What are the conceptual difficulties faced by college students in understanding hydrodynamics?

Arturo C. MARTÍ, Sandra KAHAN

Universidad de la República, Montevideo, Uruguay
Álvaro SUÁREZ

Instituto de Profesores Artigas, Montevideo, Uruguay

Genaro ZAVALA

Escuela de Ingeniería y Ciencias, Tecnológico de Monterrey, Monterrey 64849, Mexico

Facultad de Ingeniería, Universidad Andres Bello, Santiago 7500971, Chile

We discuss the conceptual difficulties faced by college students in understanding hydrodynamics of ideal fluids. We based our study in the analysis of hundreds of written exams of first-year Engineering and Science university students complemented with several oral interviews. Using these inputs, we identified a series of misconceptions held by the students. The most critical difficulties arise from the students' inability to establish a conceptual link between the kinematics and dynamics of moving fluids, and from a lack of understanding of how different regions of a system interact.

1 Introduction

The physics of ideal fluids is studied at the introductory level in the first-year university courses. An in-depth understanding of this topic requires, in addition to a knowledge of the concepts of classical mechanics (statics, kinematics and dynamics), knowledge of the specific concepts to fluids among them streamlines, pressure, material derivatives, and conservation of different physical quantities such as momentum in control volumes.

Physics education research (PER) shows that the conceptual difficulties to understand the phenomena associated with fluids have received relatively uneven attention. On the one hand, difficulties associated with hydrostatic principles have been deeply analyzed by various authors, who showed how students continue to present serious difficulties in understanding the basics, even after attending university courses where these topics are covered (see for example [1–2]). On the other hand, students' understanding of ideal fluid hydrodynamics has received less attention. Studies in existing literature mainly relate to the application of Bernoulli's equation and the results that might derive from it (see for instance [3-4]). As a consequence, there are many open questions regarding students' understanding of ideal fluid hydrodynamics that need to be addressed. How do they interpret the origin of forces acting on a volume element of a moving fluid? Do they connect changes in velocity with pressure gradients? How do they apply mass conservation in non-confined fluids?

To address these and other questions we designed a research based on the analysis of midterm tests and exams, and of the responses obtained in interviews conducted with students who successfully passed general physics courses, which covered fluid mechanics topics. All the features of the study: methodology, results, discussion and conclusion were recently published in [5]. Here we review the most important misconceptions found.

2 Misconceptions in hydrodynamics

We explored the difficulties encountered by students enrolled in standard general physics courses. To do this, we evaluated 600 exams with emphasis on continuity and Bernoulli's equations. Analyzing these errors, we formulated hypotheses about the students' conceptions that reflected those wrong interpretations. Next, to validate these hypotheses, we designed three new problem scenarios and proposed them in interviews carried out with 16 volunteers enrolled in the science and engineering courses. All the interviewees met the requirement of having successfully passed a general physics college course that covered topics related to ideal fluids' hydrodynamics. We asked the interviewees to solve problems aloud and to complement their verbal reasoning with written diagrams.

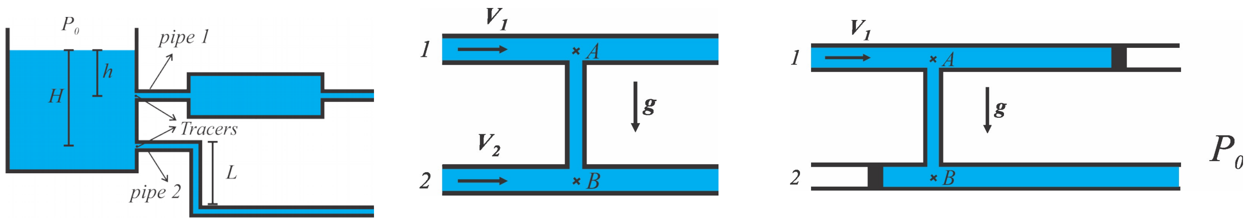

Fig. 1 Three different setups corresponding to the written responses analyzed.

The most remarkable misconceptions observed were the following:

- *The pressure of a fluid in motion is the same as the pressure of a fluid at rest.* The left panel in Fig. 1 depicts a typical situation. When the students were asked to calculate the pressure in the horizontal pipes they used the Bernoulli but neglecting the velocity contribution.
- *In vertical pipes of uniform cross section, fluid velocity increases due to gravitational acceleration*. This is also illustrated in the left panel of Fig. 1. where students frequently claim that tracers' speed along vertical pipes increases due to gravitational acceleration.
- *For a fluid to be at rest in a vertical pipe, the pressure difference between its extremities must be zero.* This misconception is found in situations like the shown in the central panel of Fig. 1.
- *Applying Bernoulli's equation to two points of a fluid, one of which is at rest.* The right panel of Fig. 1 is a typical situation where this difficulty arise.

References

[1] M. E. Loverude, P. R. L. Heron, and C. H. Kautz, Identifying and addressing student difficulties with hydrostatic pressure, *Am. J. Phys*. **78** (2010) 75.

[2] M. Goszewski, A. Moyer, Z. Bazan, and D. J. Wagner, Exploring student difficulties with pressure in a fluid, *AIP Conf. Proc.* **1513** (2013) 154.

[3] L. H. Barbosa, Development and validation of an instrument to measure student learning: the Bernoulli's law test, *Revista Educación en Ingeniería* **8** (2013) 24.

[4] G. Recktenwald, R. Edwards, D. Howe, and J. Faulkner, A simple experiment to expose misconceptions about the Bernoulli equation, in Proceedings of the ASME International Mechanical Engineering Congress and Exposition (The American Society of Mechanical Engineers, New York, 2009), **7**, 151–160.

[5] Alvaro Suarez, Sandra Kahan, Genaro Zavala, and Arturo C. Marti, Students' conceptual difficulties in hydrodynamics, *Phys. Rev. Phys. Educ. Res.* **13** (2017) 020132.