Problem 7.

Making a Splash

Problem

A solid object is dropped into water from a height of 50 cm. Investigate the factors that would minimize the splash.

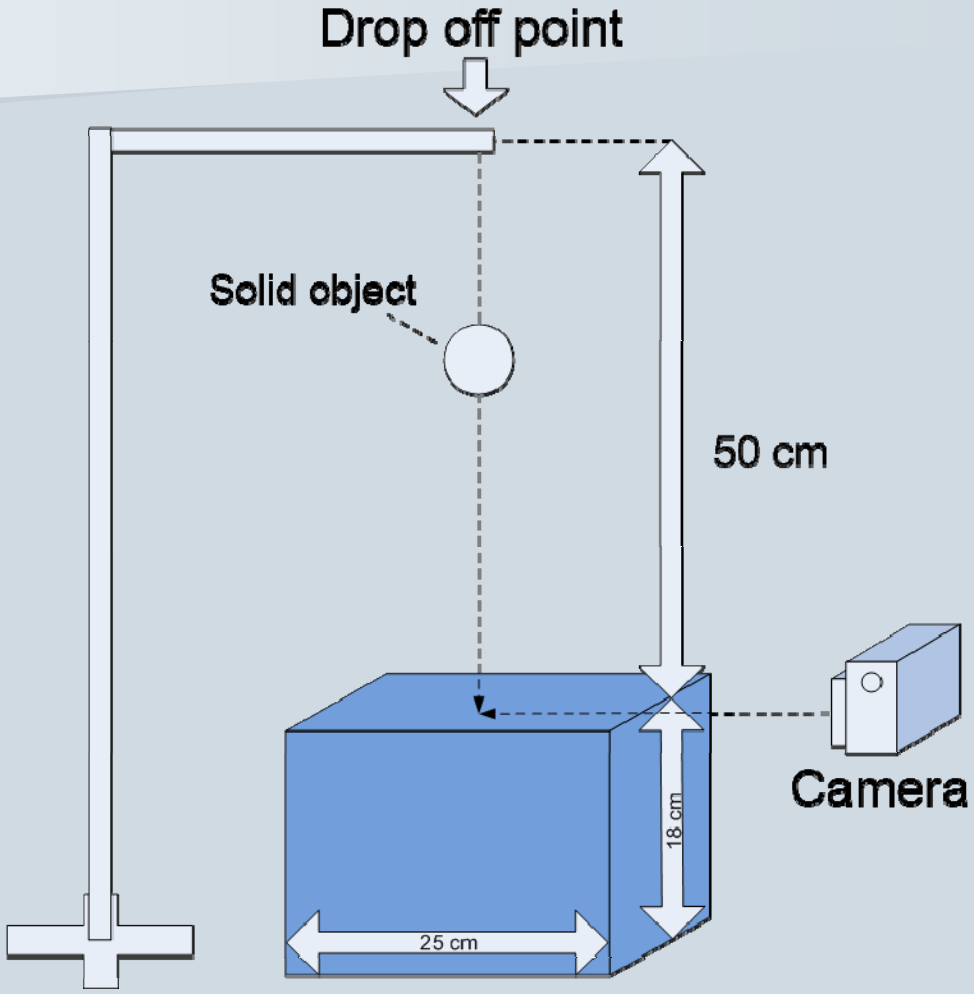
Content

- Meaning of splash
- Two types of splashes
- Comparing rough and smooth splashes
- Cause of different types of splashes
- Splash dependence on different parameters
- Theoretical approach
- Comparison of splash type and sound
- Conclusion

Meaning of “splash”

- To move through water making drops fly everywhere
- To fall noisily onto a surface

First experiment



Two types of splashes

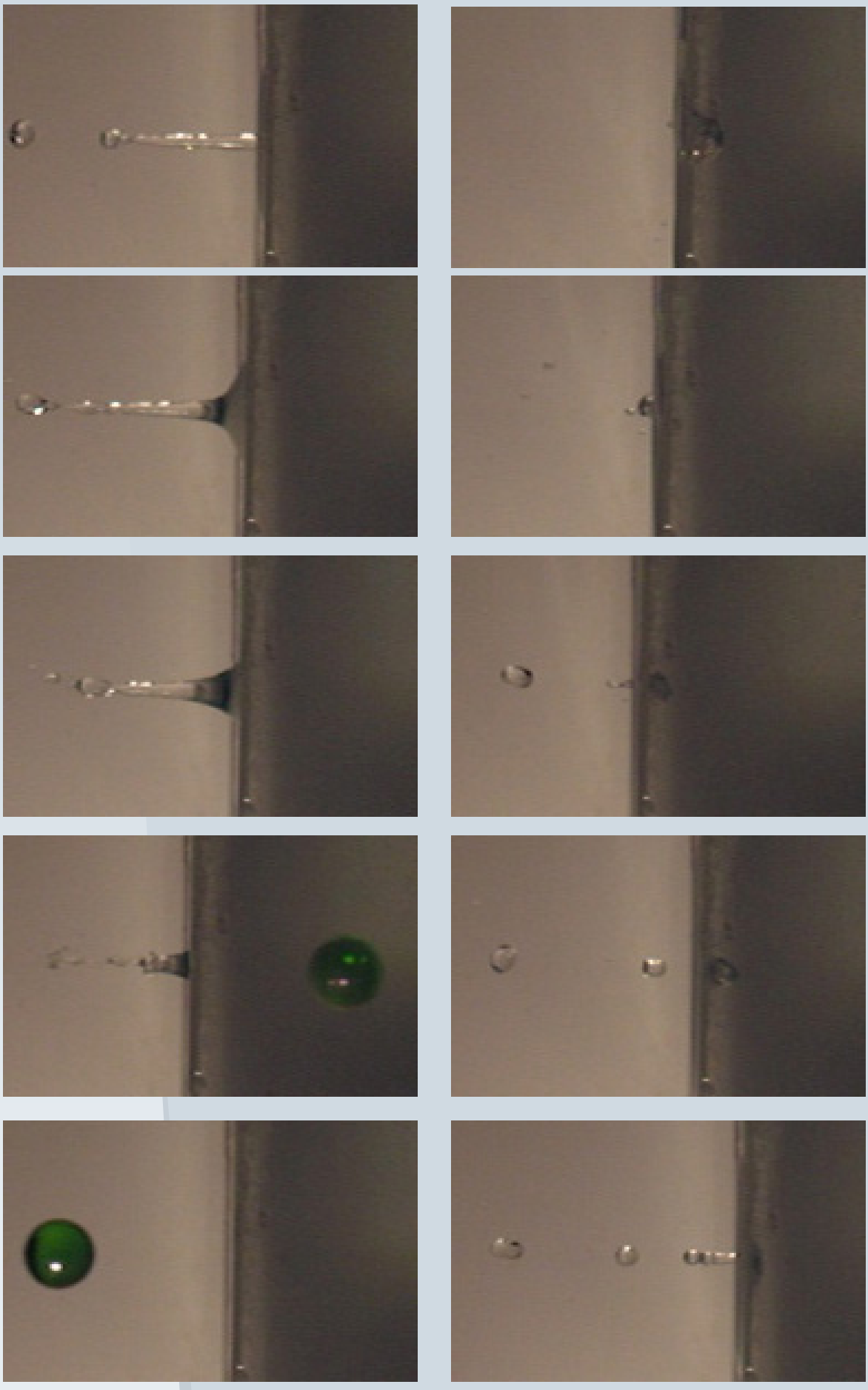
- While dropping spheres made out of different materials, it was noticed that two types of splashes occur

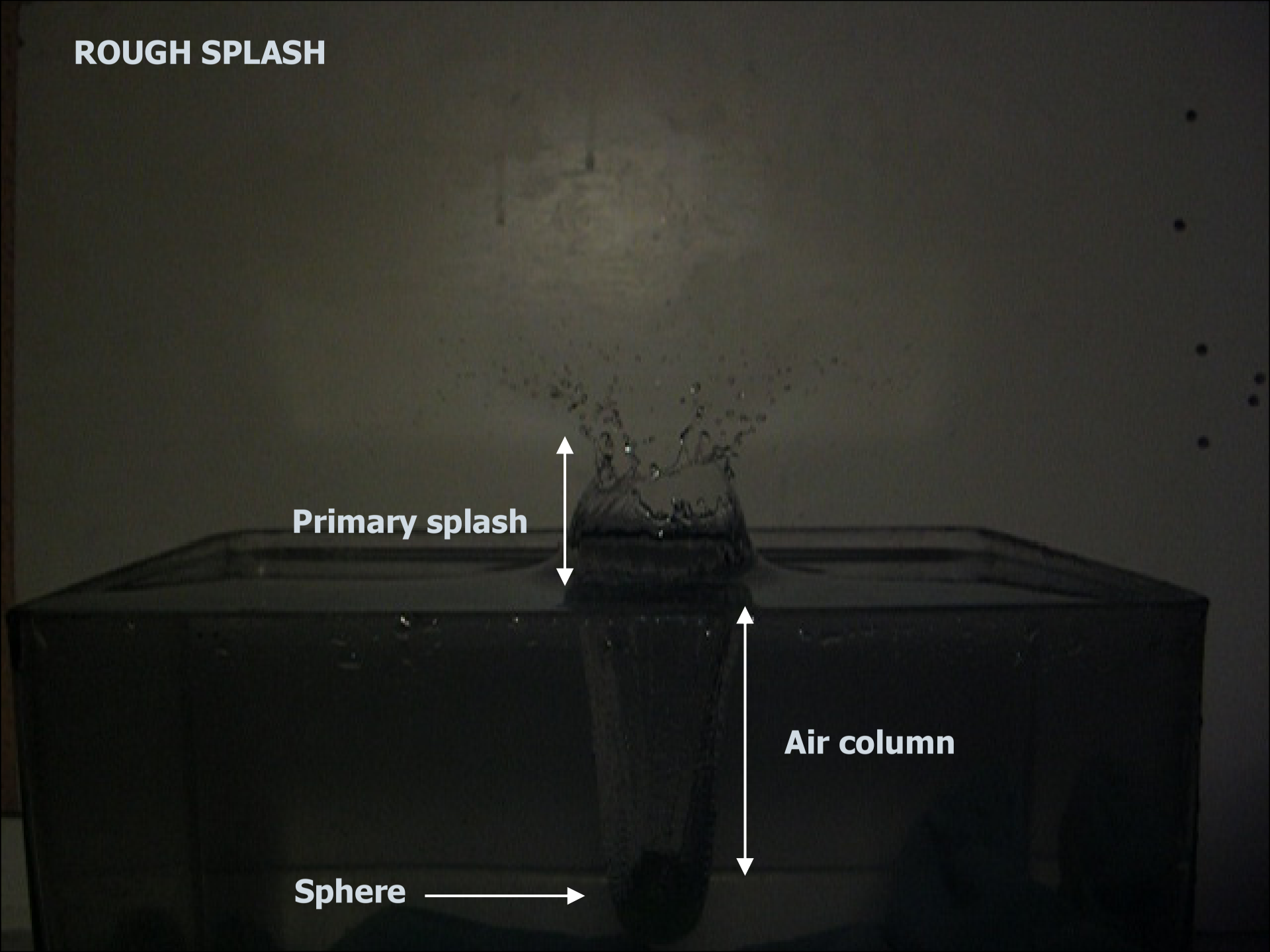
- By their look we called them “rough” and “smooth” splash

SMOOTH SPLASH

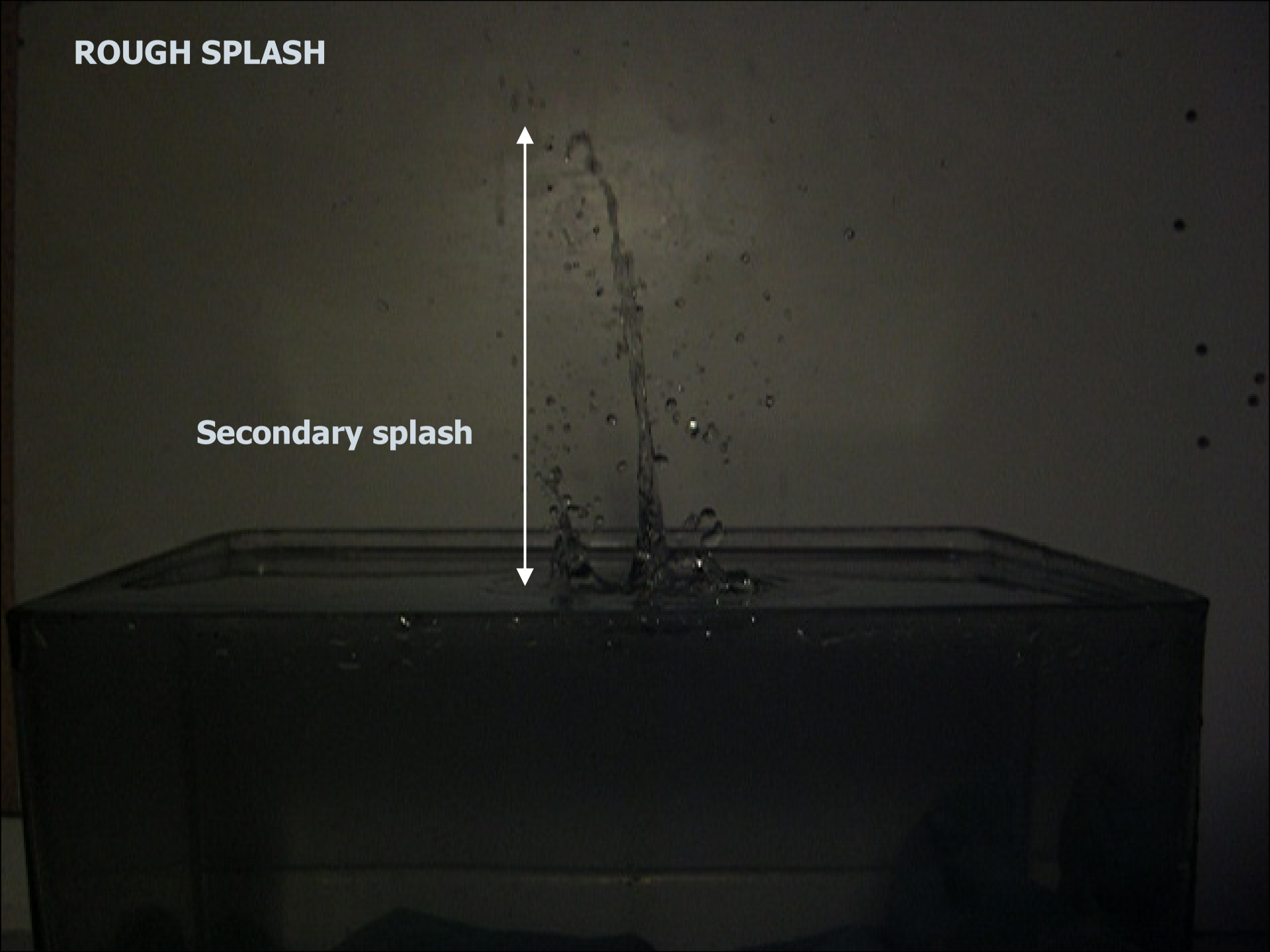
SMOOTH SPLASH


SMOOTH SPLASH




ROUGH SPLASH
Primary splash
Air column
Sphere

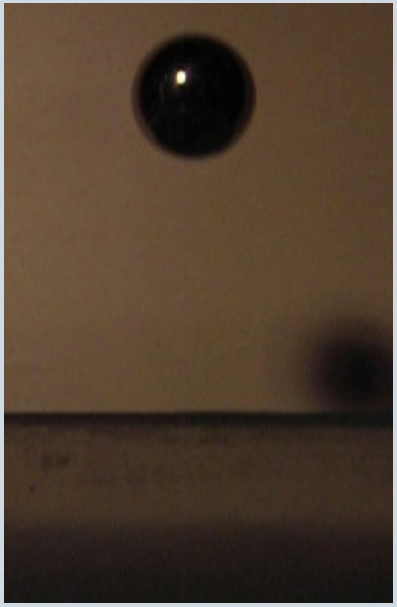
ROUGH SPLASH


ROUGH SPLASH
Secondary splash


ROUGH SPLASH

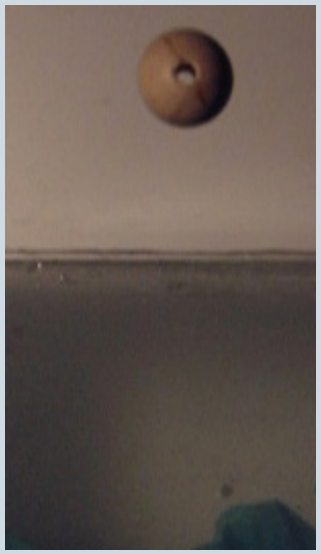
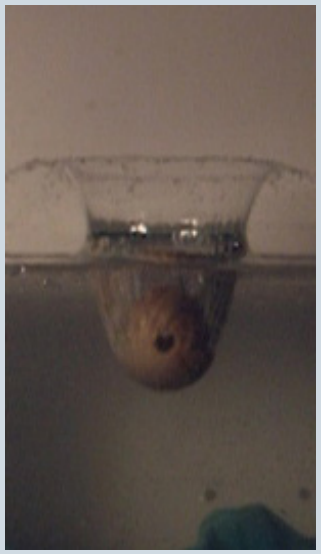
Smooth splash

- When the sphere enters water, water follows the sphere's surface
- The sphere doesn't pull any air



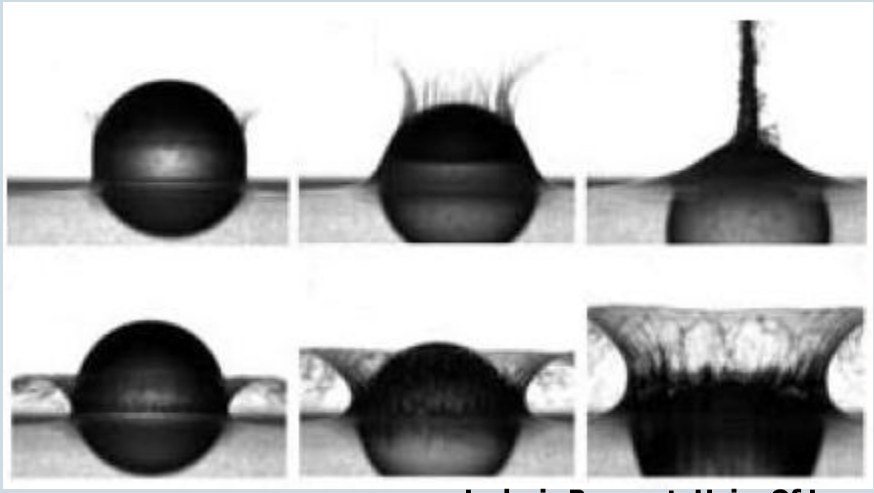
Rough splash

- When the sphere enters water, water separates from sphere's surface
- Makes space for air column to be created


Comparing rough and smooth splashes

- Smooth splash
- Rough splash



Lyderic Bocquet, Univ. Of Lyon

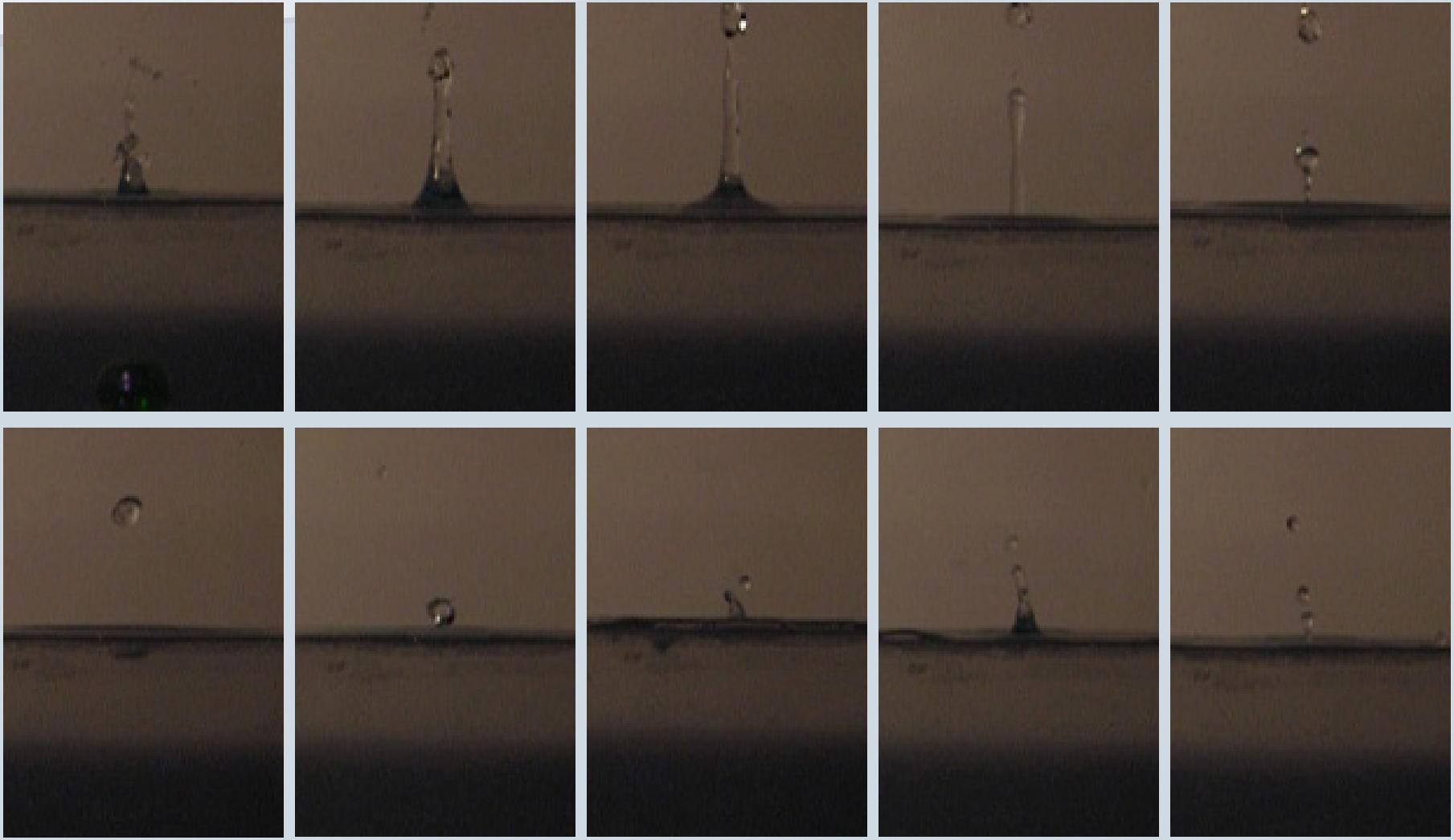
Cause of different types of splashes

- Difference between forces of cohesion and adhesion
- Roughness of sphere's surface
- Hydrophilic or hydrophobic surface

Difference between forces of cohesion and adhesion

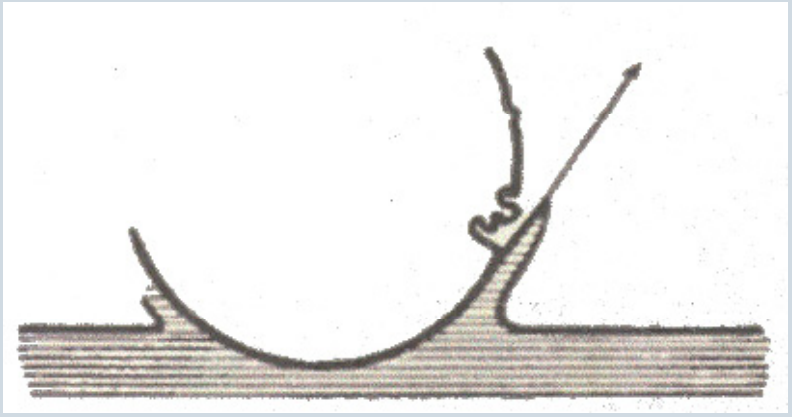
- Force of adhesion between water and glass is stronger than force of cohesion between molecules of water
- That would explain smooth splash while dropping solid objects made out of glass

Splash – glass sphere

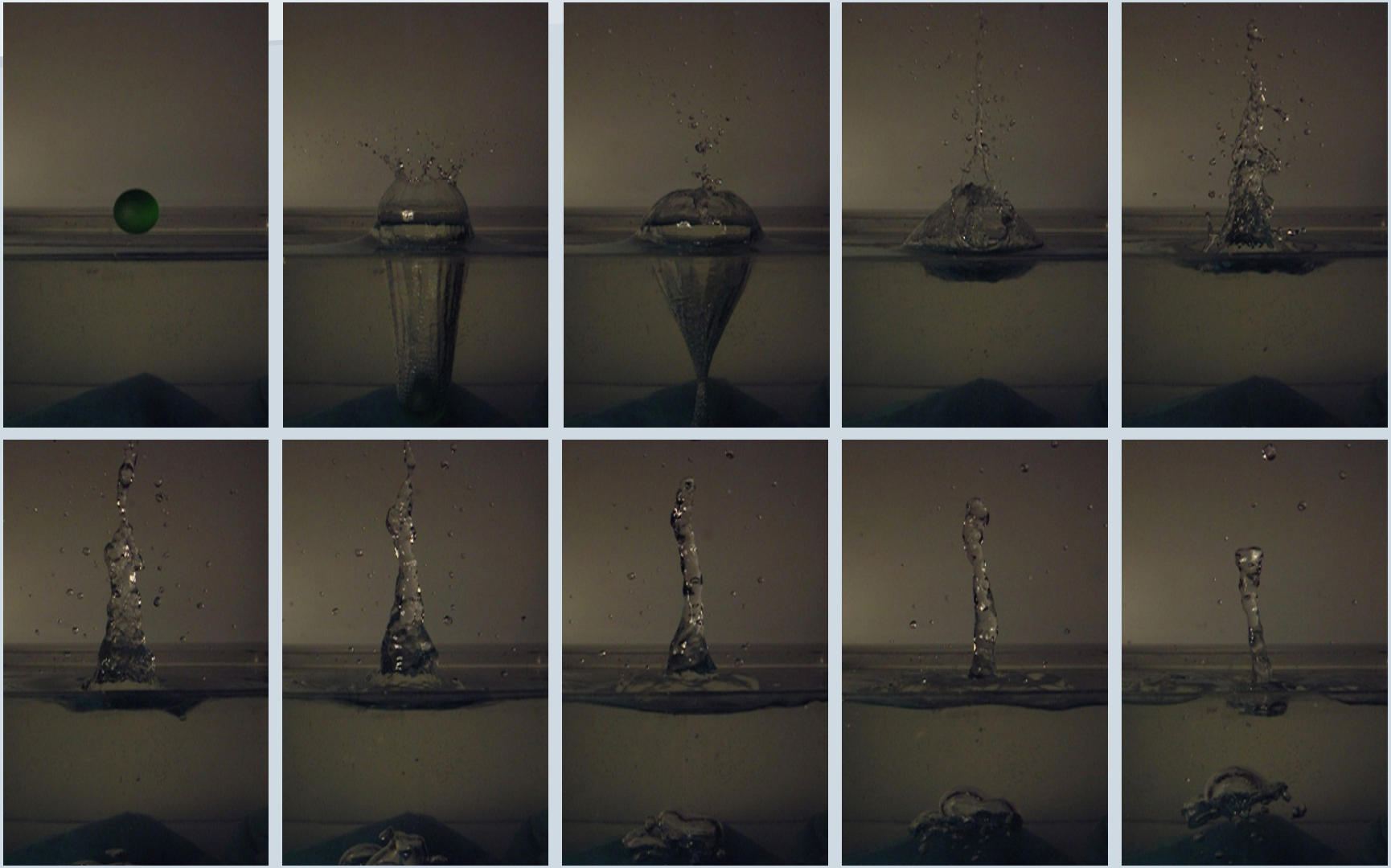


Roughness of surface

- Rough surface of the sphere sends water away from its surface
- Water has no possibility to follow the sphere's surface, rough splash occures



Splash – glass sphere with rough surface



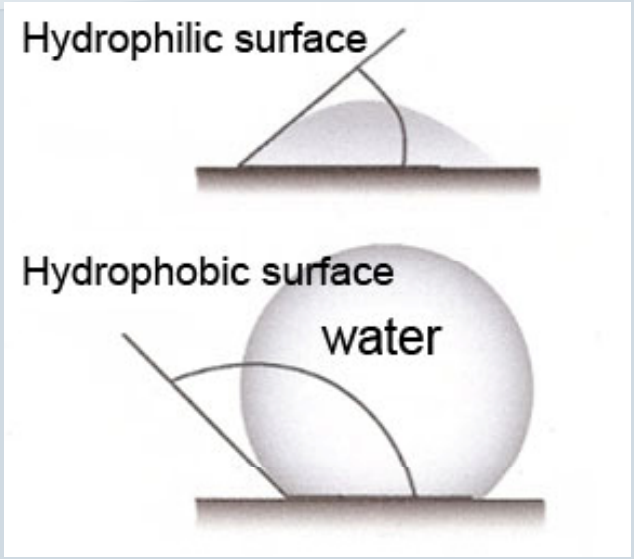
Hydrophilic and hydrophobic objects

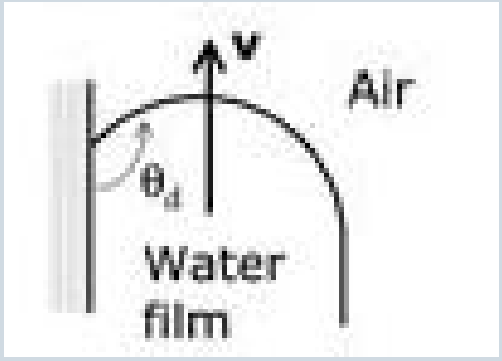
- **Hydrophilic objects** – tend to keep water on themselves; hydrogen bonds between molecules of object and molecules of water
- **Hydrophobic objects** – send away water from their surfaces as a result of repulsion between molecules of water and molecules of object

Hydrophilic and hydrophobic objects

- Different contact angle
- Contact angle – angle between surface and film of water
- Hydrophilic surfaces
  small contact angle (0º-90 º)
  Hydrophobic surface
  large contact angle (150º-180º)

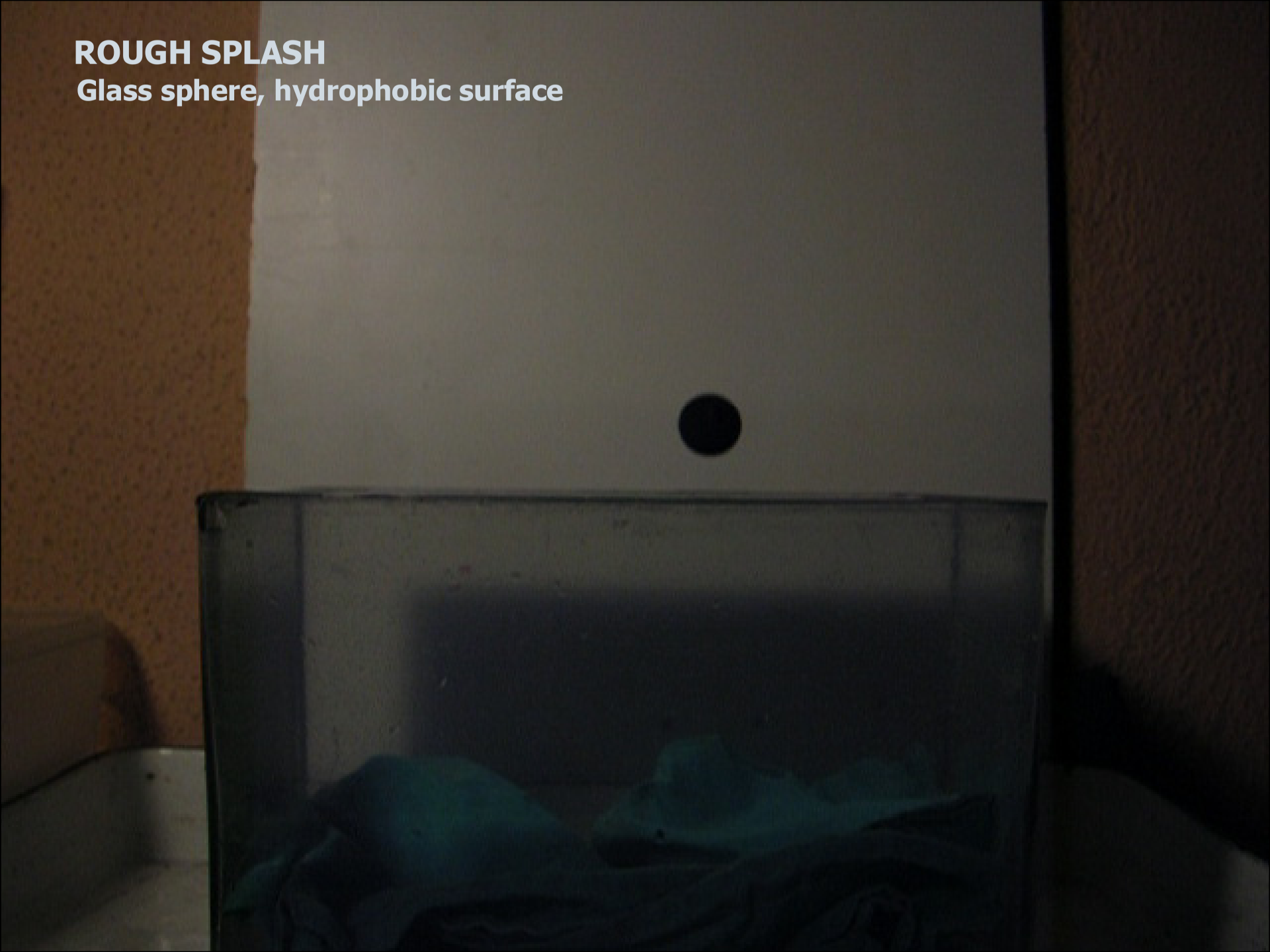
Hydrophilic and hydrophobic objects

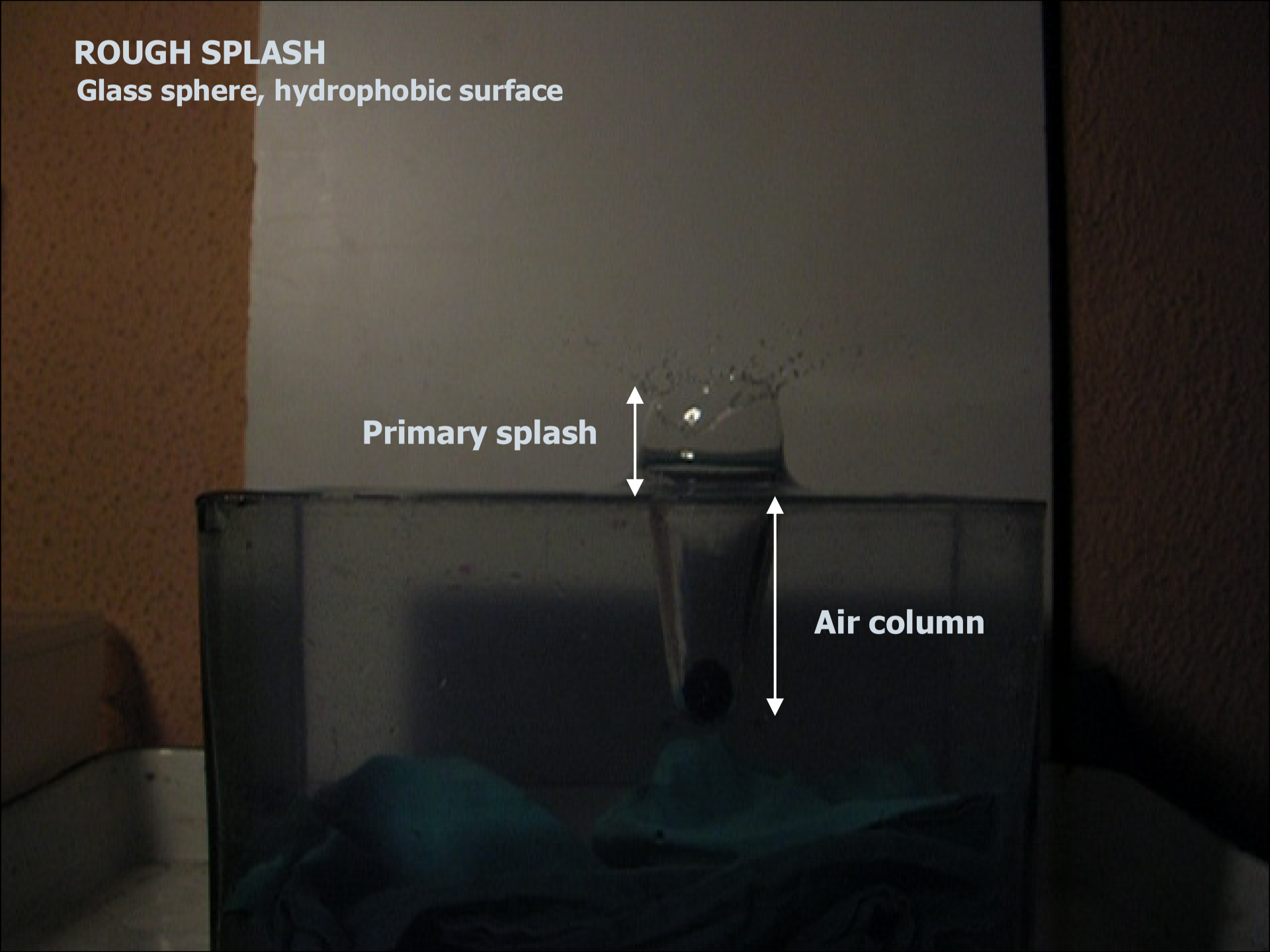


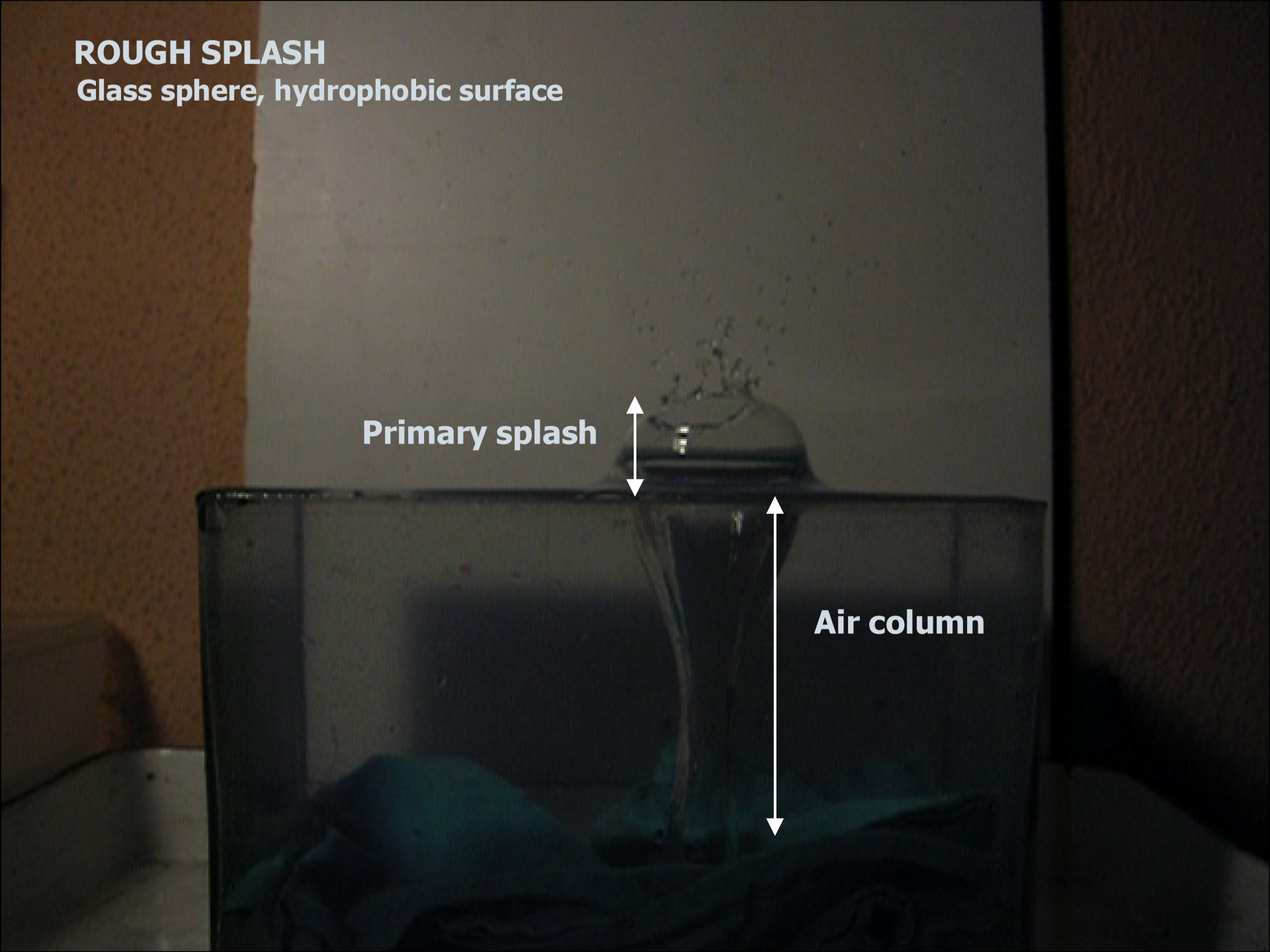


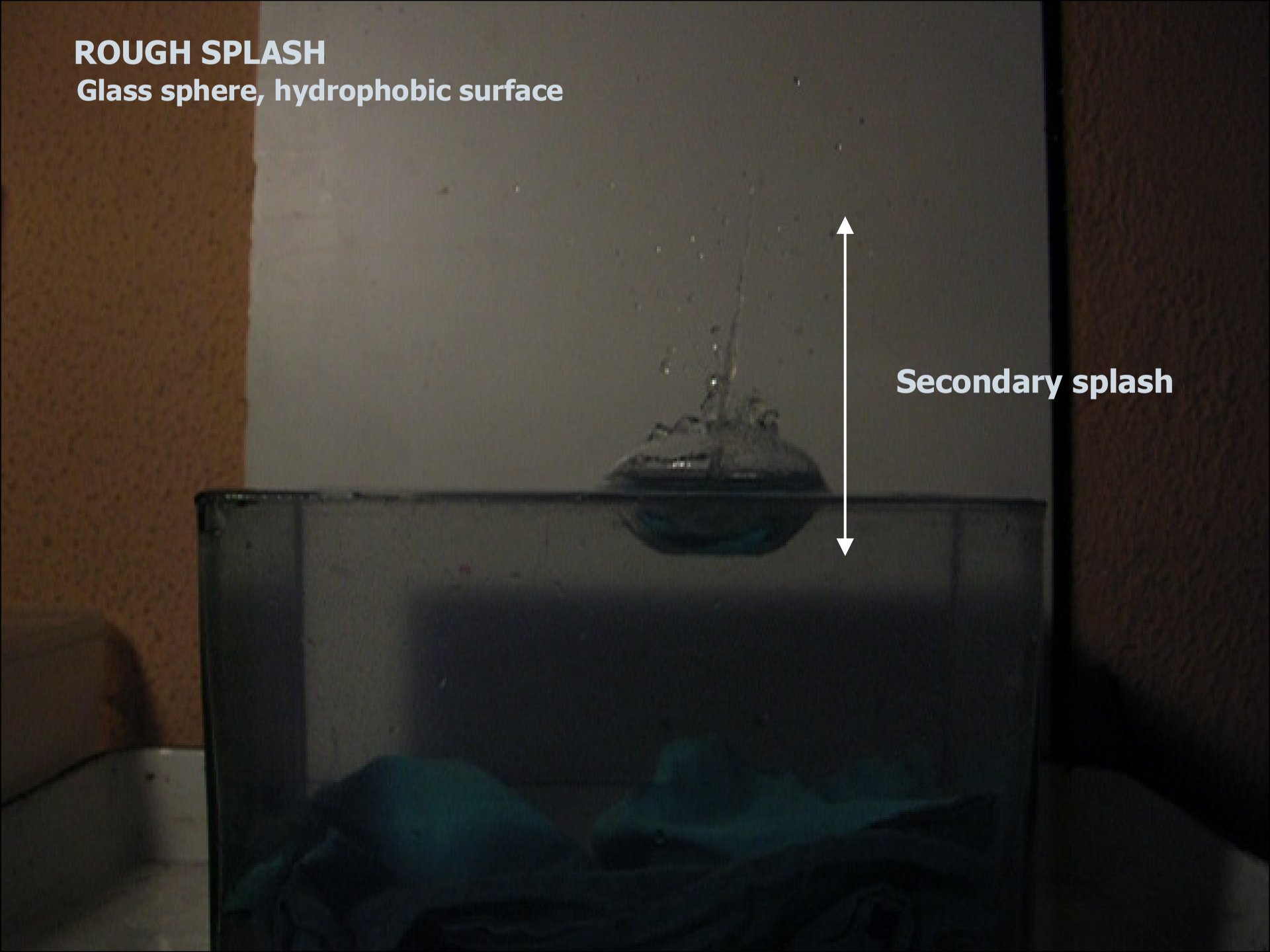
Hydrophilic and hydrophobic objects

- **Hydrophilic surface** – glass sphere
- **Hydrophobic surface** – glass sphere with carbon coating
- Same properties – weight, volume


ROUGH SPLASH
Glass sphere, hydrophobic surface

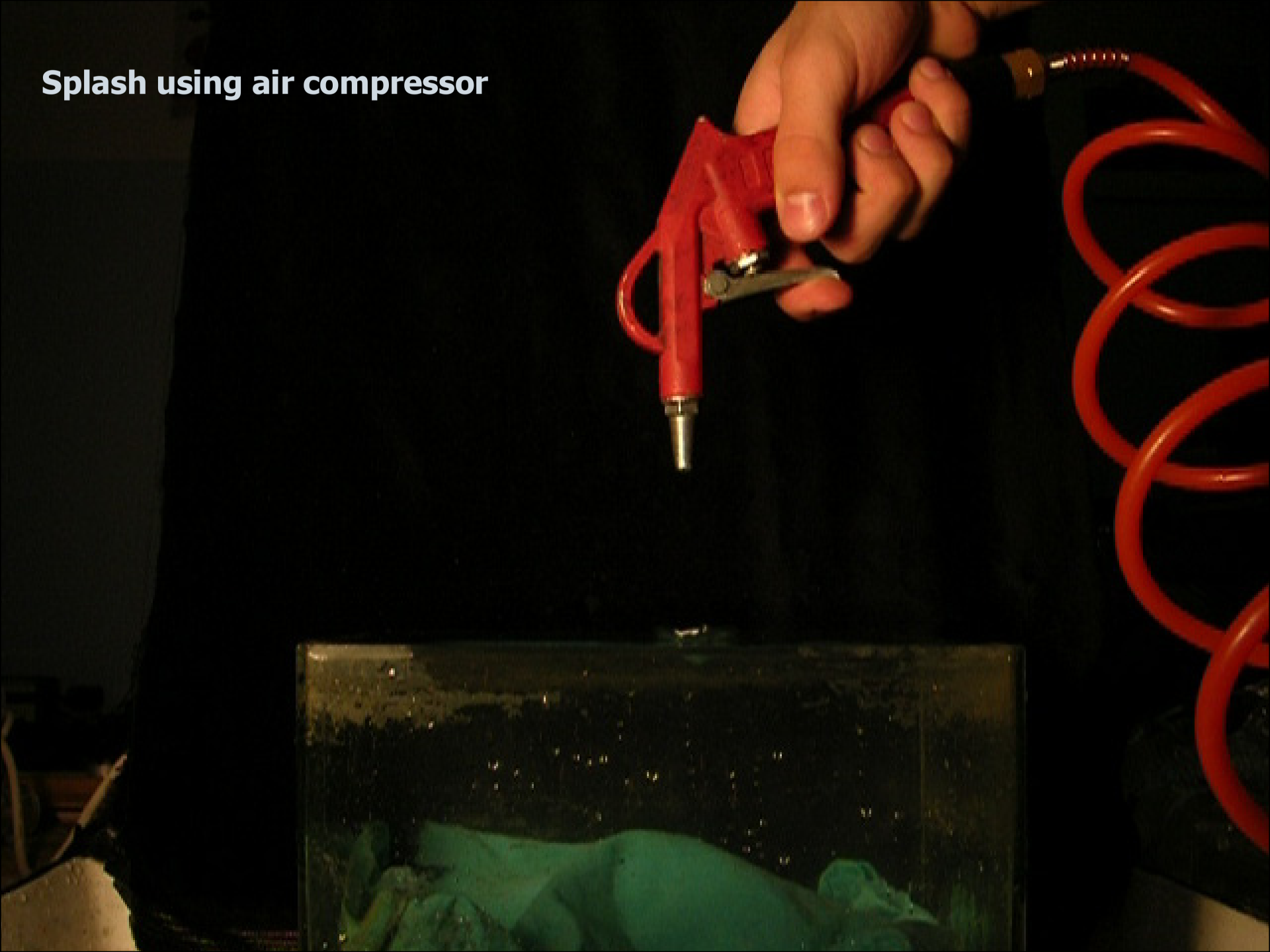

ROUGH SPLASH
Glass sphere, hydrophobic surface
Primary splash
Air column


ROUGH SPLASH
Glass sphere, hydrophobic surface
Primary splash
Air column

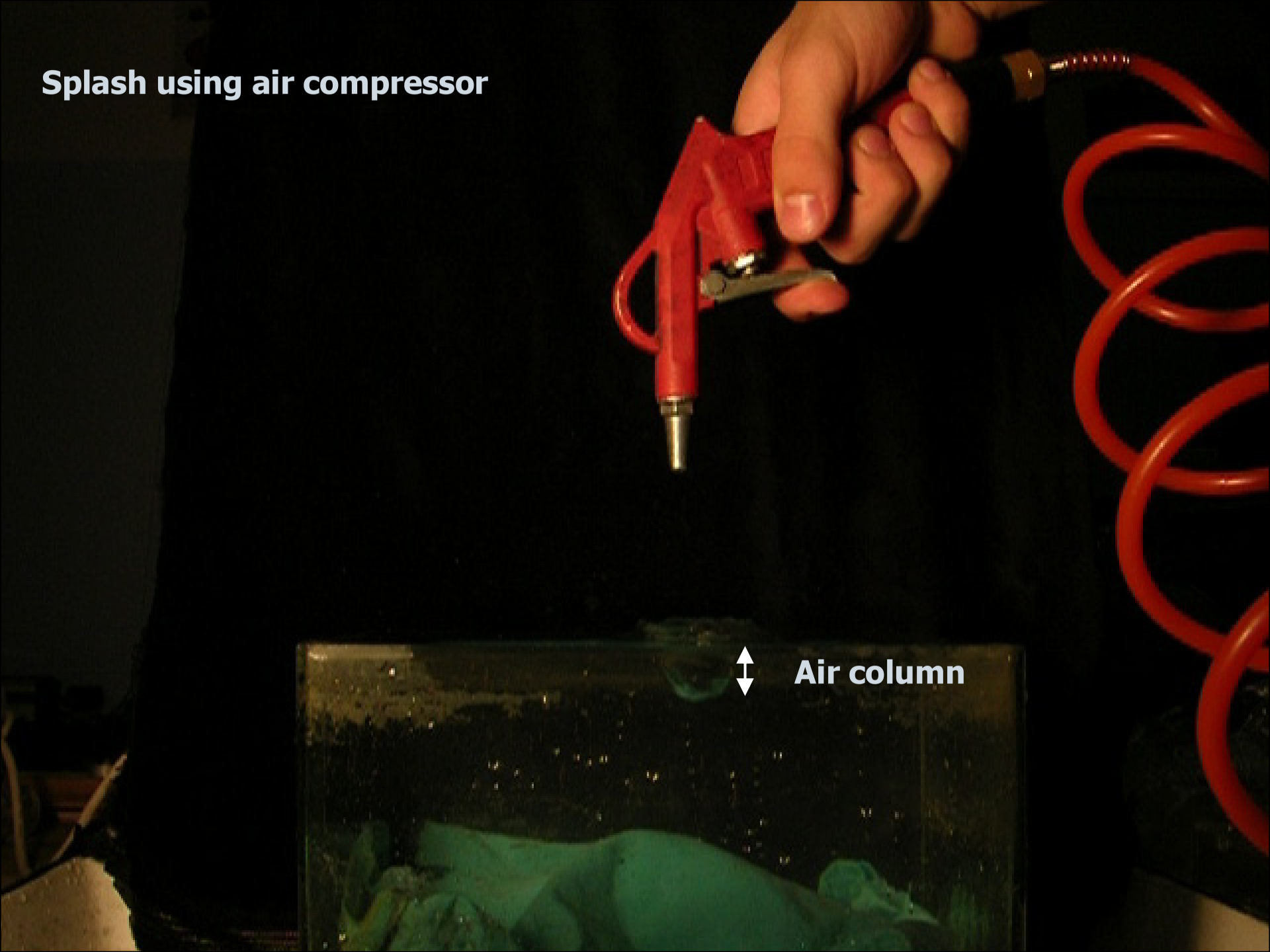

ROUGH SPLASH
Glass sphere, hydrophobic surface
Secondary splash


ROUGH SPLASH
Glass sphere, hydrophobic surface

Splash using air compressor



Splash using air compressor



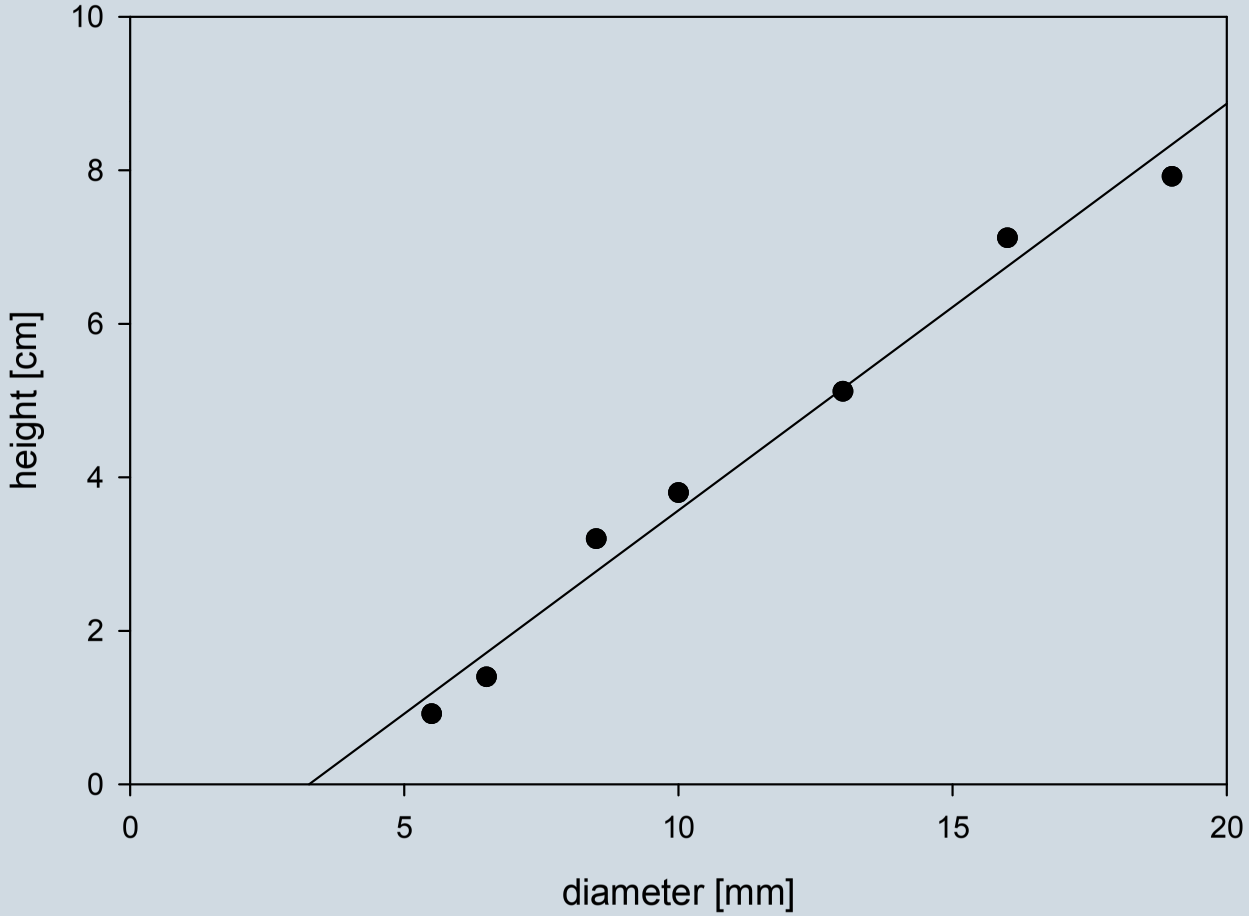
Splash using air compressor

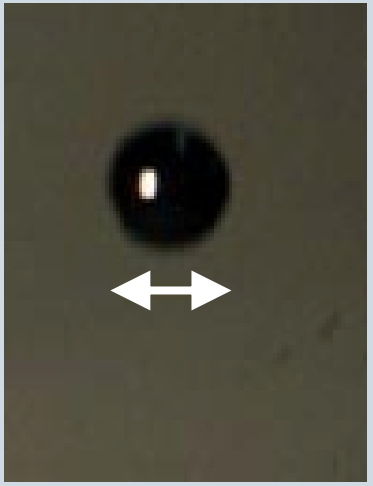
Splash using air compressor

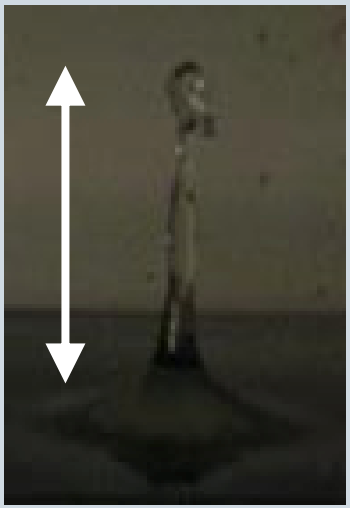
Splash dependence on sphere diameter

Smooth splash, steel spheres, smooth surface

Sphere diameter: 5.5 – 19 mm



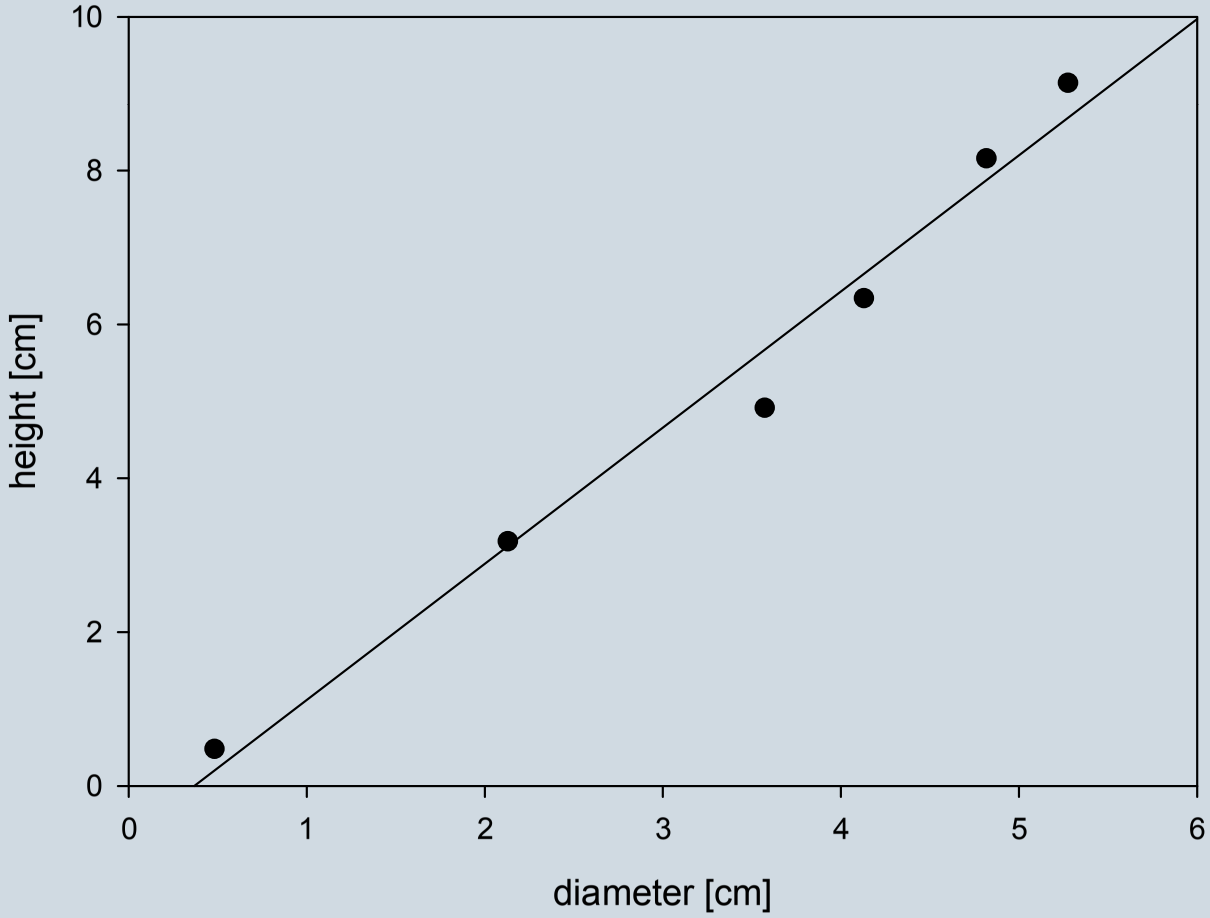


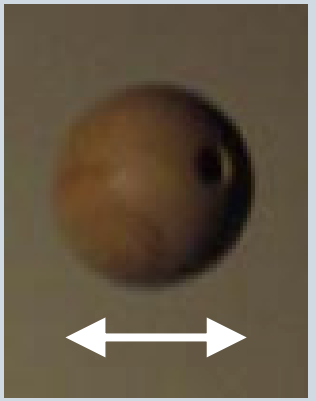


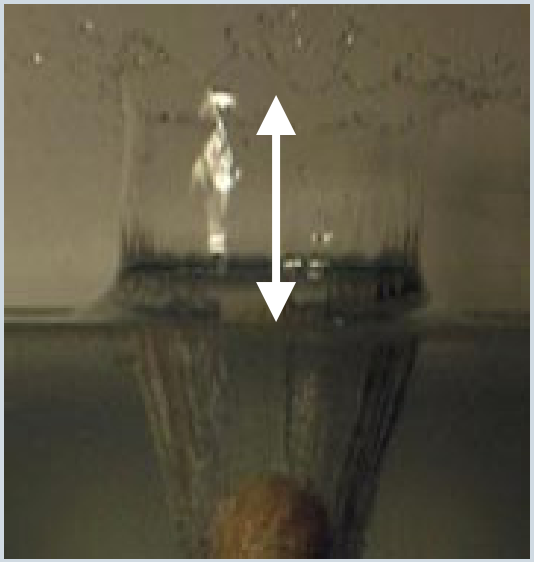
Primary splash dependence on sphere diameter

Rough splash, wooden spheres, rough surface

Sphere diameter: 0.5 – 5.2 cm



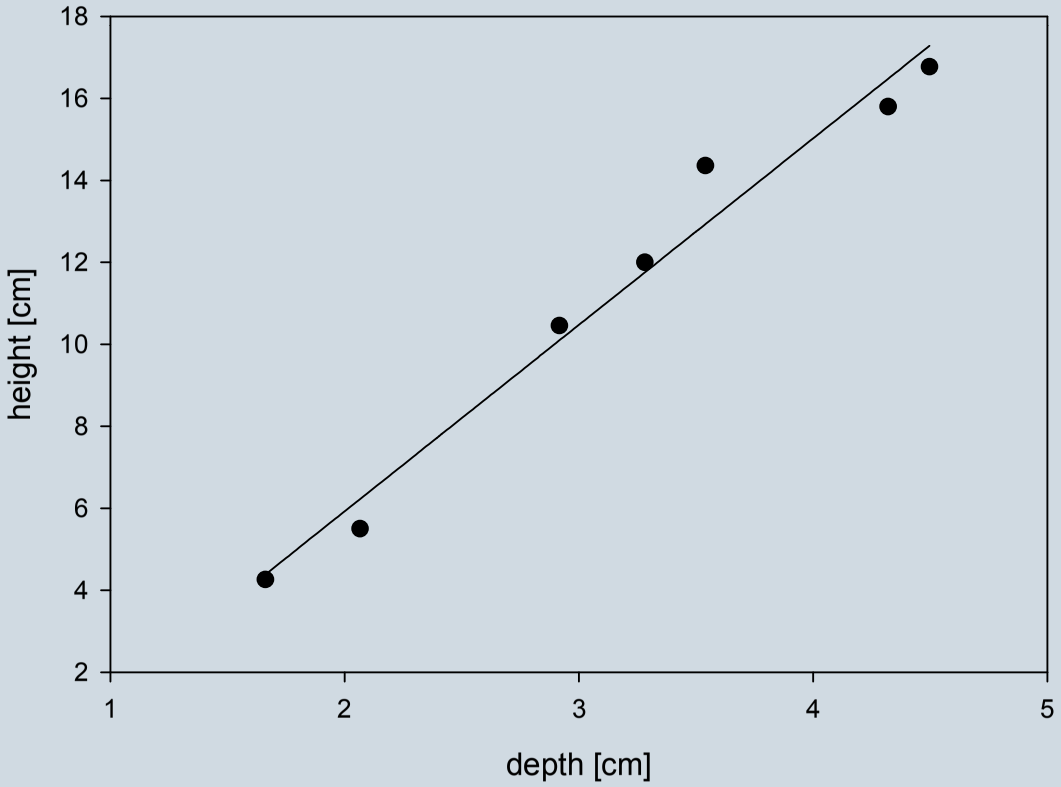


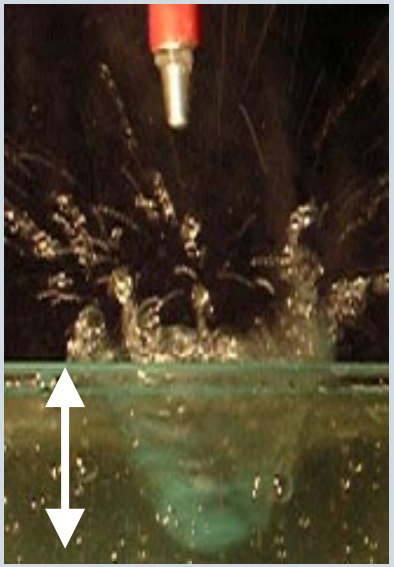


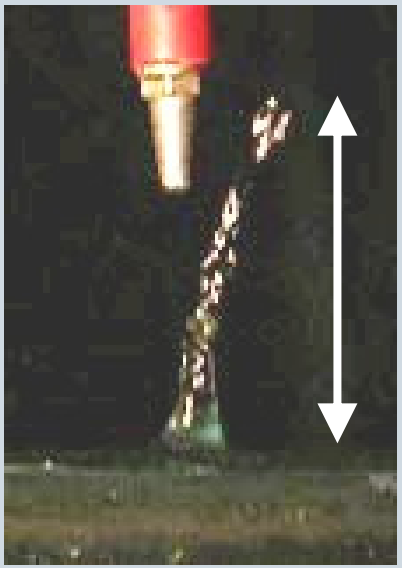
Splash dependence on size of air column

Simulating a rough splash by using air compressor

Size of column: 1.6 – 4.5 cm

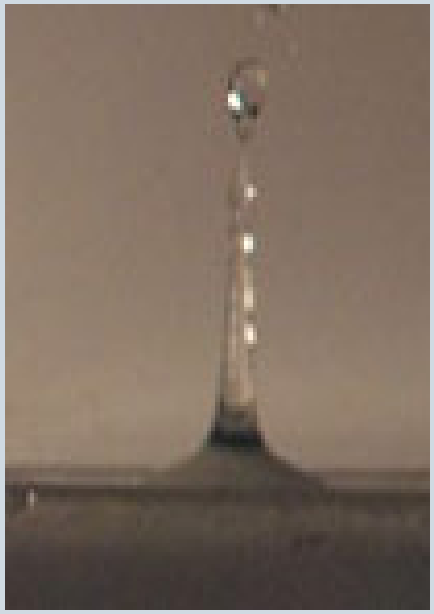






Splash dependence on surface tension

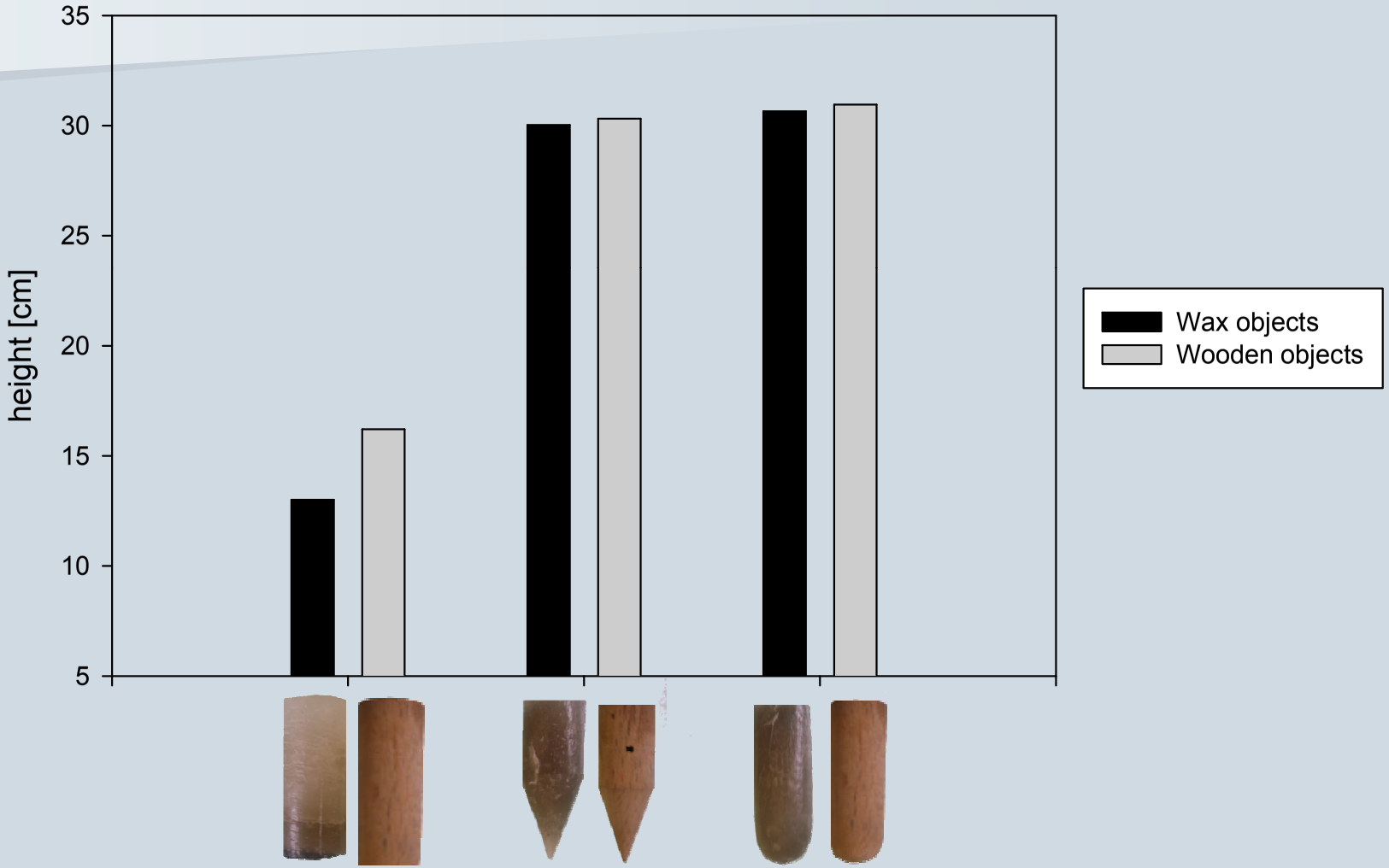
- Lowering surface tension by adding surfactant
- Splash size reduces, shape changes



Normal water

Water with surfactant

Making a splash with different objects



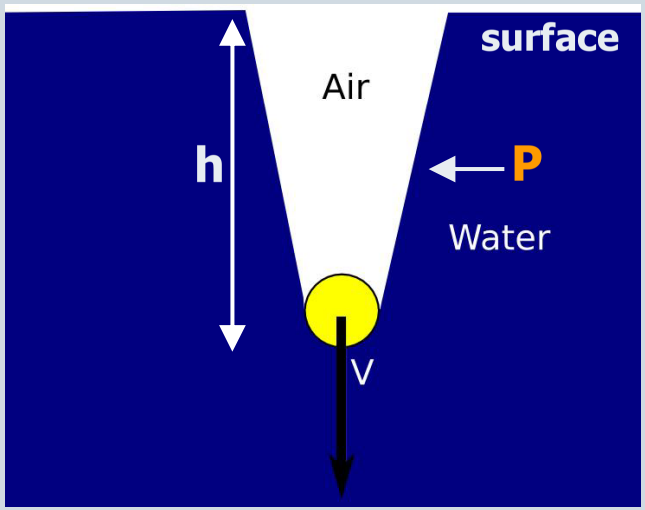
Theoretical approach – rough splash

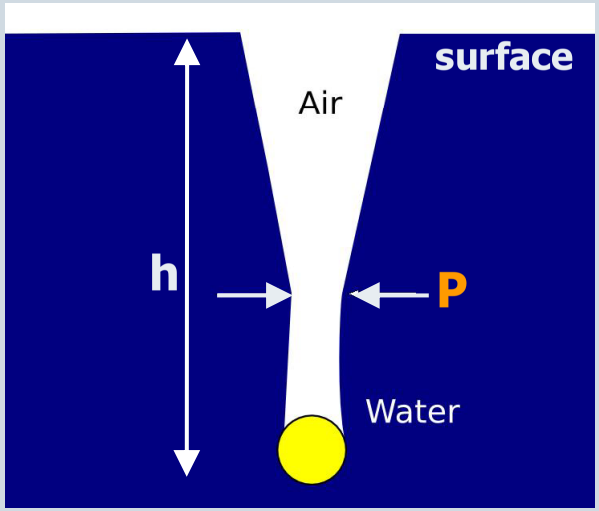
- Hydrostatic pressure

$$P = \rho g h$$

ρ - liquid density
g - gravitational acceleration
h - height of liquid above

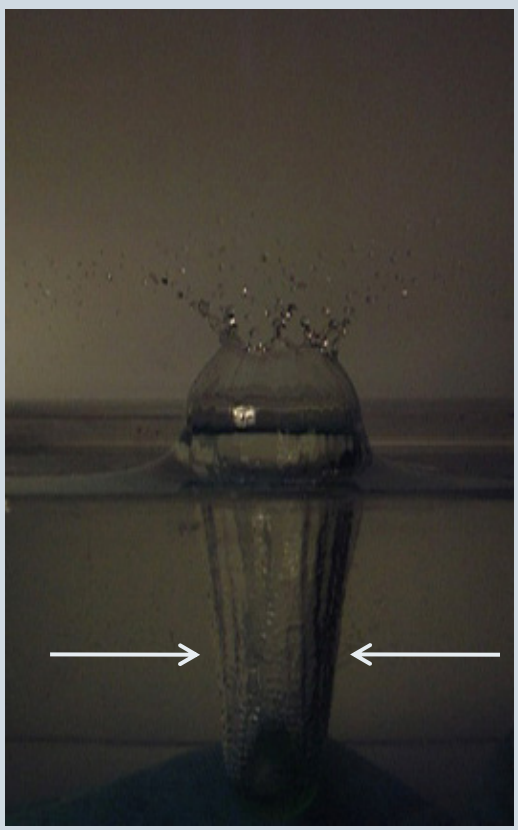
- If air column is bigger (h), hydrostatic pressure is stronger, which produces higher splash

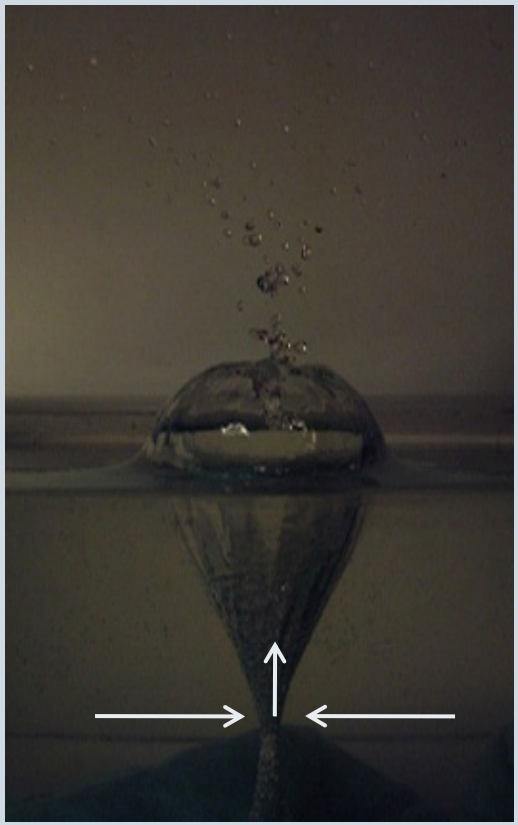


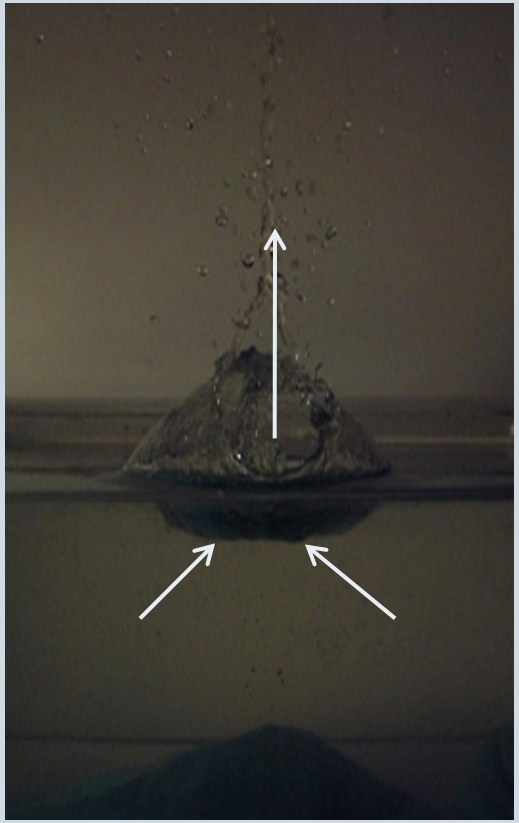


Theoretical approach – rough splash

- Air column contracts under hydrostatic pressure and water erupts producing secondary splash

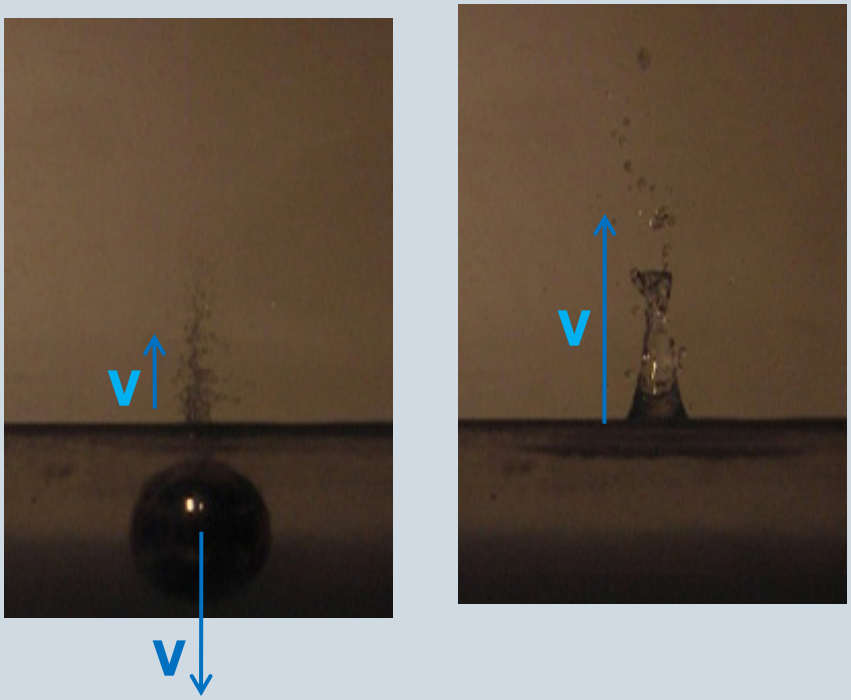






Theoretical approach – smooth splash

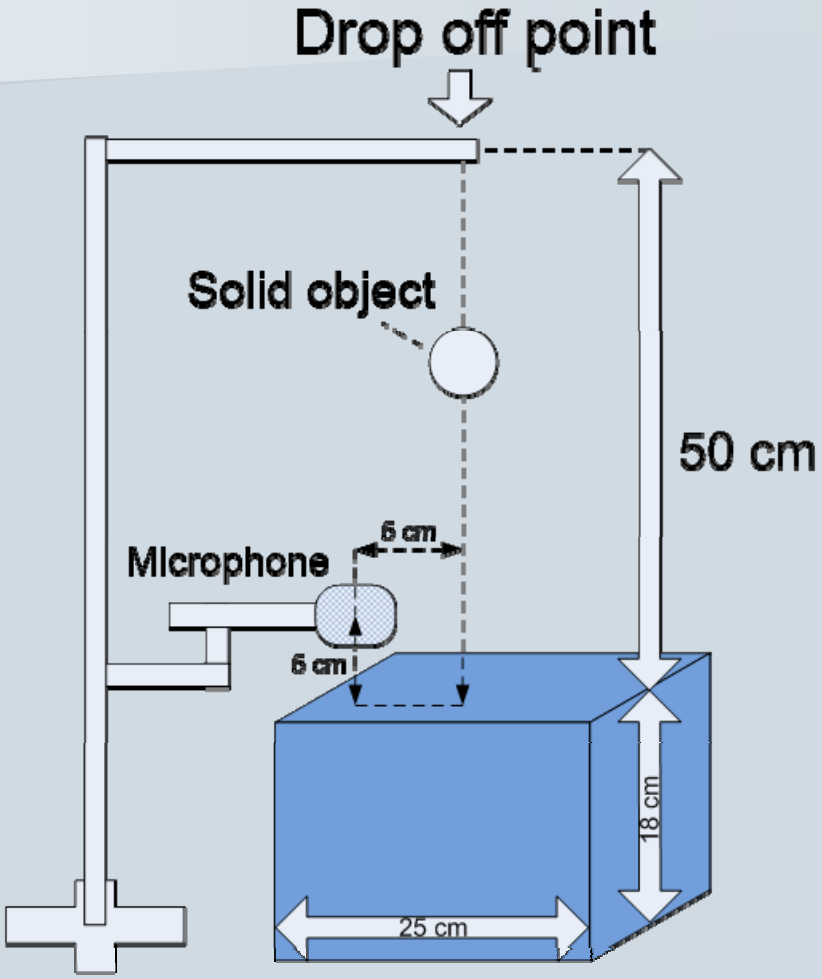
- Increasing sphere radius water speed increases and splash size increases



$$We = \frac{\rho v^2 l}{\sigma}$$

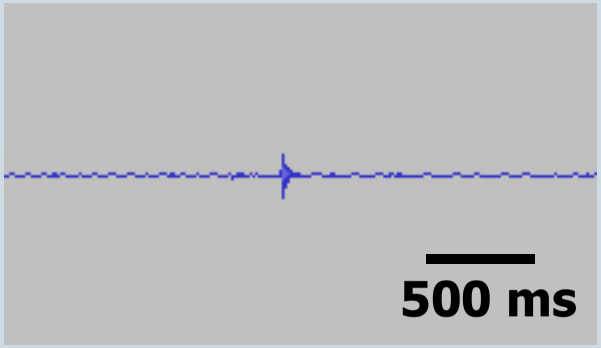
- Using Weber number we can compare objects and splash
- Spheres with higher Weber number will produce higher splash

Second experiment

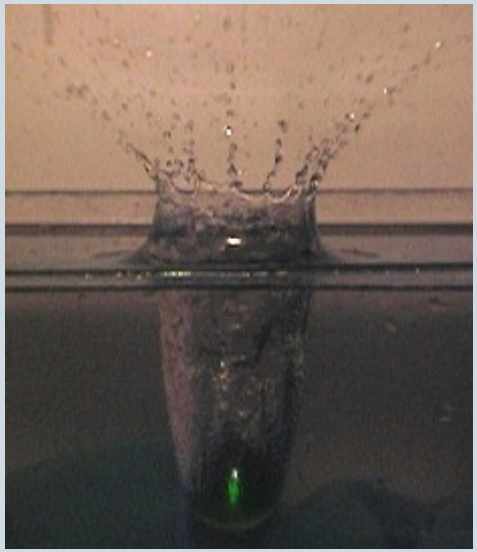


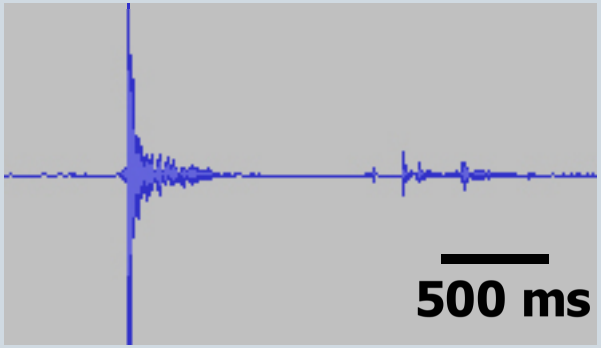
Comparison of splash type and sound

Smooth splash



Rough splash





Comparison of splash type and sound

- Smooth splash – sound with lower intensity
- Rough splash – sound with higher intensity

- Decreasing a splash (smooth or rough), the intensity of sound also decreases

Comparison of splash type and sound

- Size of the splash depends on sphere radius
  (in both cases, smooth and rough splash)
- Sphere with smallest radius produces sound with smallest intensity
- Impossible to make splash without producing sound

Conclusion

- Factors that would minimize the splash :
  - Lower surface tension
  - Object properties:
    Smooth surface
    Hydrophilic surface
    Object size (Steel spheres with radius smaller than 3,5 mm don't cause splash)

  - Sound intensity depends on the same factors

Thank you for your attention