# Espresso extraction from a bottomless portafilter

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MCEN 5151: Flow Visualization
Assignment: Get Wet

18 September 2026

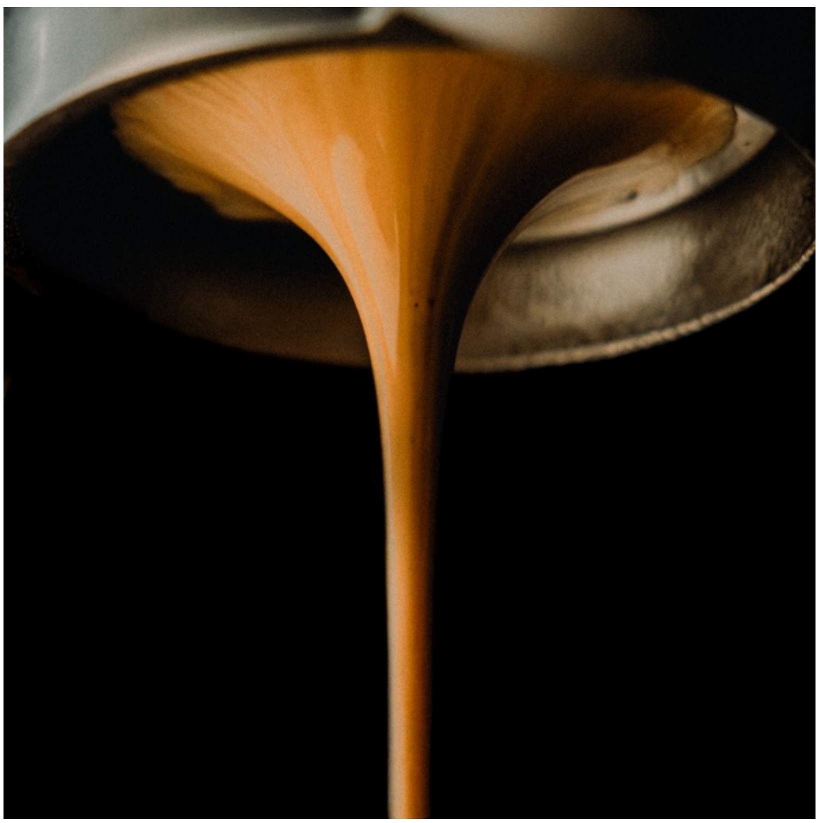

Figure 1: Espresso leaving the underside of a 54 mm bottomless portafilter basket

## Context and Purpose

This image (Figure 1) was made for the MCEN 5151 – Flow Visualization *Get Wet* assignment. My aim was to capture the interesting flow behaviors of espresso flowing out of a bottomless portafilter. In an ordinary portafilter, espresso is directed through spouts for a cleaner, more forgiving extraction. A bottomless portafilter exposes the entire bottom of the filter basket, allowing for instant visual feedback on how the espresso is flowing. Hot water is forced at 9 bar through a compacted bed of ground coffee (a porous granular medium), emerging through hundreds of small holes in the bottom of the filter basket and streaming down into a cup below. Baristas use bottomless portafilters to judge how evenly a shot is extracting. An even extraction will result in one smooth jet (see Figure 1), while an unevenly packed bed will result in uncontrolled spurts.

My intent was to capture visually-interesting features of a well-extracted shot. I shot photos from the first viscous drops to the steady-state jet to the final sputter. Figure 2 shows the first few viscous honey-like drops of the extraction. This was initially my favorite photo, but ultimately decided the multiple streams were distracting and didn't showcase the uniform flow behavior I intended. My final image, Figure 1, shows the convergence of the many small streams into a single sheet of liquid clinging to the underside of the filter basket, then converging into a gravity-driven jet that narrows as it accelerates. I also wanted the image to feel at-home in a coffee magazine or hung on a wall, with the caramel-colored liquid isolated against a black background.

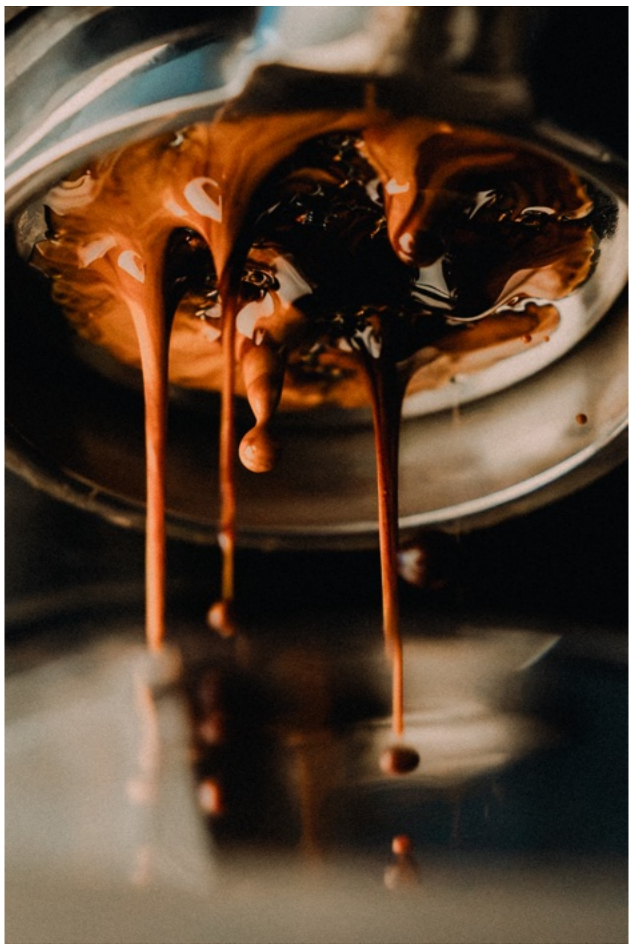

Figure 2: First viscous drops of espresso emerging from the filter basket.

## Flow Apparatus and Physics

I used a Breville Bambino Plus with 18 g of ground coffee in a 54 mm bottomless portafilter to pull a 36 g shot of espresso in 20 sec. Breville states that the machine heats water to 93 °C and brews at 9 bar of pressure. Figure 3 shows a schematic of the espresso flow and imaging setup, including dimensions of the portafilter.

The flow can be examined in three phases, each governed by different forces: flow through the packed coffee grounds, a thin liquid sheet coalescing on the underside of the filter basket, and a free, gravity-driven jet. I will cover flow through packed coffee grounds and a free, gravity-driven jet below.

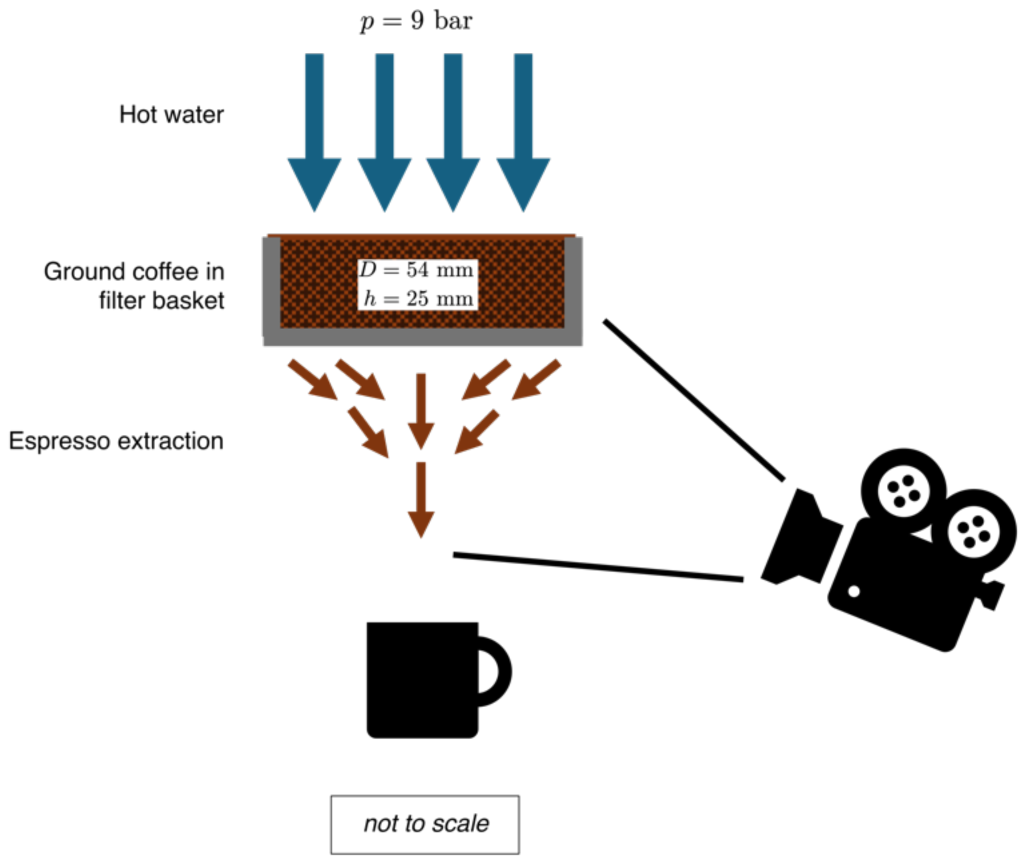


Figure 3: Schematic of the espresso flow and imaging setup

## Flow through the packed coffee grounds

The pump's pressure difference $\Delta P = 9$ bar drives water through the tamped bed (a porous granular packing). During the later part of the shot, the mass flow rate was 3 g/s, and taking the density of espresso to be 1 g/mL, the volumetric flow rate $Q \approx 3 \times 10^{-6}\ \mathrm{m^3\,s^{-1}}$.

For steady flow at low pore-scale Reynolds numbers, the flow through the bed follows Darcy's law (Corrochano et al., 2015):

$$Q = \frac{KA}{\mu L}\,\Delta P, \tag{1}$$

where $A = \pi D^2/4 = 2.3 \times 10^{-3}\ \mathrm{m}^2$ is the basket cross-sectional area, the puck depth $L = 25$ mm, the viscosity of water at 93 °C $\mu \approx 3.1 \times 10^{-4}\ \mathrm{Pa \cdot s}$, and bed permeability $K$. If we solve for $K$:

$$K = \frac{\mu L Q}{A\,\Delta P} = \frac{(3.1 \times 10^{-4}\ \mathrm{Pa \cdot s})(0.025\ \mathrm{m})(3 \times 10^{-6}\ \mathrm{m^3/s})}{(2.3 \times 10^{-3}\ \mathrm{m^2})(9 \times 10^{5}\ \mathrm{Pa})} \approx 1 \times 10^{-14}\ \mathrm{m}^2, \tag{2}$$

which falls within the $10^{-14}$–$10^{-13}$ m$^2$ range measured for espresso packings by Corrochano et al. (2015). The packing of grains provides enough resistance against the flow to balance the pressure applied by the machine. In a well-pulled shot, espresso oozes from the basket with no turbulence. Because local flow rate is directly proportional to $K$, any areas of lower packing density (such as cracks or voids) in the puck result in a higher flow rate, known as "channeling." Water will always take the path of least resistance through a granular packing, so any inconsistencies result in uneven extraction and are a main source of variability between shots (Cameron et al., 2020; Moroney et al., 2019). If using a bottomless portafilter, a single, centered jet is a visual indicator that the permeability was nearly uniform across the puck, and any spurts or off-centered flow is a sign of inconsistencies or channeling.

### Free, gravity-driven jet

Measured from the image, the diameter of the converged espresso jet is approximately $d \approx 3$mm, so the velocity can be calculated:

$$U = \frac{4Q}{\pi d^2} = \frac{4\left(3 \times 10^{-6}\,\mathrm{m}^3\,\mathrm{s}^{-1}\right)}{\pi\left(3 \times 10^{-3}\,\mathrm{m}\right)^2} \approx 0.4\,\mathrm{m/s}. \tag{3}$$

The Reynolds number is:

$$Re = \frac{Ud}{\nu} = \frac{\left(0.4\,\mathrm{m\,s}^{-1}\right)\left(3.0 \times 10^{-3}\,\mathrm{m}\right)}{3.3 \times 10^{-7}\,\mathrm{m}^2\,\mathrm{s}^{-1}} \approx 4 \times 10^3 \tag{4}$$

*Note: This is an upper bound on* Re, *since $\nu$ is higher for espresso than pure water, and we use $\nu$ of pure water in this calculation. The flow likely has a lower* Re *than this approximation.*

Espresso carries roughly 10% dissolved solids (Mestdagh et al., 2017), so the liquid is more viscous than water. A Reynolds number of $4 \times 10^3$ is within the transitional region, but the jet of espresso flowing from the portafilter looks laminar. The best evidence of this is the "tiger-striping." With no turbulent mixing, the color differences from different regions of the packing, caused by varying levels of extraction, result in smooth streaklines that allow us to visualize the history of the flow.

## Visualization Technique

This flow visualization was simple. No tracers or dye were added to the espresso, even though "tiger striping" is visible in the espresso flow, a visually-appealing pattern resulting from differing concentrations of crema throughout the flow. The "tiger striping" acts as streaklines, allowing us to trace the flow over time. I used a diffuse lamp to illuminate the flow from the bottom-left side. This allowed the background to stay dark and improves visualization of the 3D curvature of the jet.

## Photographic Technique

The field of view was approximately $70 \times 70$ mm. The distance from the lens to the flow was approximately 0.5 m. I used a Canon EOS R6 Mark II digital camera with a Canon RF 24 – 70 mm $f/2.8$ lens. This image was shot at 70 mm, $f/5$, 1/2000 s, and ISO 10,000. The original image was 4000 × 6000 px and the final cropped image was 2283 × 2283 px. See Figure 4 for the original, unedited image.

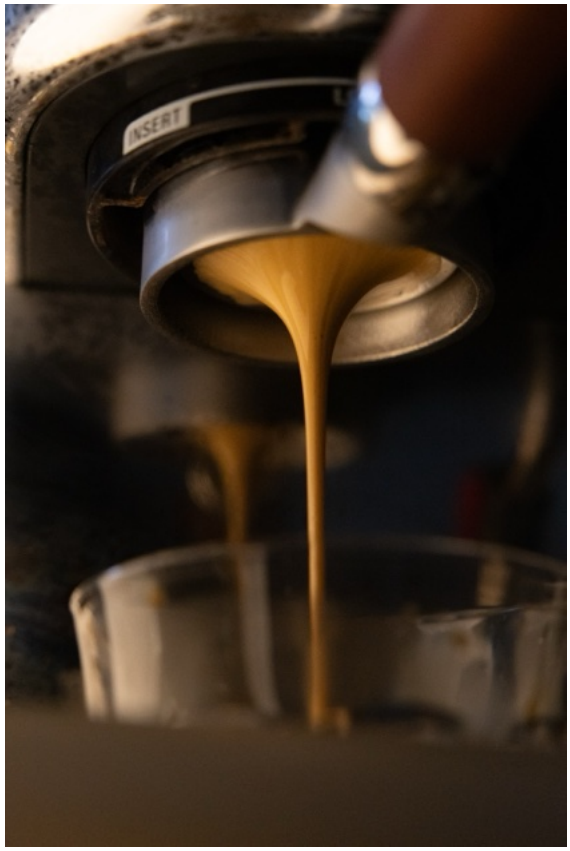


Figure 4: Unedited image

## Discussion

My image shows an inverted cone of espresso coalescing into one honey-like jet that thins as it falls into a cup below. I am happy with the quality of the image, the cropping, and the color grading. I could imagine this image being printed in an advertisement or hung on the wall of a coffee shop. I think the "tiger stripes" are useful streaklines, allowing viewers to trace the path of the espresso as it converges from the filter basket into a jet. This espresso shot came out slightly faster than I would have preferred, so if I were to do this again, I'd grind the coffee finer to achieve a slower flow.

## References

Michael I. Cameron, Dechen Morisco, Daniel Hofstetter, Erol Uman, Justin Wilkinson, Zachary C. Kennedy, Sean A. Fontenot, William T. Lee, Christopher H. Hendon, and Jamie M. Foster. Systematically Improving Espresso: Insights from Mathematical Modeling and Experiment. *Matter*, 2(3):631–648, March 2020. ISSN 2590-2393, 2590-2385. doi: 10.1016/j.matt.2019.12.019. URL `https://www.cell.com/matter/abstract/S2590-2385(19)30410-2`.

B. R. Corrochano, J. R. Melrose, A. C. Bentley, P. J. Fryer, and S. Bakalis. A new methodology to estimate the steady-state permeability of roast and ground coffee in packed beds. *Journal of Food Engineering*, 150:106–116, April 2015. ISSN 0260-8774. doi: 10.1016/j.jfoodeng.2014.11.006. URL https://www.sciencedirect.com/science/article/pii/S0260877414004737.

Frédéric Mestdagh, Arne Glabasnia, and Peter Giuliano. Chapter 15 - The Brew—Extracting for Excellence. In Britta Folmer, editor, *The Craft and Science of Coffee*, pages 355–380. Academic Press, January 2017. ISBN 978-0-12-803520-7. doi: 10.1016/B978-0-12-803520-7.00015-3. URL https://www.sciencedirect.com/science/article/pii/B9780128035207000153.

Kevin M. Moroney, Ken O'Connell, Paul Meikle-Janney, Stephen B. G. O'Brien, Gavin M. Walker, and William T. Lee. Analysing extraction uniformity from porous coffee beds using mathematical modelling and computational fluid dynamics approaches. *PLOS ONE*, 14(7):e0219906, July 2019. ISSN 1932-6203. doi: 10.1371/journal.pone.0219906. URL https://journals.plos.org/plosone/article?id=10.1371/journal.pone.0219906.