# Laminar to Turbulent Flow over Rock

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Get Wet

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## Introduction

The purpose of this assignment, Get Wet, is to "get your feet wet" with capturing fluid flow. For this assignment, I tried several different experiments in hope to capture different fluid flow phenomena. I was unsuccessful in my efforts, so I ended up taking a video of water in a stream flowing over a rock. I chose to record the transition from laminar to turbulent flow in a video because I know it would be relatively easy to capture and the flow phenomenon is intuitive. This report will cover how the video was created and the physics behind the flow.

## Camera Setup

The camera set up to capture this flow phenomenon is quite simple. The photo was taken at Boulder Creek near the practice fields. A diagram showing the setup is detailed in Figure 1.

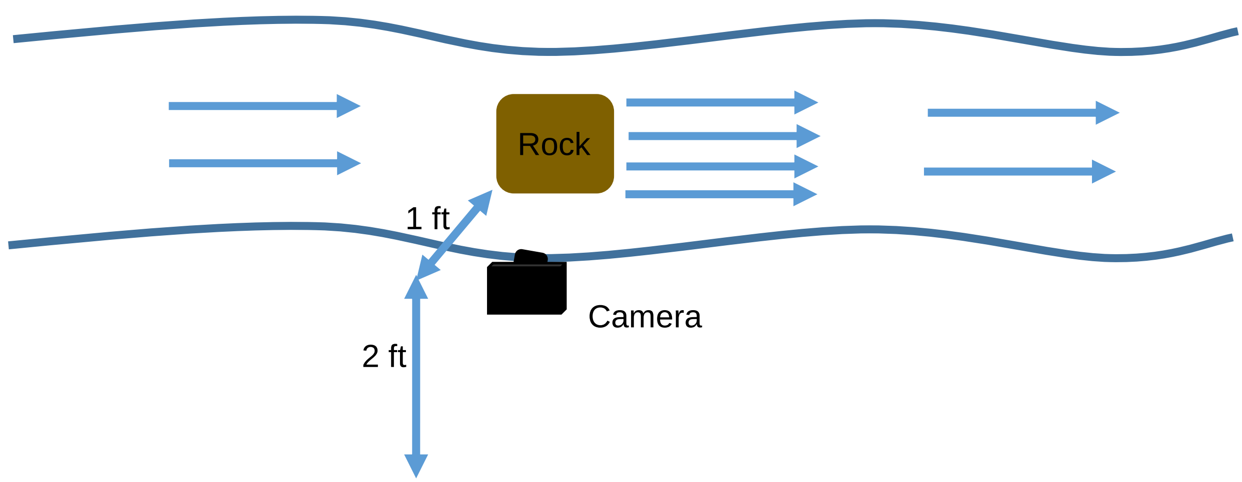


**Figure 1:** *Camera Setup*

**Flow Physics**

The flow phenomenon observed can be explain with Bernoulli's principle. Bernoulli's principle states that the sum of the kinetic, potential energy, and internal energy of a fluid is constant. [1] Equation 1 illustrates this fact in mathematical form,

$$\frac{v^2}{2} + gz + \frac{P}{\rho} = constant \qquad (1)$$

where *v* is velocity, *g* is the gravitational constant, *z* the relative height, *P* is the pressure, and *ρ* is density. If Equation 1 is constant, then:

$$\frac{{v_1}^2}{2} + gz_1 + \frac{P_1}{\rho} = \frac{{v_2}^2}{2} + gz_2 + \frac{P_2}{\rho} \qquad (2)$$

Equation 2 can be used to describe what is observed in the video. I will analyze the phenomenon with a reference height zero at the water-air border and with point 1 before the rock and point 2 directly above the rock. Figure 2 is an illustration of this analysis. An assumption to make to simplify this analysis is that the change in pressure between points 1 and 2 is negligible, and since the density of water remains the same, we can simplify Equation 2 to Equation 3.

$$\frac{{v_1}^2}{2} + gz_1 = \frac{{v_2}^2}{2} + gz_2 \qquad (3)$$

Now, the change in velocity is only dependent on the change in height. Since the relative height at point 1 is greater than the relative height at point 2, water at point 2 has a greater velocity.

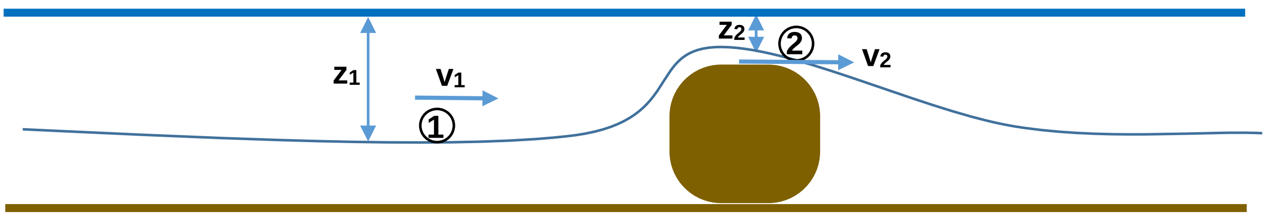


**Figure 2:** *Bernoulli's Principle Diagram*

A Reynolds number is a dimensionless parameter that is used to describe flow patterns. Equation 4 is the mathematical equation to find the Reynolds number,

$$Re = \frac{\rho v L}{\mu} \qquad (4)$$

where, *ρ* is density, *v* is velocity, L the length, and *μ* is the dynamic viscosity of the fluid [1]. Following Equation 4, the Reynolds number is directly proportional to the fluid's velocity. Low Reynolds numbers describe the laminar regime which result in fluids having a steady, sheet-like flow. High Reynolds numbers describe the turbulent regime in which a fluid has chaotic, fluctuating flow. Water in the turbulent regime creates air bubbles, which create the "white water". Reynolds numbers under 5,000 are considered to be laminar, while Reynolds numbers of 10,000 are considered to be turbulent.

Estimating that the water is about 50°F, $\mu = 2.5 * 10^{-5} \frac{\text{lbf}}{ft*s}$ and $\rho = 62.4 \frac{\text{lbm}}{ft^3}$. Additionally, I will assume values of $v_1 = 0.1 \frac{ft}{s}$, and $v_2 = 0.8 \frac{ft}{s}$ based on back of the envelope calculations using a floating leaf and a stop watch. Using a length of

$L = 0.25ft,$

$$Re_1 = \frac{\rho v_1 L}{\mu} = \frac{62.4\frac{\text{lbm}}{ft^3} * 0.1\frac{ft}{s} * 0.25ft}{2.5 * 10^{-5}\frac{\text{lbf}}{ft*s} * 32.2\frac{lbm*ft}{lbf*s^2}} = 1938$$

$$Re_2 = \frac{\rho v_2 L}{\mu} = \frac{62.4\frac{\text{lbm}}{ft^3} * 0.8\frac{ft}{s} * 0.25ft}{2.5 * 10^{-5}\frac{\text{lbf}}{ft*s} * 32.2\frac{lbm*ft}{lbf*s^2}} = 15503$$

This confirms that the water flowing over the rock transitions form laminar to turbulent flow.

## Visualization Technique

This video is of a creek in nature so no dye or other visual aid fluid were used. Additionally, only indirect ambient light was used, no additional light or camera flash.

## Photographic Technique

I used a Nikon CoolPix P100 DSLR camera with a 4.6-120 mm, 1:2.8-5.0 lens to record the video. The video was taken at 60 frames per second and a resolution of 1080p. I held up the camera about 1 foot away from the rock and 2 feet above the water. The camera was pointed at the rock at about a 45° angle. The rock is about 2 feet long by 1 foot wide. I altered the raw footage on Final Cut Pro. I decreased the frame rate by 75% and shortened the clip to about 2 seconds in order to limit camera shake. I then looped the video in order to increase video length. Figure 3 shows the changes I made to the saturation and exposure so that the colors in the video would pop more.

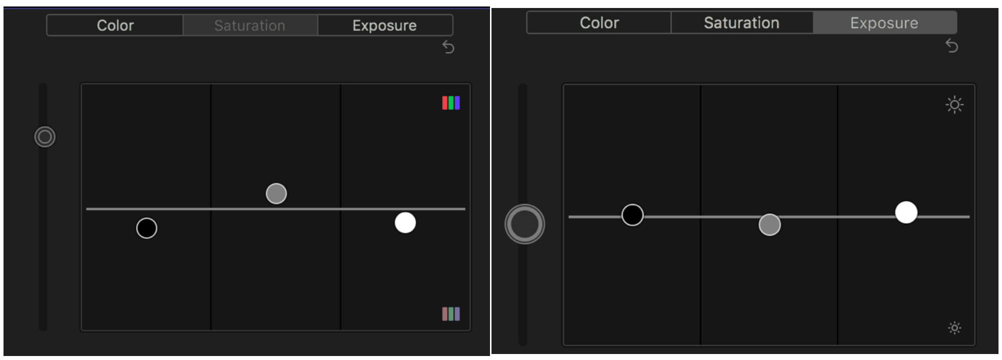


**Figure 3:** *Final Cut adjustments*

## Results

I really like the simplicity of this video. It is obvious in the video that the water changes its flow pattern when going over the rock. The flow phenomenon is clearly displayed. Next time, I want to use a tripod to reduce video shakiness. Additionally, I think playing around with the video more in the post-processing stage could bring out more detail in the video. I do not have any questions about the fluid physics. To take this idea to the next stage, using an experimental set up in a lab and adding colors could bring a new perspective to this phenomenon.

## References

[1] Gerhart, Philip M., et al. *Munson, Young, and Okiishi's Fundamentals of Fluid Mechanics*. 8th ed., John Wiley & Sons, Inc. 2016.