Aadit Gohil
Team Second Assignment: Flow Visualization
MCEN 4151
November 1, 2026



This image was taken for the Team Second assignment in Flow Visualization. My goal was to capture waves moving into the rocky shoreline at Marshall's Beach in San Francisco. I wanted to see how the rocks affected the water as the waves came in and moved around them. I also wanted to get a good sunset picture since the lighting and colors looked pretty cool. The photo was taken on October 24, 2026 at 6:04 PM. I took the photo myself with no collaborators.

I was sitting on a large rock at Marshall's Beach, just west of the Golden Gate Bridge, looking out toward the ocean. I was roughly at the same height as one of the larger rocks in the image. The closest rocks were around 20 feet away and were about 10 to 20 feet wide and 2 to 5 feet tall. The waves were moderate and would come in, move around the rocks, and then go back out.

As waves approach shore, the water gets shallower, causing them to slow down and get steeper until they eventually break [1]. In this image, the waves are relatively small and the water is mostly moving around the rocks rather than crashing into them. Some water also moves through the gaps between rocks, where it can speed up. This creates some of the different patterns and smaller ripples seen in the image.

The main forces here are gravity, inertia, and pressure. Gravity acts to bring the water surface back toward equilibrium, while inertia keeps the water moving toward the rocks. The rocks force the flow to change direction, and some energy can be lost through turbulence as the water moves around them. The waves carry energy toward shore even though the water itself mostly moves back and forth [2].

For the Reynolds number, I assumed a water velocity of about 1.0 m/s since I didn't measure it. I used a length of 1.0 m based on some of the smaller rock features the water was flowing around, rather than the entire rocks. For seawater, I used a kinematic viscosity of 1.1 x 10^-6 m^2/s based on typical seawater properties at around 18 C [4].

Re = UL / v -> Re = (1.0 m/s)(1.0 m) / (1.1 x 10^-6 m^2/s) -> Re = 9.1 x 10^5

Reynolds number compares inertia to viscosity [3]. The value is pretty high, meaning inertia has a much larger effect than viscosity. This makes sense since the water is being redirected around the rocks, even though the waves themselves aren't very large. The actual value would change as the waves came in and went back out.

I also estimated the Froude number using an assumed water depth of 0.5 m.

Fr = U / sqrt(gh) -> Fr = 1.0 / sqrt(9.81 x 0.5) -> Fr = 0.45

The Froude number compares inertia to gravity in a flow with a free surface. Since it is below 1, the flow would be subcritical under these assumed conditions. However, this wouldn't apply everywhere since the water depth and velocity are constantly changing.

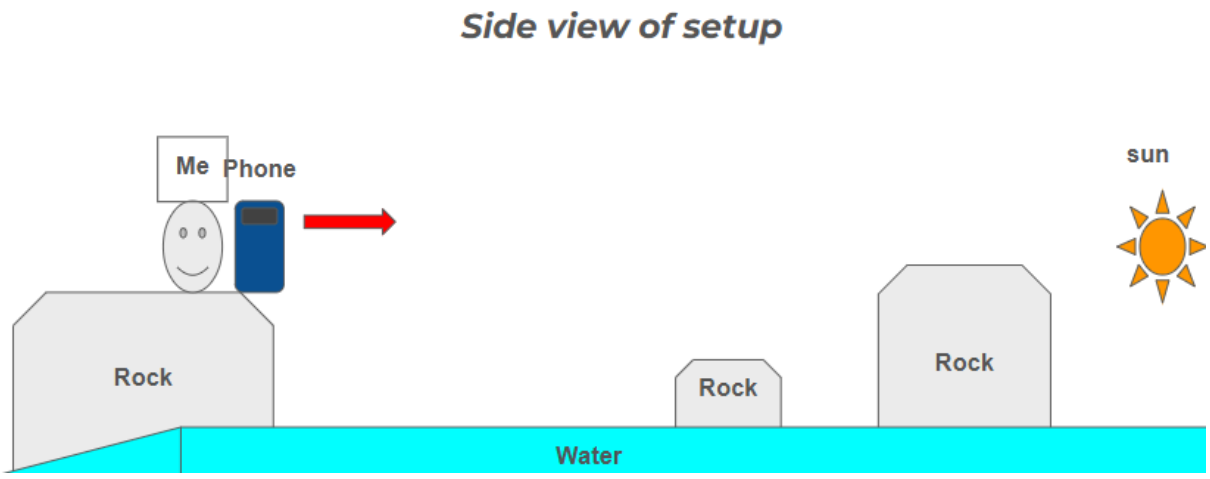


Figure 1. Approximate side view of the setup showing my camera position, viewing direction, rocks, and sunlight.

No dye or other materials were used to show the flow. Instead, the water was visible from sunlight reflecting off the surface and the small amounts of foam around the rocks. The reflections helped show the ripples and changes in the water surface, while the foam made some of the flow around the rocks easier to see.

The photo was taken around sunset with the sun low over the Pacific Ocean. The lighting gave the water an orange color while leaving the rocks pretty dark. This gave the image some nice contrast and made the water easier to see. I didn't use any flash or artificial lighting.

I took the photo using my iPhone 17 Pro with the telephoto camera. The lens was 100 mm equivalent at f/2.8, with the photo taken at a reported equivalent focal length of 137 mm. The shutter speed was 1/471 second and ISO was 50. I was about 20 feet from the closest rocks. The original RAW image was reported by my phone as 4058 x 5011 pixels, and the final image was about 1658 x 2048 pixels.

For editing, I increased the contrast and saturation to bring out the colors a little more. I also cropped the photo slightly and exported it at a smaller resolution.

To estimate spatial resolution near the closest rocks, I used the approximate camera distance of 20 feet and the reported focal length of 137 mm. Since this is a full frame equivalent focal length, I used an equivalent sensor width of 24 mm for the portrait image. This is only a rough estimate since I didn't measure the exact distance or account for cropping though.

Field of view = (Sensor width x Distance) / Focal length -> Field of view = (24 mm x 6.1 m) / 137 mm -> Field of view = 1.07 m

Using the final image width of 1658 pixels gives

Spatial resolution = Field of view / Image width -> Spatial resolution = 1070 mm / 1658 pixels -> Spatial resolution = 0.65 mm/pixel

This gives an approximate image scale of 0.65 mm per pixel at the estimated distance. The scale would be different for the water and rocks farther away, and the actual value also depends on the cropping. This is an estimate of image scale rather than the camera's actual resolving capability.

I also calculated how far the water would move during the exposure using the assumed velocity of 1.0 m/s.

Distance traveled = Velocity x Exposure time -> Distance traveled = (1.0 m/s)(1/471 s) -> Distance traveled = 0.00212 m = 2.12 mm

So the water would move about 2.1 mm during the exposure. This is pretty small compared to most of the waves in the image, which helps explain why the water looks fairly sharp. Smaller and faster moving features could still be blurred. Frame rate and playback rate don't apply since this was a photo.



Figure 2. Original photo before cropping and changes to contrast and saturation.

I think the image turned out pretty well. You can see the water moving around the rocks, and I liked how the sunset lighting turned out. One thing I would improve is capturing a larger wave actually crashing into the rocks, since the waves in this photo were relatively small. I think more foam and spray would make the flow easier to see and probably make for a better picture too. I would also like to try taking a video to see how the water moves as each wave comes in and goes back out. Overall, I think I got what I wanted, which was to show the waves interacting with the rocks while also getting a good sunset photo.

References

[1] NOAA National Ocean Service, "Waves," Currents Tutorial.
https://oceanservice.noaa.gov/education/tutorial_currents/03coastal1.html

[2] NOAA National Ocean Service, "Why does the ocean have waves?"
https://oceanservice.noaa.gov/facts/wavesinocean.html

[3] NASA Glenn Research Center, "Similarity Parameters," Beginner's Guide to Aeronautics.
https://www1.grc.nasa.gov/beginners-guide-to-aeronautics/similarity-parameters/

[4] MIT, "Seawater Property Tables," Kinematic Viscosity of Seawater.
https://web.mit.edu/seawater/2017_MIT_Seawater_Property_Tables_r2b_2023c.pdf