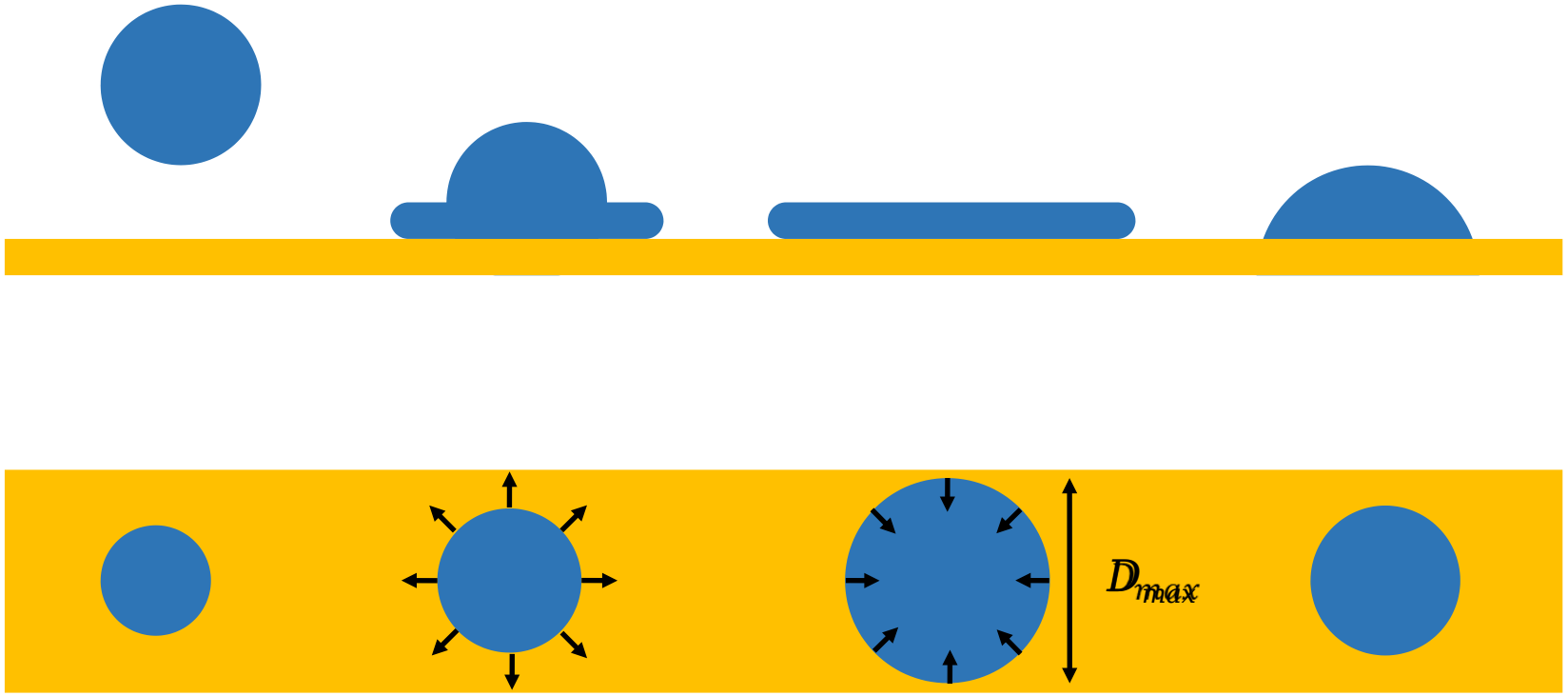
λ = shape factor

liquid nonsense

Let us make some key assumptions!

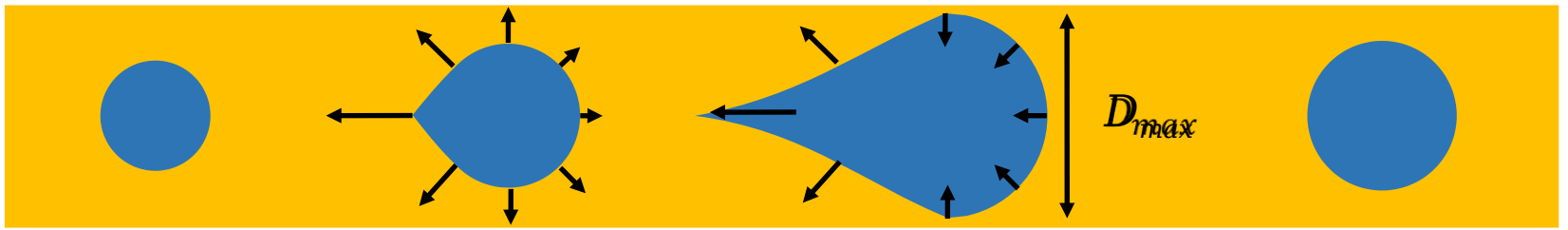
THEORETICAL MODEL

Stationary Surface



THEORETICAL MODEL

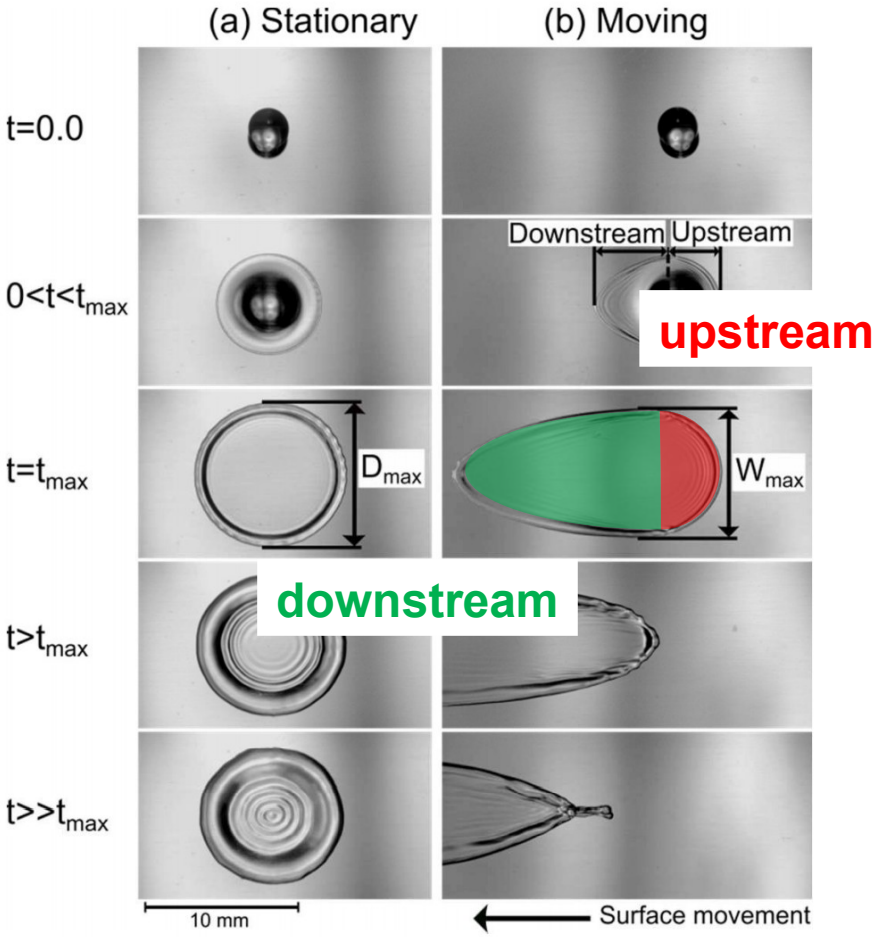
Moving Surface



THEORETICAL MODEL

Radius

$$r(t) \equiv R\left[1-\exp\left(-\left(\left(\frac{2\gamma_{LG}}{R_{12}^{12}}+\frac{\rho g}{9R_{10}^{10}}\right)\frac{24\lambda V^4 t}{\pi^2\eta}\right)\right)\right]^{\frac{1}{6}}$$



EXPERIMENTS

EXPERIMENTS

[1] H.Almohammadi, A.Amirifazli, 'Understanign the drop impact onto a moving hzdrophilic and hydrophobic surfaces', Department of Mechanical Engineering, York University, Toronto

Velocity of the Surface - v_S

$0\,m/s < v_S < 17\,m/s$ **in paper [1]**

try to focus on the boundary velocities when creating phase diagrams

Velocity of the Drop - v_N

Change initial height of the drop (pipette) – free fall

$v_N = \sqrt{2gh}$

Wettability of the Surface

Use variety of different surfaces and determine wettability by measing contact angle for stationary surface for particular liquid

Hydrophilic – Stainless Steel $\theta < 40°$ *Use impregnation spray*

Hydrophobic – Teflon $\theta > 110°$

EXPERIMENTS

Surface Tension - γ

Use detergent to change surface tension of the water

dynamic viscosity and density should not be affected significantly

Dynamic Viscosity - η

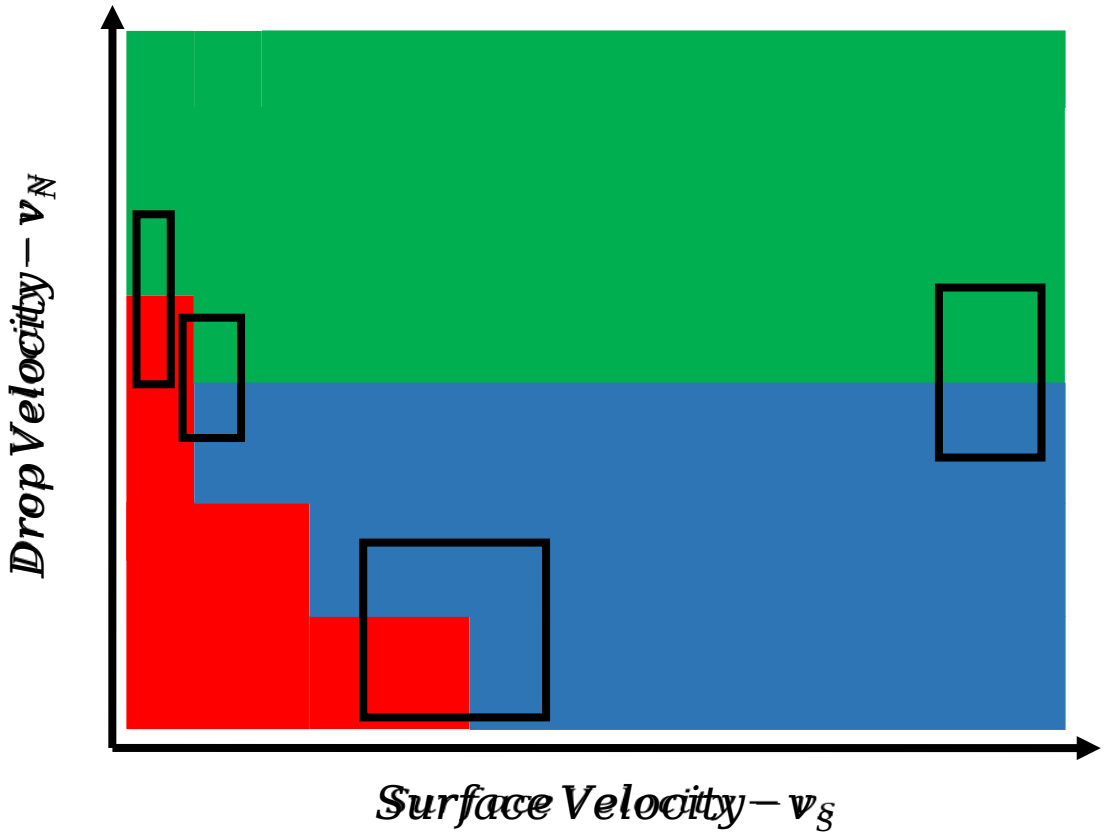
Use glycerol to effectively change dynamic viscosity of the water **in paper [1]**

Table 1. Physical properties of the working fluids

Liquid name	Percentage of glycerol (wt %)	Density ρ (kg/m^3)[25]	Surface tension σ (mN/m)[25]	Dynamic viscosity μ $(mPa.s)$[26]
Water	0	998.2	71.7	1.005
Mixture 1	24	1057.2	70.6	2.025
Mixture 2	42	1104.7	69.2	4.106

EXPERIMENTS

Statistical Phase Diagrams



- reflected
- attached
- splashed

always provide analysis of the statistical phase diagram

EXPECTATIONS

EXPECTATIONS

1 BEGINNERS

- Change all parameters in the section EXPERIMENTS systematically
  - Velocity of the surface
  - Velocity of the droplet (height of the pipette)
  - Surface tension
  - Dynamic viscosity
  - Material of the surface (wettability)
  - Size of the droplet
- Quantify wettability (by measing contact angle θ)
- Create statistical phase diagrams
- Provide qualitative explanation behind behaviour of the droplet (Why?)
- Ability to control size of the droplets (good pipette)
- Uncertainties in the measurement (essential for this problem)
  - one experiment is certainly not sufficient for overall understanding
- Always provide proofs of your ideas of explanation (HFR video)

EXPECTATIONS

2 ADVANCED

- Provide quantitative analysis of the experiment
  - Look at the behaviour of the droplets – change of lamella shape
  - Length of the upstream and downstream of the droplet for various velocities
- Quantitative model describing change of contact angle
- Phase diagrams with change of the droplets maximum diameter D_{max} and analysis of critical diameter
- Try to combine parameters of the liquid into one crucial parameter (try dimensionless numbers in hydro physics – Weber's Number, Bond Number, Reynolds number, but justify their applicability
- Provide quantitative theory and give predictions based on initial parameters

THANK YOU