Devolution from Laminar to Turbulent Flow in Water Vapor

Photo Assignment #2

MCEN 5151

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Introduction:

This photo, taken for the second assignment in MCEN 5151, depicts the flow of vaporized water exiting an essential oil diffuser. It is visually interesting and clearly shows the devolution of the flow from laminar to turbulent. This image also emphasizes the effect of gravity on a fluid, which I will briefly discuss later. The fluid itself is mostly water vapor, with an orange essential oil added to give it a slight tint. This tint was emphasized in the editing of this image because it helps create contrast between the background and subject. The diffuser vaporizes water into its gas state, allowing it to flow out of the system through a small, angled slit shown on left side of the diffuser. Overall, this image successfully illustrates the fluid's transitional period from laminar to turbulent flow and emphasizes the effects of gravity on a fluid.

Science of the Flow:

Laminar flow is a type of fluid flow in which there is no mixing the fluid travels in regular paths [1]. It is characterized numerically by having a Reynold's number below 2,300 [2]. Reynold's number is determined by the following equation, in which *ρ [kg/m^3]* is density, *u [m/s]* is velocity, *L [m]* is characteristic length, and *μ [Pa*s]* is dynamic viscosity:

$$Re = \frac{\rho\, u\, L}{\mu}$$

In the picture above, the flow is laminar at the exit of the diffuser, with input variables shown in the following table:

Variable	Value
Density	0.7618 [kg/m^3] [3]
Velocity	0.1 [m/s]
Characteristic Length	0.01 [m]
Dynamic Viscosity	1.52E-6 [Pa s] [4]

Table 1 - Laminar flow input variables

When these values are substituted into the Reynold's number equation above, we can determine that the Reynold's number of our system as it exits the mouth of the oil diffuser is 501, which falls nicely into the laminar regime. As the flow continues from the mouth of the diffuser, the characteristic length of the flow increases significantly. Quickly, as shown in the photo, the flow switches from laminar, to transitional, to turbulent. At an intermediate point in the flow, we can reassess the Reynold's number with the following input values:

Variable	Value
Density	0.7618 [kg/m^3] [3]
Velocity	0.1 [m/s]
Characteristic Length	0.05 [m]
Dynamic Viscosity	1.52E-6 [Pa s] [4]

Table 2 - Transitional flow input variables

These input values result in a Reynold’s number of 2,505. This value is between 2,300 and 4,000 making this flow transitional [2]. As the flow continues even further, it becomes more and more turbulent. Looking near the left side of the image, we can see that the characteristic length has grown once again. Let’s reevaluate the Reynold’s number using the following input variables:

Variable	Value
Density	0.7618 [kg/m^3] [3]
Velocity	0.1 [m/s]
Characteristic Length	0.1 [m]
Dynamic Viscosity	1.52E-6 [Pa s] [4]

Table 3 - Turbulent flow input variables

With these variables, the Reynold’s number becomes 5,011. This value is considered turbulent because it is greater than 4,000 [2]. Thus, the image illustrates the transition from laminar to turbulent flow of steam exiting an oil diffuser.

It is also important to address other factors that can affect the flow of this steam. Because the flow begins at an upward angle, we can clearly assess the effects of gravity. What I love about this image is it basically follows the parabolic path predicted by Newtonian mechanics, as shown in the following image:

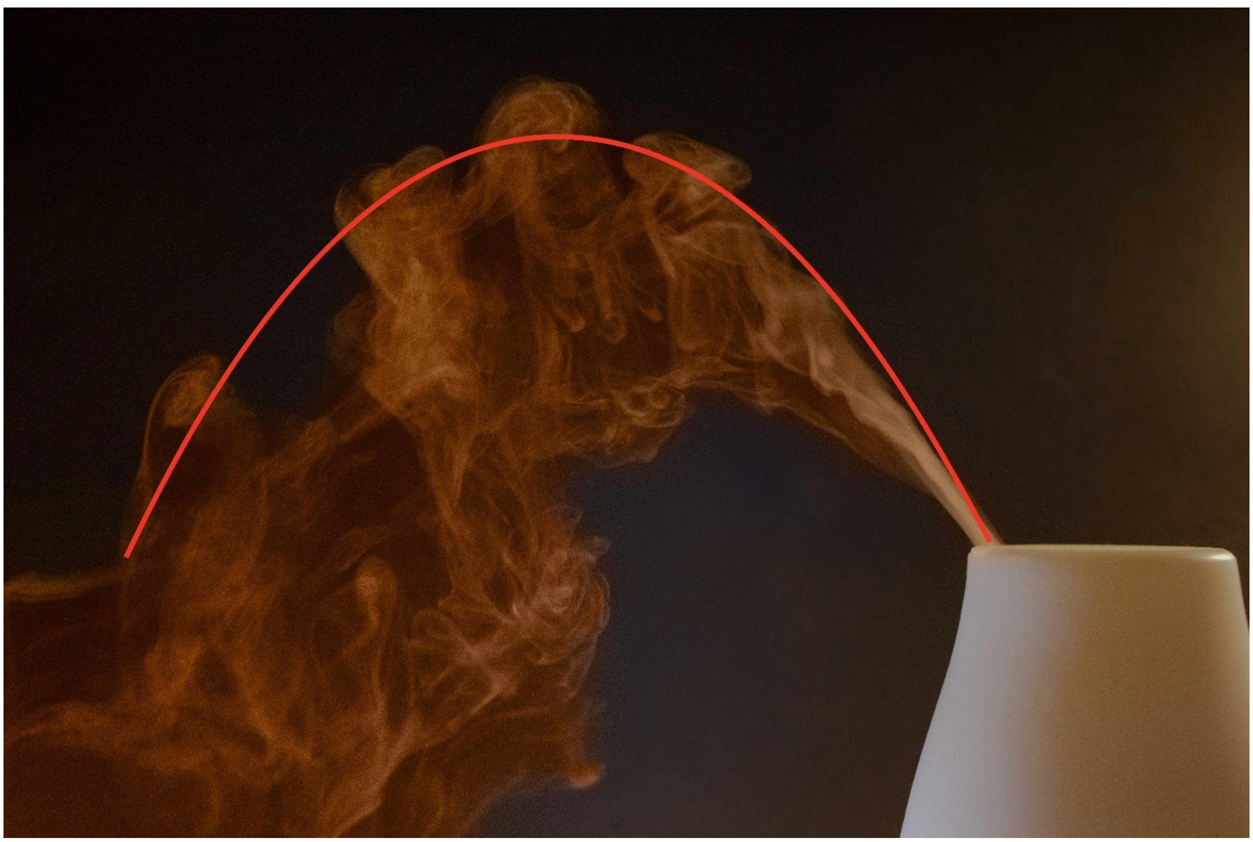

Figure 1 - Parabolic path of flow

Experimental Setup:

This photo was taken indoors with artificial, warm lighting. The fluid exited the diffuser at an upward angle, helping display the effects of gravity. The fluid was water vapor generated by an essential oil diffuser. This water vapor mixed with the ambient air, resulting in the turbulence seen in the image. The background of the photo is a black posterboard, and there are lights on both sides of the setup to emphasize the flow. Importantly, the light on the left side was placed significantly further away from the subject than the light on the right side. This helped the camera capture a clear image of the water vapor. The camera, a Canon Rebel T2i, was placed on a tripod around a foot away from the diffuser to generate this image. The overall experimental setup is shown below:

Figure 2 - Experimental setup

During this session, hundreds of photos were taken at different angles and with different settings. The best of those photos was edited into the photo at the top of this report, using the settings shown here:

Camera model	Canon Rebel T2i
ISO speed	ISO-1600
F-stop	f/3.5

Exposure time	1/160 sec
Flash mode	No flash
Focal length	20 mm

Table 4 - Camera settings

Conclusion:

In this experiment, I captured an image that clearly depicts the transition from laminar to turbulent flow in oil diffuser steam. The image also emphasizes the effects of gravity on a fluid. The fluid I used was water vapor, which mixed with air to generate the turbulent vortexes shown on the left side of the image. I was very happy with how this image turned out because there is great contrast between the fluid and the background, and the physics involved is clear to the viewer.

Bibliography

[1] The Editors of Encyclopaedia Britannica, "Laminar Flow," *Britannica,* 2018.

[2] Simscale, "What is Reynolds Number?," *Simwiki,* 2021.

[3] W. V, "What is the Density of Air at STP?," *MAC Instruments,* 2019.

[4] Engineering ToolBox, "Steam Viscosity," *The Engineering ToolBox,* 2004.