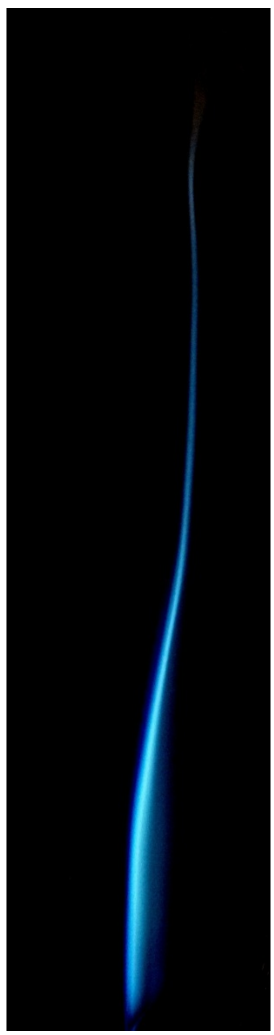
Team Second Image



This image was taken in an attempt to capture an example of laminar smoke. The image captures a smoke plume from an extinguished match rising.

The set up for the experiment was simple but effective. A flash light was placed behind a metal box and propped up in a position in order to illuminate the smoke plume. A match was then lit and held over the light. The bottom part of the match was soaked in water previous to the test in order to extinguish the match in a controllable fashion. As the smoke plume rose the images were taken. In order to control the environment the experiment was carried out in a large room with all of the windows shut. The room was at room temperature at the time of the experiment. As a safety precaution there was a bowl of water to deposit used matches into and a fire extinguisher nearby in case of the surrounding materials were to catch on fire. The entire set up was in front of a black backdrop in order to help the smoke plume stand out.

The image shown captures the buoyant forces caused by the heating of the air surrounding the hot match carrying soot particles from the match up into the air. As the air heats up it changes how it acts with the surrounding air. The effect the heat from the match has on the surrounding air can be explained using the Ideal Gas law $PV = nRT$ In the experiment Pressure, number of moles being studied and the gas constant will not change. In the small area around the match the pressure will not change because the gas is not confined in a container and can expand in order to equalize with the surrounding pressure. The number of moles remains constant even though the volume may increase. Thus in a system such as this the Volume and Temperature are related. As the temperature increases the volume the studied parcel of air takes up must increase as well. This results in the same amount of air taking up a larger area which results in a decreased density. This less dense air then rises through the surrounding parcels of air carrying the soot with it.

In the image the smoke trail is laminar and dissipates prior to becoming turbulent. The type of flow can be deterred mathematically by using the Reynolds number[1]. The remolds number is shown below and is solved for by using density (ρ), Velocity of the fluid (V), the characteristic length (L), and the dynamic viscosity of the fluid (μ).

$$Re = \frac{\rho V L}{\mu}$$

For the flow to be laminar the Reynolds number must be below 2300[1]. By assuming that the flow is indeed laminar we can solve for the velocity. If the velocity is a reasonable value then it is confirmed that the flow is laminar. The viscosity of air at 20 deg c is $1.58\text{x}10^{-5}\text{m}^2/\text{s}$. The density of the air can be assumed to be 0.960 kg/m3[3] here in Boulder. The length of the plume was just over 8 inches which is

.203 m. The

$$Re = \frac{\rho V L}{\mu}$$

$$V = \frac{Re * \mu}{\rho L} = \frac{2300 * 1.58 * 10^{-5}\frac{m^2}{s}}{0.960\frac{kg}{m^3} * .203m} = .189\, m/s$$

This velocity is well above what is expected for the speed of the air rising thus it is confirmed that the flow is laminar.

In order to create the flow that was captured the match was a weather resistant match found in a Meal Ready to Eat. The matches' tail was soaked in water in order to cause the flame to be extinguished in a controllable manner. This was done in order to avoid the turbulence that is created by blowing on or waving the match to extinguish it. In order to illuminate the smoke plume a flashlight was used. The flashlight used was a Nitecore MT2A, it has an output of 345 lumens and utilizes a CREE XP-G2 R5 LED[4]. The blue tint is partially a result of the blue hue that the LED outputs. The light was positioned behind the smoke in order to avoid accidentally casing shadows on the smoke plume.

The image was taken with a Sony alpha camera. The settings that the camera used to capture the image are shown in Table 1. The final image has a size of 1015x3928 pixels. In post processing I first cropped the image and then moved the tone curve. With the tone curve I moved the cutoff level for both the black and white pixels. This allowed me to force the background to become a uniform black and removed the slight variations the background that the camera picked up. By decreasing the cutoff for the white level allowed for the thin parts of the smoke plume to stand out against the background.

Setting	Value
F-Stop	f/3.5
Exposure Time	1/25 sec
ISO Speed	ISO - 3200
Focal Length	16mm
Max Aperture	6.617

Table 1 Camera Setting

This image reveals the buoyant forces that are caused by the heated air and carry up soot particles. This image reveals the laminar nature of the fluid flow. I was able to fulfil my intent of capturing the fluid flow. I would have liked to be able to include the very thin transient section shown at the top of the original image. I was unable to bring out the flow while not over exposing the main body of the laminar flow. In future setups I would recommend using a light that has a wider throw in order to make it easier to capture all parts of the smoke plume.

Figure 1 Original Image

1 Reynolds Number
"Reynolds Number." Reynolds Number. N.p., n.d. Web. 10 Nov. 2015.
<http://www.engineeringtoolbox.com/reynolds-number-d_237.html>.

2 Viscosity of Air
"Dry Air Properties." Dry Air Properties. N.p., n.d. Web. 10 Nov. 2015.
<http://www.engineeringtoolbox.com/dry-air-properties-d_973.html

3 Density of Air
Compton, Tom. "Air Density." N.p., 1997. Web. 10 Nov. 2015.
<http://www.analyticcycling.com/ForcesAirDensity_Page.html>.

4 Flashlight
http://flashlight.nitecore.com/product/mt2a