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Flow Visualization

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Get Wet Report

This report documents the first project of the Flow Visualization course, completed individually as an at-home experiment without access to laboratory equipment. The goal was to capture a flow phenomenon that was visually accessible, colorful, and physically meaningful without requiring specialized fluids or optics. Thermal convection driven by radiative heating was selected as the subject, as it represents a fundamental and well-understood heat transfer process that could be observed on the surface of a candle wax pool. The time-lapse video captures approximately 30 minutes of this process, during which a heat lamp suspended above a candle gradually melts the solid wax surface and drives surface mixing through buoyancy-driven convection. The intent was to visualize two related phenomena simultaneously: the rate at which radiative heating from the lamp liquifies the solid wax, and the surface mixing patterns that emerge as thermal gradients develop across the melt pool. A heat lamp and candle were chosen because they represent a textbook example of non-contact heat transfer—the lamp transfers thermal energy through the air via radiation, which is then absorbed by the wax surface and conducted downward through successive solid layers, continuously repeating the melting process.

The heat lamp was purchased through Amazon.com and is an incandescent/LED bulb rated at 50 watts. It was suspended approximately one inch above the lip of the candle jar during the entire experiment, with no change in position or power setting throughout the 30-minute recording. The candle was housed in a 5.5 oz forest green frosted glass jar, making the jar translucent rather than fully transparent. The candle is labelled Threshold and can be found at Target and is a blend of palm and paraffin wax. Paraffin wax, commonly used in commercial candles, has a melting point in the range of approximately 120–160°F, while palm wax has a melting point between 130-150ºF[1,2]. With the surface wax in this experiment being an unknown blend concentration of both, we can estimate the melting point to be a within a range of 125-155ºF instead of a specific temperature. The experiment was arranged on a nightstand surface 20.5 inches high, with the phone mounted on a tripod stand 6 inches high positioned approximately 5 inches from the candle jar, oriented in landscape mode. A labeled diagram of this setup is provided as **Figure 1**.

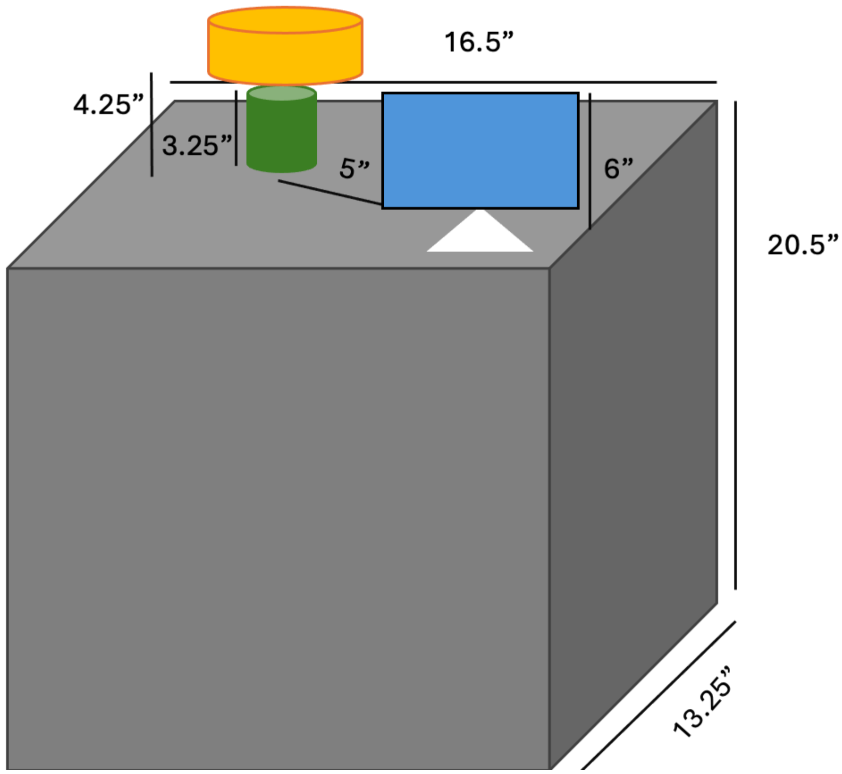

Figure 1: Diagram detailing experiment setup and flow capture. The capture was done in a tight space to preserve optical camera settings for close-up video capture. Because the only light source is the lamp, it was important to keep the camera close.

The flow observed over the 30-minute period began as a slow, gradual softening of the solid wax surface nearest to the lamp, followed by the development of a visible liquid layer that deepened over time. The melting rate was not constant—early in the recording, heat transfer was primarily limited by the thermal resistance of the solid wax surface, but as the melt pool deepened, the liquid layer itself began to act as a more efficient conductor, accelerating energy transfer to the solid-liquid interface below. This behavior is consistent with Stefan-type melting problems (**Figure 2**), in which the position of the solid-liquid interface varies with time as the thermal boundary layer within the liquid grows[3,4].

$$\frac{\partial T}{\partial t} = \alpha \frac{\partial^2 T}{\partial x^2}$$

- T: Temperature
- t: Time
- x: Distance from the flame
- α: Thermal diffusivity (how fast heat moves through the liquid or solid wax)

$$\rho L \frac{dS}{dt} = k_s \frac{\partial T_s}{\partial x} - k_l \frac{\partial T_l}{\partial x}$$

- ρ: Density of the wax
- $\mathbf{L}$: Latent heat of fusion (the energy needed to melt 1 gram of solid wax)
- $\frac{\mathbf{dS}}{\mathbf{dt}}$: The **speed of the melting interface** (how fast the pool deepens)
- $\mathbf{k_s}, \mathbf{k_l}$: Thermal conductivities of solid and liquid wax
- $\frac{\partial \mathbf{T}}{\partial \mathbf{x}}$: The temperature gradients pushing heat into and away from the boundary

Figure 2: Stefan type melting equation describing one-dimensional melting in the upper equation. The candle melting experiment is considered one-dimensional melting as it concerns only one phase change, which is solid to liquid. Liquid to solid is not considered as it will not occur under constant heat. The lower equation calculates the incorporation of the liquid pool as it increases with depth and its impact on the net melting rate, as a deeper liquid pool will increase the solid to liquid phase change.

Buoyancy forces acting on the warmer, less dense fluid near the top of the melt pool drove the surface convection visible in the video, providing a warming feedback loop as the melting pool deepened.

The visualization technique relied on the optical properties of the frosted glass jar itself rather than an added dye or tracer. A clear glass jar was deliberately avoided for two reasons: the harshness of direct transmission through clear glass under the bright heat lamp would likely have overwhelmed the camera sensor, washing out the subtle layering details at the wax surface, while the frosted finish instead diffused the transmitted light and made the depth of the liquid melt pool and the position of the solid-liquid interface legible as distinct tonal regions. The boundary between the translucent liquid wax and the opaque solid wax below it served as a natural, passive flow marker—no foreign material was introduced into the fluid. The forest green color of the jar further enhanced contrast between the illuminated liquid surface and the darker solid region below. All lighting in the scene was provided exclusively by the heat lamp itself. The experiment was conducted at night in a room with no other light sources active, ensuring that the lamp's output was the sole illumination and that its beam pattern on the wax surface remained clearly visible without competing ambient light.

The video was captured using an iPhone 15 Pro Max mounted on a tripod in landscape orientation, using the time-lapse camera mode. The camera was set to 2x optical zoom, which corresponds to the maximum magnification achievable before the device switches from the optical telephoto lens to a digital zoom, which is functionally equivalent to cropping the image and would reduce effective resolution. A 1x zoom was tested initially and included the full candle jar in frame, but this framing captured excessive background detail and the lamp's light did not penetrate visibly through the full depth of the jar at that scale. Since cropping would have been necessary in post-processing regardless, using the full optical zoom from capture was preferable to preserve pixel-level detail at the region of interest. The exposure was manually lowered to one quarter of the minimum brightness setting available in the iPhone camera interface, darkening the overall image to prevent the lamp from overexposing the frame and to increase the contrast between the bright liquid surface layer and the darker solid wax below. All post-processing was completed within the native iPhone Photos app, and the “Dramatic Cool” filter was applied at full strength. Brightness, exposure, and shadows were reduced further in editing to reinforce the tonal separation between the liquid and solid wax layers. Vibrance, contrast, and sharpness was increased to make the color of the lamp's beam on the wax surface more saturated and prominent, aiding in the visual distinction of the heated zone. The original image dimensions, final export resolution, and video frame rate are 1920 x 1080 at 1080p and 30fps, captured on the 12-megapixel telephoto sensor of the iPhone 15 Pro Max.

The time-lapse format is the strongest element of this visualization, compressing 30 minutes of slow melting into a readable sequence that clearly shows the rate and spatial pattern of the process. The frosted green glass effectively separates the liquid and solid wax layers, and the iPhone performed well in low-light conditions at close range. The main limitation is the absence of temperature measurement—without knowing actual surface temperatures, quantitative physical interpretation is difficult. A logging thermometer and a single-component wax of known formulation would make the experiment significantly more precise and reproducible. For future development, heating the candle from below rather than above would produce a fundamentally different convective regime, raising the question of whether the wax melts uniformly upward or fractures and detaches in chunks. Pairing that geometry with controlled temperature inputs would move this demonstration meaningfully closer to a quantitative physical experiment.

References

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*Artificial Intelligence (Claude, Sonnet 4.6) was used for sentence rephrasing, restructuring, and drafting between September 17-18, 2026. The author states that he uploaded a draft with writing and outlined sections that Claude assisted with writing. The text was reviewed before submission, and all sources were found by the author.