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

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Physics of Fluids (nonviscous and incompressible)

Important topic in1st year university courses in **science, engineering, life sciences**

In addition to basic concepts in **classical mechanics**, requires **specific** concepts:

continuous media, streamlines, surface and body forces, pressure, mass conservation

Written exams:

Freshman **engineering students** (Uruguay)

Physics 2: standard lectures (large groups) (*Resnick, Tipler, Serway, Sears Zemansky)*
15 weeks, 5 h/w (3 weeks → Fluids)

600 *(6 prob. x 100 students)* randomly selected answers to problems on hydrodynamics

Wrong answers reviewed **one by one,** classified according to most frequent errors

Oral interviews:

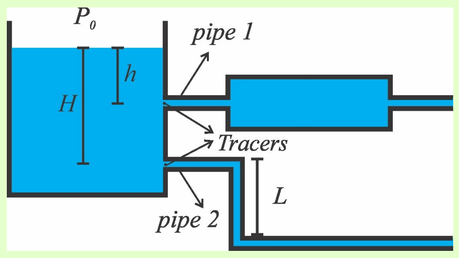
New scenarios to check the hypothesis

3 problems (with several questions) specially designed to "reveal" the previous detected errors

16 volunteers enrolled in Science and Engineering courses who had **successfully passed Physics**

Asked to solve problems "aloud" while writing their answers

Error 1: Confusion with statics and dynamics pressure



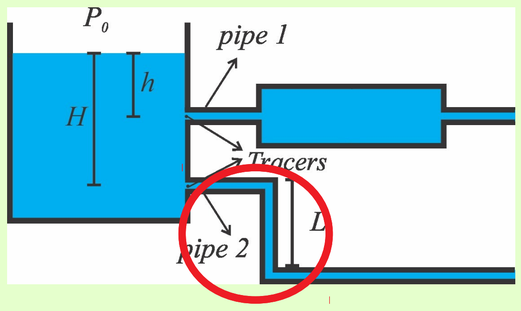
When pressure in points 1 or 2 is needed, students **neglect velocity** term in **Bernoulli** eq:

$$p_1 = P_0 + \rho g h + \frac{1}{2}\rho v_1^2$$

Students attempt to apply hydrostatic notions in hydrodynamics contexts
Do not associate velocity changes with pressure gradients

Error 2: in **vertical pipes of uniform cross section** the fluid **velocity *increases*** due to **gravitational acceleration!**

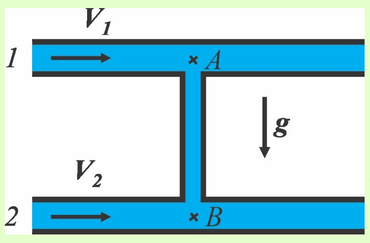
Tracers inside a vertical pipe → frequently state that tracers follow **accelerated motion**



Fluid portions as **free-falling particles Non-interacting** elements.
Do not recognize forces on a fluid element.
Contradictions with mass conservation.

Error 3: To determine the pressure in A and B so that the fluid is at **rest** in the **vertical pipe**, some students claim that the **pressure difference** between A and B should **be zero 1: Confusion with statics and dynamics pressure**

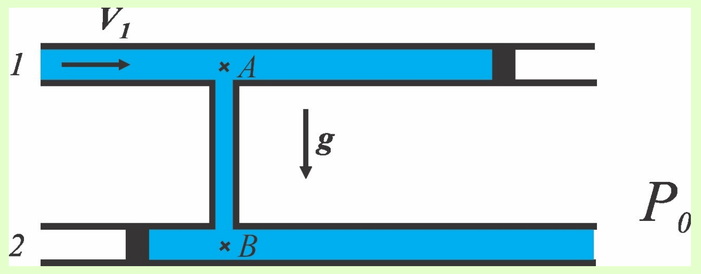
They omit the body (gravitational) forces exerted on a fluid region.



Do not understand **forces** acting on fluid elements.
* Neglect **body forces** when working with surface forces (pressure).

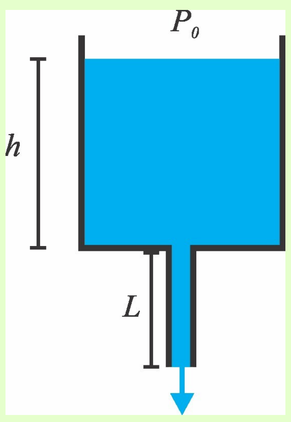
Error 4: Apply Bernoulli equation to 2 points of a fluid, **one of them is at rest**

Typical misconception: "fluid velocity decreases down to zero"



Not be aware of the **range of validity of Bernoulli** eq.
Do not see the contradiction with the **mass conservation**

Problem 1: flow in a vertical pipe (3 questions):

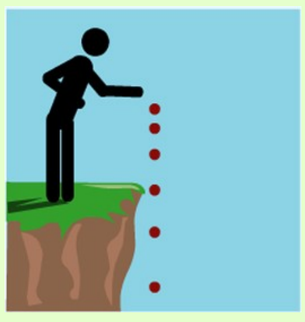


Motion of a tracer in the vertical pipe
→ accelerated motion :(

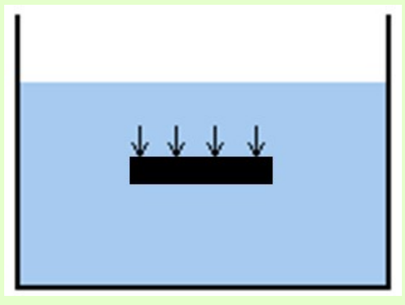
Pressure differences at different points
→ confusion with statics and dynamics pressure :(

Draining time
→ failed to analyze forces on a fluid volume :(

Some of the **misconceptions** associated



Fluid behavior similar to a set of particles which **do not interact**



Force on a fluid element is exerted **only by the fluid above** it

Conclusion:

We analyzed the most common conceptual difficulties related to ideal fluid hydrodynamics

We found several misconceptions

Recommendations:

More emphasis on Newton's laws

Role of body and surface forces (pressure) and interactions between different regions of a fluid

Conservation of mass

Deeper discussion of Bernoulli limitations

Highlight differences **statics ↔ dynamics**

Additional information:
Suarez, A., Kahan, S., Zavala, G., & Marti, A. C. (2017)
„Students' conceptual difficulties in hydrodynamics"
Physical Review Physics Education Research, **13(2), 020132**