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IV 2
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Visualizing Transition From Laminar to Turbulent Flow

The intent behind this image is to show the transition from laminar to turbulent flow. The change from smooth, laminar flow to chaotic turbulent flow is interesting to observe in nature and was desired to be captured in this image. This image was taken at the Boulder Creek in Boulder, CO.

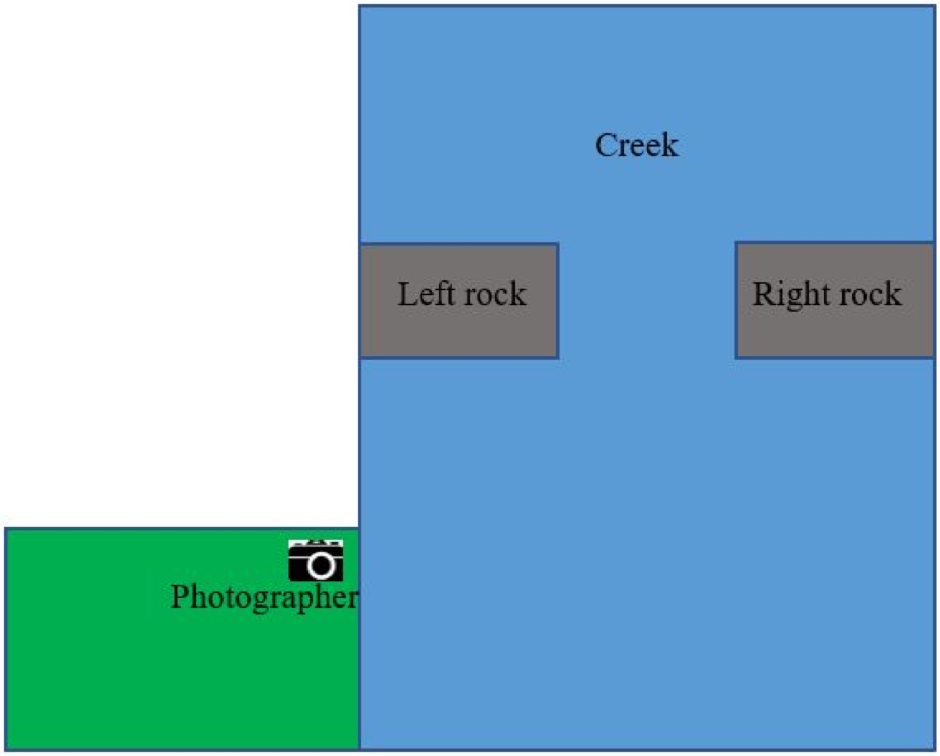

Figure 1: Photographic setup

The setup of this image is shown in the figure above. This is a gravity driven flow, since the decline of the creek keeps the water flowing and the origin of the creek comes from water flowing from the mountains at higher altitude. The Reynolds number, which is a non-dimensional parameter in fluid mechanics that characterizes the ratio of inertial to viscous forces in a flow, can be used to predict the onset of turbulence in a flow[1,2]. The Reynolds number is calculated as shown below:

$$Re = \frac{UL}{\nu} = \frac{1.5\ m/s \cdot 5\ m}{1.3 \cdot 10^{-6}\ m^2/s} = 5.7 \cdot 10^6 ,$$

where U is the average velocity of the creek flow, L is the characteristic length, in this case the width of the creek, and ν is the kinematic viscosity of water. This flow can be modelled as a channel flow as it is bounded between two solid boundaries[2]. This high Reynolds number corresponds to a turbulent flow[1], as seen in this image.

For this image, no external visualization medium was needed since the flowing water provided the visualization itself. In particular, the transition to turbulent flow can be seen by the white water downstream and the laminar flow can be seen by the smooth, clear water upstream. In terms of lighting, only sunlight was used for this image. This image was taken in the late afternoon in September, so there was plenty of sunlight, but taking it earlier in the afternoon could have provided more lighting for this image.

For this image, the goal was to get close enough to capture the details of the flowing water, while still being far enough away to see the transition from laminar to turbulent flow as the water flowed between the rocks. To capture the flow between the rocks, the horizontal field of view is about 15 feet and the distance from the object to the lens is about 20 feet. The camera used was a DSLR Canon EOS Rebel SL and the image is 1300 x 842 pixels. The lens focal length is 34 mm. The image has an ISO of 100, f-stop of f/4.5, and exposure time of 1/60 seconds. The image was post-processed by cropping it to be framed by the two rocks, while still showing the transition from laminar to turbulent flow. In addition, the color balance was adjusted to increase the brightness of the image due to the late-afternoon shadows over the creek. The original image can be seen below.

Figure 2: Original image

This image reveals the transition from laminar to turbulent flow as the water flows between the rocks. This transition is visually interesting and the rocks on the edge help frame the image. The physics of laminar and turbulent flow are seen by the clear, smooth laminar flow compared to the white, chaotic turbulent flow. The lighting in this image could be improved by taking the image during a time with more direct sunlight. In addition, a higher shutter speed could be used to help with the motion blur seen in the middle of the water flowing between the rocks. This idea can be further developed by capturing other examples of water transitioning from laminar to turbulent, such as with a large waterfall.

References

1. Wei, T., & Willmarth, W. W. (1989). Reynolds-number effects on the structure of a turbulent channel flow. *Journal of Fluid Mechanics, 204*(-1), 57. doi:10.1017/s0022112089001667
2. Kim, J., Moin, P., & Moser, R. (1987). Turbulence statistics in fully developed channel flow at low Reynolds number. *Journal of Fluid Mechanics, 177*, 133-166. doi:10.1017/s0022112087000892