# Spontaneous Droplet Jump with Electro-bouncing

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We investigate the dynamics of water droplet jumps from superhydrophobic surfaces in the presence of an electric field during a step reduction in gravity level. In the brief free-fall environment of a drop tower, when a strong non-homogeneous electric field (with a measured strength between 0.39 and 2.36 kV/cm) is imposed, body forces acting on the jumped droplets are primarily supplied by polarization stress and Coulombic attraction instead of gravity. The droplet charge, measured to be on the order of $2.3 \cdot (10^{-11})$ C, originates by electro-osmosis of charged species at the (PTFE coated) hydrophobic surface interface. This electric body force leads to a droplet bouncing behavior similar to well-known phenomena in 1-g, though occurring for larger drops ~0.1 mL for a given range of impact Weber numbers, $\mathbf{We} < 20$. In 1-g, for $\mathbf{We} > 0.4$, impact recoil behavior on a super-hydrophobic surface is normally dominated by damping from contact line hysteresis and by air-layer interactions. However, in the strong electric field, the droplet bounce dynamics additionally include electrohydrodynamic effects on wettability and Cassie-Wenzel transition. This is qualitatively discussed in terms of coefficients of restitution and trends in contact time.

## 1. Introduction

- Bouncing droplets, impacts on S.H. surfaces
- Motivation: phase change devices, substitute body force
- Spontaneous droplet jump
- DDT Spurrious forces

### 1.1. *Experiment description*

Study of the electrostatically bounced droplets in $/mu$-gravity conditions on square and rectangular superhydrophobic surfaces. Parametric variation in droplet volume, and surface charge density.

## 2. Analytics

- Full Navier-Stokes EHD
- Low current assumptions
- Charging time assumptions
- Free surface damping assumptions
- Water as a dielectric medium
- Equation of motion
- Far field: Coulombic with image charges
- Near field: Spherical conductor, pane of charge

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- Near field: Legendre polynomials
- Near field: Dielectrophoresis
- Characteristic time scales
- Poisson solver for potential, *Gerris*
- Reduced Bouncing model, stability, bifurcation
- Mechanism for discharging, simulation

## 3. Methods

Description of drop tower operations.

### 3.1. *Superhydrophobic surfaces*

Wetting hystersis. Methods of fabrication, comparison of wetting properties. Methods for determination of properties, roll-off angle, contact angle using *SE-FIT*. Cassie-wenzel transition. Damping.

### 3.2. *Charge*

Method of charging insulators. Surface charge density via electrostatic fieldmeter, transformations for finite surfaces, estimate of error. Milikans experient. Direct measurement of droplet charge using Faraday cup and high impedence electrometer. Sources of charge (electro-osmosis, induced charge). In-site high-precision techniques limited in drop tower context (15-g deceleration).

### 3.3. *Conductor experiment*

Measurement of fluid properties, red-dye, viscosity (per Al Jubari, un-published. Circuit diagrams. Microcontroller logic. Verification of low current $>> 1$ $\mu$A. Filming at high speed. Camera, LED panel, high shutter speed. Machined Rayleigh-plateau breakup system.

### 3.4. *Data Reduction*

Particle tracking methods using ImageJ. Data reduction (filtering, polynomial fitting, finite derivatives).

## 4. Results

- Comparison of jump velocities between surfaces.
- Qualitative discussion of bounces
- Qualitative discussion of multi-drop interactions
- Validity of the stability model
- Composite images
- ANOVA to compare variance of jump velocity to variance in charge or nonuniformity of field between tests.

## 5. Notes

### 5.1. *Bouncing on thin air*

### 5.2. *Electric field makes Leidenfrost droplets take a leap*

### 5.3. *Experimental Determination of the Charge Induced on Water Drops*

- Use of a ring shaped induction electrode. Droplet charges are a function of the electrode potential, as measured using a pico-ampmeter.
- The electric field attracts free charge in a continuous conductor, which leads to net charged drops by mass separations (e.g. induced charge) during droplet breakup. This requires that the time interval between breakups is sufficient for charge redistribution in the source liquid. This is distinct from net charge separation by breakup of a electric double layer. So the net charged droplets are the result of the interplay between the external electric field, free charge in a conductive stream, and the Rayleigh-Plateau instability.
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(Magarvey & Blackford ????)

REFERENCES

Magarvey, R. H. & Blackford, B. L. ???? Experimental determination of the charge induced on water drops **67** (4), 1421–1426.