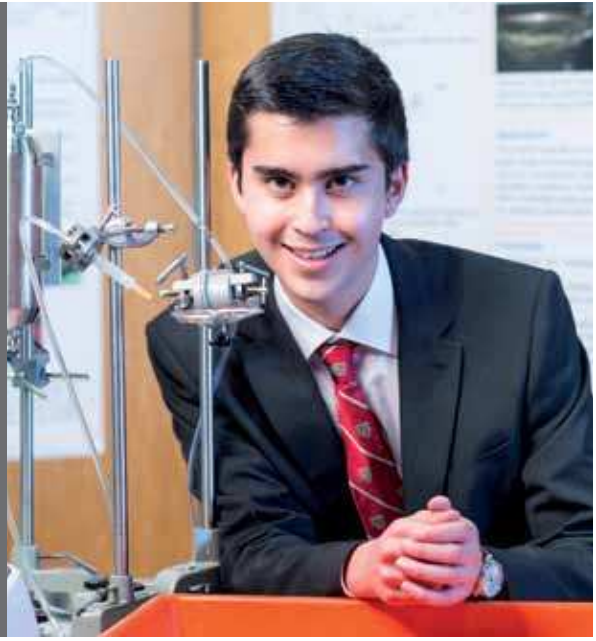

Eric Schertenleib, 1994
Küsnacht, ZH

Rämibühl-MNG
Daniel Keller

Würdigung durch den Experten
Albert Fässler

In Abhängigkeit des Eintrittswinkels eines Flüssigkeitsstrahls in eine ebene Seifenlamelle (Film) und der dimensionslosen Weberzahl werden die möglichen Fälle theoretisch und experimentell untersucht. 1. Refraktion: der Strahl durchdringt gebrochen den Film, analog zur Optik. 2. Absorption des Strahls in den Film. 3. Kritisches Übergangsgebiet zwischen Refraktion und Absorption. Das mathematische Modell einer Publikation wird zu Recht kritisiert. Darüber hinaus wird sogar ein verbessertes Modell konstruiert, das die Messresultate der aufwändigen physikalischen Experimente gut beschreibt.

Prädikat: Hervorragend
Sonderpreis Aldo und Cele Daccò
European Union Contest for Young Scientists (EUCYS 2014)

Jet and Film – On the interaction between a laminar jet

Introduction
I came in contact with this phenomenon through the International Young Physicists' Tournament, IYPT. For the 2013 tournament in Taiwan, they stated the following problem: «Jet and Film: A thin liquid jet impacts on a soap film. Depending on relevant parameters, the jet can either penetrate through the film or merge with it, producing interesting shapes. Explain and investigate this interaction and the resulting shapes.»

Methods
By studying previous literature, we could determine what requirements our set-up must meet. For our experiments we used a membrane pump capable of sustaining a flow rate of up to 100ml/min and a maximal pressure of 6bar. To produce the jet, we used 10 medical injection needles of different diameters, ranging from 0.21mm to 0.84mm. The soap films were enclosed with different wire rings with diameters of 2.5cm to 23cm. The film and the jet are made of soap-water solutions of different concentrations. I used a camera with a strong zoom and then analyzed the images using «Logger Pro». All experiments were conducted under laboratory conditions.
The theoretical approach is mainly based on dimensional analysis, namely the use of the Weber number, as well as on force balance.

Results
Through experimental observations, one can conclude that there are a total of three «resulting shapes», each characteristic of a certain regime. The regimes are called absorption, refraction, and a critical regime (at which the transition occurs).
A major part of my investigation was focused on the critical regime, since the transition is largely unexplained. Using dimensional analysis, I could show that for a perpendicularly impacting jet, the critical jet velocity squared is proportional to one over the jet diameter squared. In addition, I derived a relation stating that the size of the film is an important quantity for the transition.
I derived and experimentally verified a phase diagram which predicts the boundaries of each regime and which is only dependent on the Weber number and the incident angle of the jet. In addition, I could observe that the transition between absorption and refraction occurs when the refracted angle θ_r reaches (70 ± 5)°.
In the absorption regime I was able to observe a characteristic wave formation which occurs when the jet undulates upon the film. I could verify that the wavelength is proportional to the Weber number.

Discussion
Overall, I reached a very good correlation between measurements and theory, with an average correlation coefficient of 96%. Due to the high precession of my pump, I was able to limit experimental errors. The major sources of errors are the values for the surface tension and errors from the image evaluation.
A real novelty of my paper is the investigation of the critical regime. I was able to show that for larger film diameters, the weight of the film becomes increasingly important and influences the transition.
For the refracted regime, I highlighted that the similarities to its counterpart in optics are rather limited and its name is thereby misleading. I showed that a previous study had major theoretical shortcomings in this regime, in particular the use of invalid assumptions and approximations. In addition, they failed to acknowledge that the transition occurs when the refracted angle θ_r reaches (70 ± 5)°. I was able to derive the governing relations without these approximations and could derive a phase diagram. I extensively discussed possible explanations for why $\theta_r$never reaches 90°.

Conclusions
The initial goal was to explain and investigate the interaction and the resulting shapes. I not only succeeded in reaching this goal, but also managed to predict the boundaries of each regime. I was able to show that the relevant parameters that govern this interaction are the Weber number and the incident angle of the jet. In addition, I was able to point out some theoretical shortcomings in the only previous publication in this field.
For future research, I would find it highly interesting to work further on the theoretical foundation of this phenomenon in which θ_r never reaches 90°. This would hopefully lead towards a quantification of the effect that the impacting jet has on the surface minimization of the soap film. θ_r never reaches 90°. A deeper understanding of this is of importance for all processes involving the control of mixing between two liquids, such as in the chemical industry or firefighting.