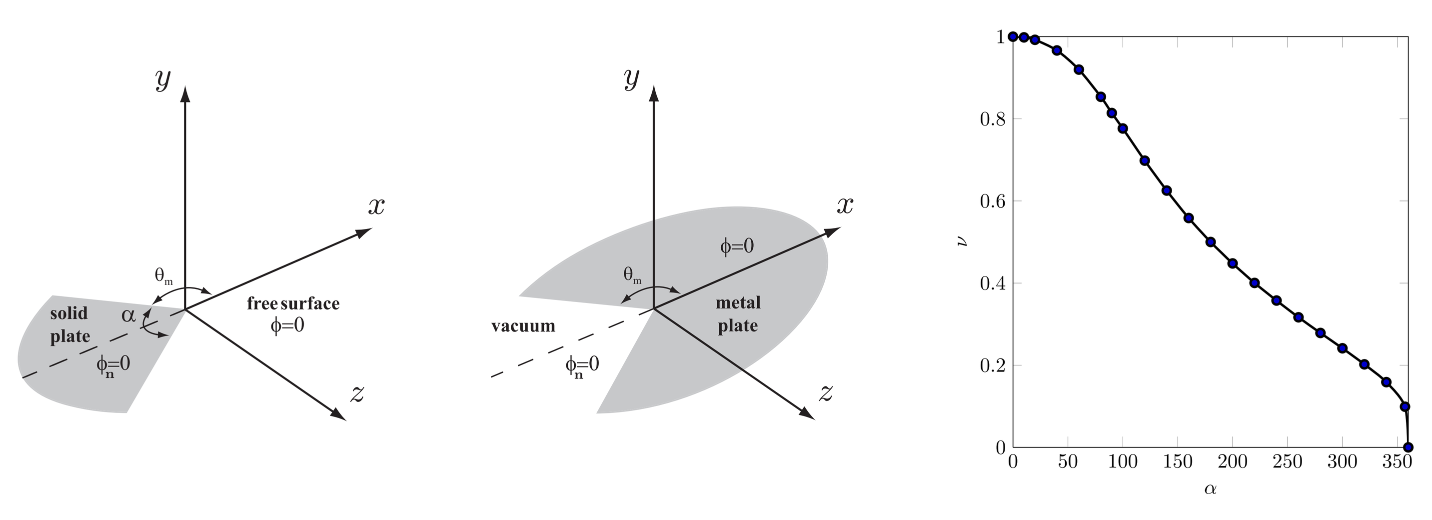
Flow around a corner: visualizing electrostatics via hydrodynamics

Roman Frolov and Rouslan Krechetnikov

On the anti-duality of the electrostatic and fluid problems



(a) Fluid problem. (b) Electrostatic problem. (c) Dependence $\nu(\alpha)$.

Figure 1 : On the anti-duality of the fluid (a) and electrostatic (b) problems [1] on the sector of angle $\alpha = 2(\pi - \theta_m)$. Figure (c) shows the general sector angle dependence for the velocity potential $\phi \sim r^{\nu(\alpha)} \Rightarrow \mathbf{v} \sim r^{\nu(\alpha)-1}$, in particular $\nu(\pi/2) = 0.814$ and $\nu(\pi) = 1/2$.

Experimental setup

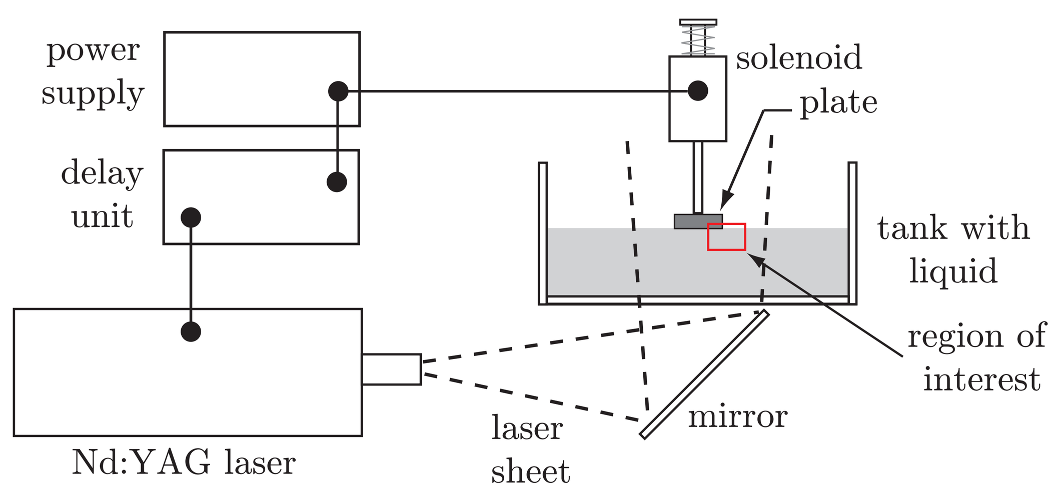
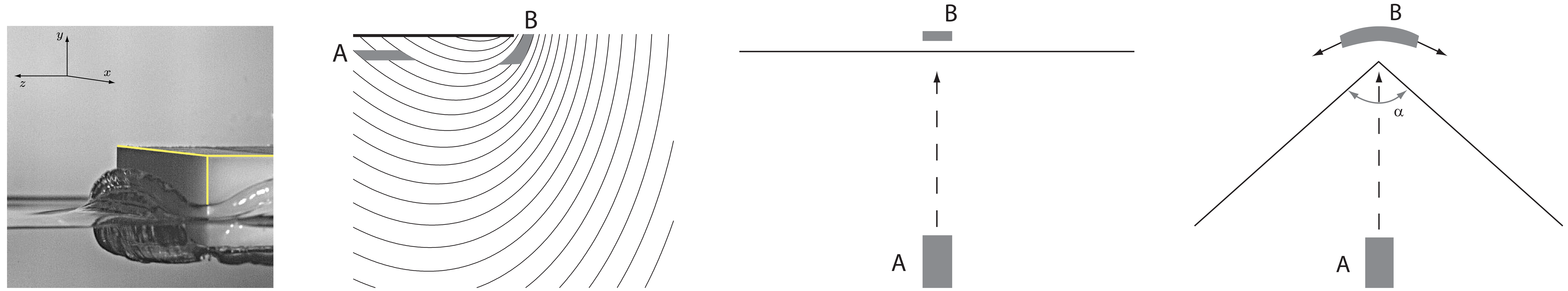


Figure 2 : A flat-bottom plate with different corner angles α is attached to a plunger of an electromagnetic solenoid, which drives it to impact the water surface. Velocity fields are obtained using a PIV system (TSI, Inc). Evolution of fluid parcels is captured by a PIV camera. Blobs of fluorescent particles are injected under the plate corners by the Harvard apparatus syringe pump (not shown) and illuminated by an expanded Nd:YAG laser beam. BNC Model 575 delay unit is used to control the photo capture timing.

Bibliography

[1] R. Krechetnikov. Flow around a corner in the water impact problem. *Phys. Fluids*, 26:072107, 2014.

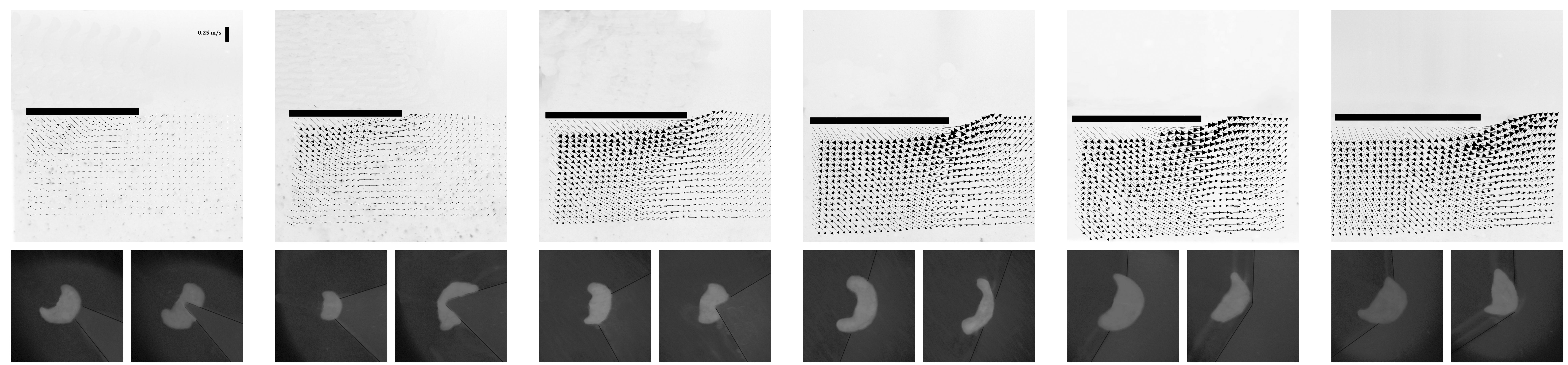
Basic idea behind the phenomena



(a) Ejecta elevation along the flat edge vs. that around the corner. (b) Cross-sectional view along the dashed lines in Figures (c,d). (c) Top view (2D, $\alpha = 180°$). (d) Top view (3D, $\alpha < 180°$).

Figure 3 : Figure (a) illustrates the *key question* on the origin of the observed difference in the ejecta elevation along the flat edge compared to that near the corner. The singular behavior close to the edge, $|\mathbf{v}| \sim r^{\nu-1}$, occurs due to the fluid parcel being squished between streamlines as it travels from underneath the plate to the free surface – the closer to the edge, the stronger the parcel stretching, cf. Figures (b,c). Fluid parcel in the 3D case (d) is being stretched sidewise (arrows) for $\alpha < 180°$ and squished for $\alpha > 180°$ as opposed to the 2D case (c).

PIV fields and fluid parcel deformations



(a) $\alpha = 30°$ (b) $\alpha = 60°$ (c) $\alpha = 90°$ (d) $\alpha = 180°$ (e) $\alpha = 210°$ (f) $\alpha = 240°$

Figure 4 : PIV measurements (top images) confirm the analytically predicted increase in the singularity of the near-the-edge velocity with α. Taken from below the impactor plate images of the blobs of fluorescent particles injected right before the impact (left) and deformed 1 ms after the impact (right) illustrate the fluid parcels deformations: no side-wise stretching for $\alpha = 180°$, sidewise stretching for $\alpha < 180°$, and squishing for $\alpha > 180°$.

Department of Mathematical & Statistical Sciences, University of Alberta, Edmonton, Canada Mail: krechet@ualberta.ca Website: http://www.math.ualberta.ca/~rkrechet/