Understanding Reversible and Irreversible Processes through activities

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Abstract. Understanding reversible and irreversible processes in thermodynamics presents a significant challenge for undergraduate physics students in India. The idealized nature of reversible processes often proves difficult to replicate in laboratory settings. In our activity, inspired by the widely recognized demonstration of food colour drops in highly viscous liquids, we provide students with a visual representation accompanied by graphical evidence of reversible process. By manipulating the viscosity of the liquid, we also illustrate irreversible processes within this activity. The analysis of these processes was conducted using the open-source video analysis software "TRACKER," enhancing the comprehensibility and accessibility of our findings.

Introduction

Reversible and irreversible processes are one of the fundamental concepts of thermodynamics. Students can often relate to their everyday experiences of irreversible processes but they rarely come across a real-life example of a reversible process. Moreover, due to its idealized nature, it is often cumbersome to develop a demonstration/experiment for an effective understanding of the concept. It therefore poses a major hurdle in the learning process of undergraduate physics students. We present our activity based on a demonstration of Taylor-Couette flow. There have been publications investigating the properties of this laminar flow [1,2]. Some videos and simulations [3,4] have also been developed for a better understanding of the phenomenon. Our work is focused on showing the reversible and irreversible processes graphically supporting the explanation presented in a typical undergraduate physics classroom.

Reversible and irreversible processes

A *reversible* process in thermodynamics refers to a sequence of changes in a system that can be exactly undone by precisely reversing each step. In simpler terms, it is a process that can be reversed without leaving any trace on the surroundings. An *irreversible* process in thermodynamics is a sequence of changes in a system that cannot be exactly undone or reversed to restore the system and its surroundings to their original states. Irreversible processes are characterized by the fact that they involve dissipative effects, such as friction, heat transfer across finite temperature differences and irreversibilities in fluid flow. These processes are often rapid and occur far from equilibrium conditions.

The activity

In this activity, a highly viscous liquid (corn syrup) is poured into a container with a central rod connected to a shaft. As the shaft is rotated at slow speeds, the layers of liquid attain a laminar flow around the central rod. If a drop of coloured liquid, mixed with the viscous liquid, is added midway between the rod and wall of the container (Fig. 1), this colored drop gets dragged in the laminar flow thereby making the rotational direction visible (Fig. 2). The backward rotation of the central rod reverses the spread of drop till it attains its original state thereby indicating reversibility in the whole process.

Fig.1. Colour drop in the viscous liquid

Fig. 2. Spread of colour drop in viscous liquid with flow

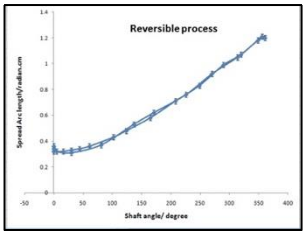

Fig. 3. Graph for Reversible process

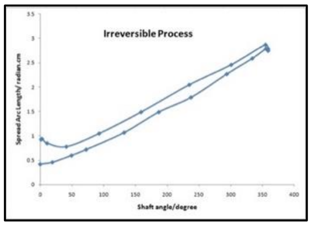

Fig. 4. Graph for Irreversible process

For an irreversible process, the corn syrup is diluted with water in certain proportion. This change in the composition of liquid, brings about significant difference in the angular spread of the drop as the flow is reversed, thus indicating the irreversibility in the process.

Analysis

A clear video of the demonstration was recorded and analyzed using an open-source software "Tracker". Using suitable tools of Tracker, for both processes, the angular spread of the drop (arc length of the drop spread) was measured for the corresponding angular positions of the shaft. The graphs (Fig. 3 and Fig. 4) indicate the angular spread of the drop for different angular positions of the shaft for reversible and irreversible processes respectively. Figure 3 indicates that the drop backtracks its every state attained during the forward rotation of the shaft clearly representing the reversible process. Figure 4 represents the graph resulting from a similar analysis carried out for the irreversible process.

Conclusion

This activity provides us with a potential teaching tool that discusses the concepts of reversible and irreversible processes graphically. This activity additionally provides the possibility of visualizing the reversible and irreversible processes.

References

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