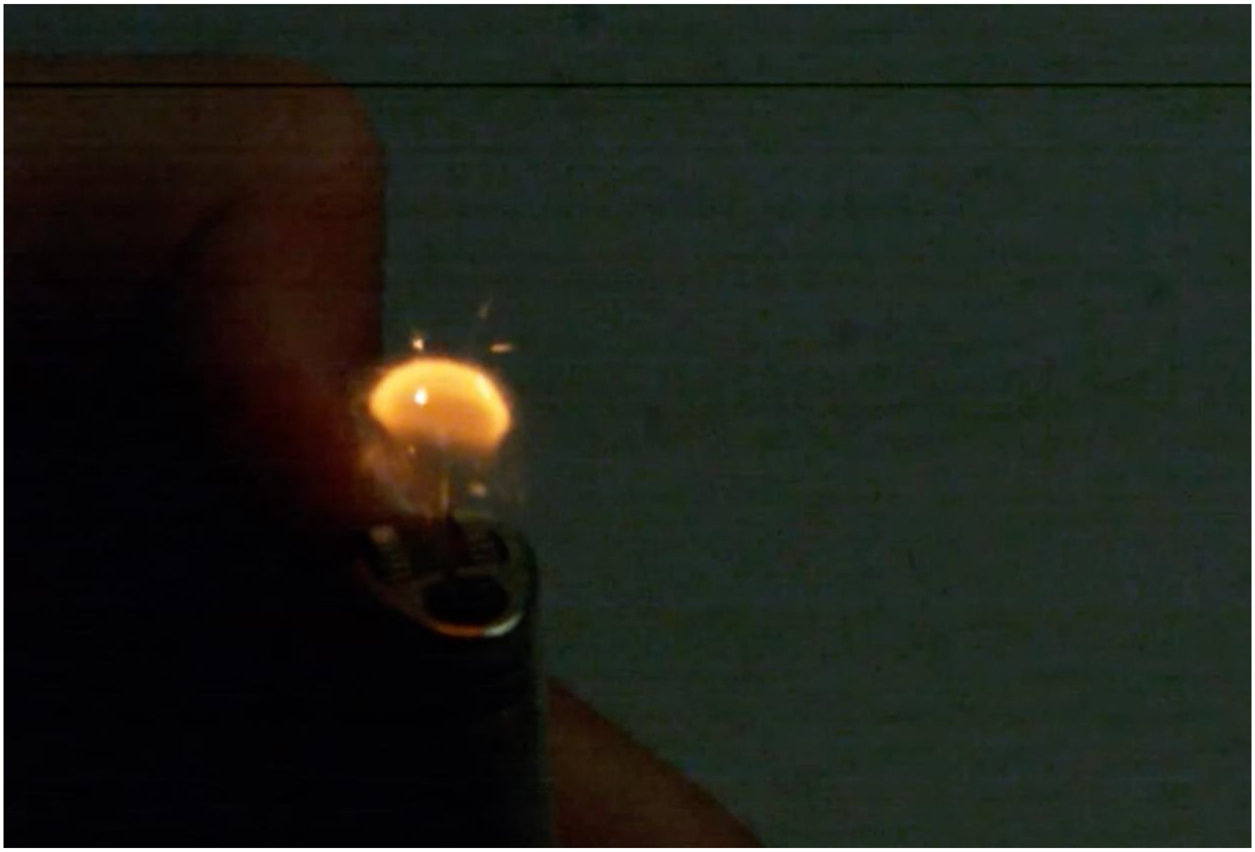
IV4 Report:

Using a High-Speed Camera to Lighter Ignition



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Nov. 16, 2022

Introduction:

In this project, I worked with Alex Kelling, Ben Carnicelli, and Nathan Gallagher to explore the ignition of aerosolized lighter fuel, using a high-speed camera. The components required for this project include:

- Phantom Miro C110 High-Speed Camera
- Lighter
- Tripod
- Concentrated light source

As mentioned in the IV3 report, high-speed cameras can be incredibly finnicky, so be prepared for several false starts as you calibrate resolution, framerate, focus, and lighting. In order to document the flow accurately with the high-speed camera, you must understand the visual conditions of the flow you are trying to create. For IV3, the flow had low a low contrast range, so we had trouble providing enough light to illuminate the entire field of view. However, for this experiment we had to illuminate much more conservatively, as the flame created a large light contrast. As with IV3, if you plan to use a high-speed camera, you the following order of operations for experimental setup worked best for us:

1. Choose shooting location based on where your field of view is
2. Place camera and calibrate focus based on your field of view
3. Place object in field of view
4. If necessary, shift lighting source
5. Take practice videos to calibrate entire system

Flow Description:

For this experiment, we pursued the following process to document the flow phenomenon.

1. Have one individual standby with the high-speed camera, while another waits to ignite the lighter
2. Trigger the camera, and continually ignite the lighter
3. You should "flick" the lighter several times, to ensure the most dramatic video!

For a visual depiction of this process, reference the diagram in Appendix A. The documentation method is further elaborated upon in *Experimental Procedure* and *Camera Settings*. T

To understand the kinetic behavior of the butane being released from the lighter, we can calculate the Reynold's number. This dimensionless number indicates whether the flow is laminar or turbulent, "smooth" or "rough". Based on Tinh (2010), the Reynold's number can be calculated using the velocity of the fluid (V), the characteristic length of the flow (L), and the kinematic viscosity of the fluid (v). If the kinematic viscosity is unavailable, this variable can be replaced with the fluid density (ρ) over the dynamic viscosity (μ)[1]. These are derived below in Eq. 1.

$$Re = \frac{VL}{v} = \frac{\rho VL}{\mu} \tag{1}$$

Because of a lack of discernable information on combusting butane, the physical properties below are of stable, gaseous butane at 30 C. The velocity of gas leaving a Bic lighter, the one we used, was approximately 3.14e-9 m/s^2[2]. The density of the butane in the lighter was approximately 2.372 kg/m^3 [3], the characteristic diameter of the lighter was about 0.001 m, and the dynamic viscosity is 7.436e-5[3].

$$Re = \frac{\rho VL}{\mu} = \frac{(2.372)(3.14e-9)(0.001)}{(0.00007436)} = 1.001\mathrm{e}-7$$

The resultant Reynold's number is 1.001e-7, implying a highly laminar flow. It should be noted that this Reynold's number is indicative of the butane at the fuel outlet, not of the flame itself.

Experimental Procedure:

The experimental procedure for this project was quite rudimentary. Most of the heavy lifting was sourced from the camera setup, as opposed to the actual flow visualization. After taking the time to ensure we had appropriately placed the camera and other accessory items, we were able to document this process in a matter of minutes.

We set out with several goals with in experiment: to create enough contrast with the experimental setup, to frame the shot correctly to catch the sparks "dancing" off the flint, and to capture enough butane combustion to show the heat profile of the flame. In order to ensure we appropriately met these goals, we essentially had to take a trial-and-error approach. After framing the lighter correctly and triggering the camera, we checked our takes to make sure the flow was framed correctly.

Lighting for this experiment was rather simple. Because we were isolating the sparks, and the flame itself, we left ourselves with very little work to do. The Phantom Miro has quite a dark exposure as a result of the frame rate. We therefore opted to test different takes with different lighting schemes. Ultimately, we found that excluding any light other than the natural light being emitted from a window created the desired contrast in the shot.

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[1] Trinh, T. (2010). On The Critical Reynolds Number for Transition From Laminar To Turbulent Flow

[2] Sluka, J. (n.d.). A Fuel Meter From A Disposable Butane Lighter. Fuel meter from a disposable butane lighter. Retrieved November 19, 2022, from http://www.inpharmix.com/jps/Fuel%20Meter%20From%20A%20Disposable%20Butane%20Lighter.html

[3] Butane - dynamic and kinematic viscosity vs. temperature and pressure. Engineering ToolBox. (n.d.). Retrieved November 18, 2022, from https://www.engineeringtoolbox.com/butane-C4H10-dynamic-kinematic-viscosity-temperature-pressure-d_2078.html.

Camera Settings:

We used the same camera, and camera settings in this experiment as our IV3 report. We used the Phantom Miro C110 camera, loaned out from the Integrated Teaching and Learning Laboratory (ITLL). The Miro C110 specs were sourced online, and can be found in *Table 1* below[4].

Spec	Description
Camera Type	Phantom Miro C110
Field of View	6" x 4"
Distance from Object to Lens	5'
Focal Length	18mm
Frames per Second	1,200
Video Resolution	1024 x 768

Table 1: Camera settings and lens specs

To produce this video, I used Adobe Premiere Pro. The only editing additions were the title slide, as well as the dissolving transitions between different cuts.

Conclusions:

In terms of exploring the capabilities of the high-speed camera on a new flow visualization technique, I feel this experiment was successful. We framed our shot well, and appropriately visualized the sparks flying off the lighter, as well as the heat profile of the flame itself. The real advantage of the high-speed camera was being able to document the entire life-cycle of such a short/delicate process. From ignition to suppression, we were able to capture a long form, high-definition video, which is interesting!

There are several improvements that could be made if this experiment were conducted again. Firstly, we could prioritize the flow over the method. After writing this report, I have further understanding on the limitations of using a high-speed camera. While I do believe that I accurately portrayed a flow pattern, purposefully, I also believe that I perhaps did not push it as far as I could have because of how well the videos turn out on the high-speed camera. In another iteration, I would be more concerned with the framing, as well as the physics behind the lighter mechanism. Another area of potential improvement is further exploration of the flame's physical properties, instead of those from the butane. The dynamics of the flame, as well as the mixture of butane and air, make it extraordinarily fickle to understand the system's kinetic behavior. With more notes at the time of experimentation, I believe that we could have yielded a better understanding of the lighter's physical behavior.

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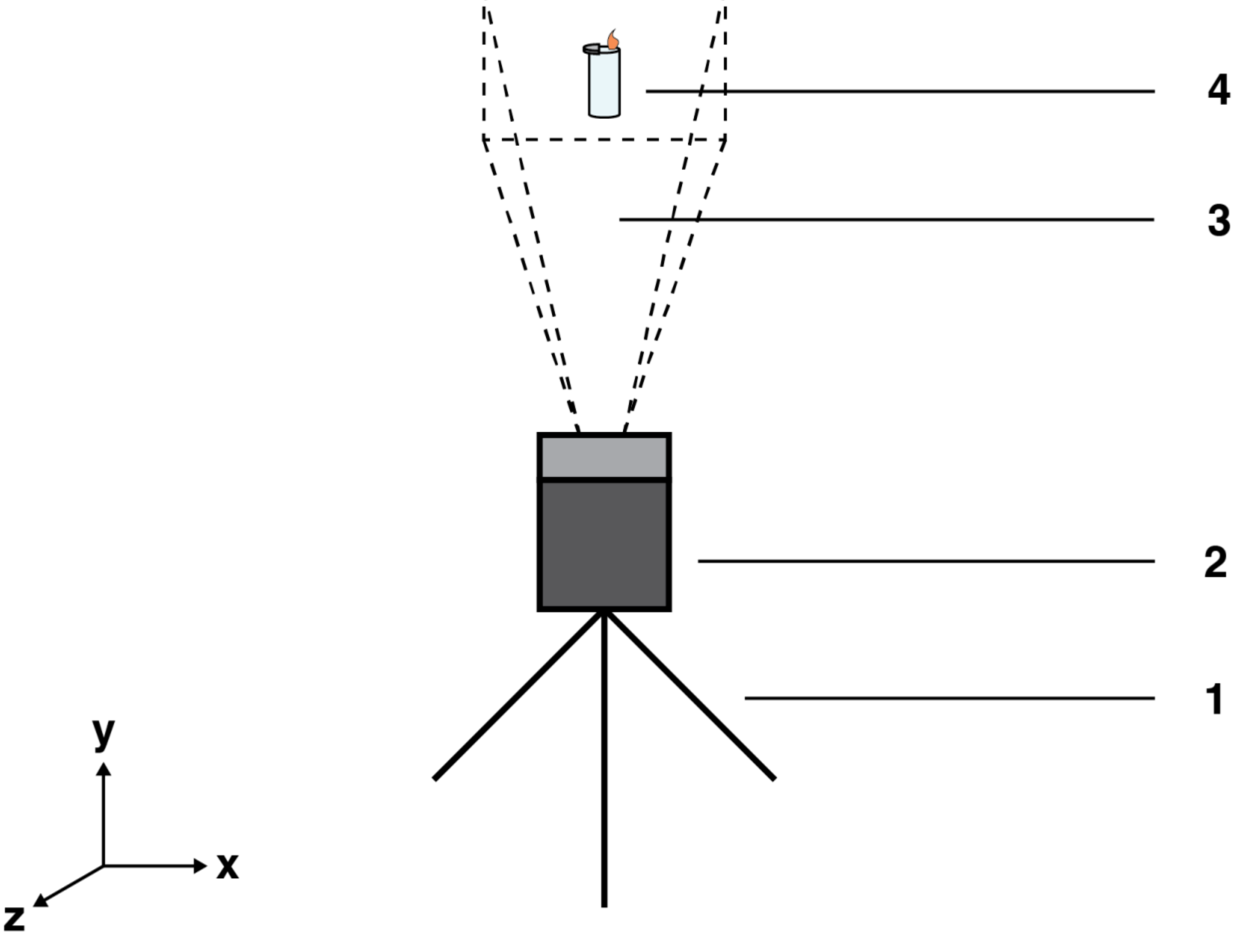
[4] Phantom Miro C110 high-speed camera. Darwin Microfluidics. (n.d.). Retrieved November 8, 2022, from https://darwin-microfluidics.com/products/phantom-miro-c110-high-speed-camera?variant=37445731680420

Appendix A



Component Ref.	Description
1	Tripod
2	Camera
3	Constrained field of view
4	Lighter