Using forces to understand pressure in a liquid

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What Is PER?

- Research on the teaching and learning of physics
- Studies a wide range of students, from pre-K to university
- Uses research about student understanding to improve instruction (develop materials, modify delivery methods, etc.)

Context for Research

Calculus-based introductory course at University of Washington
- Lecture
- Lab
- Tutorials

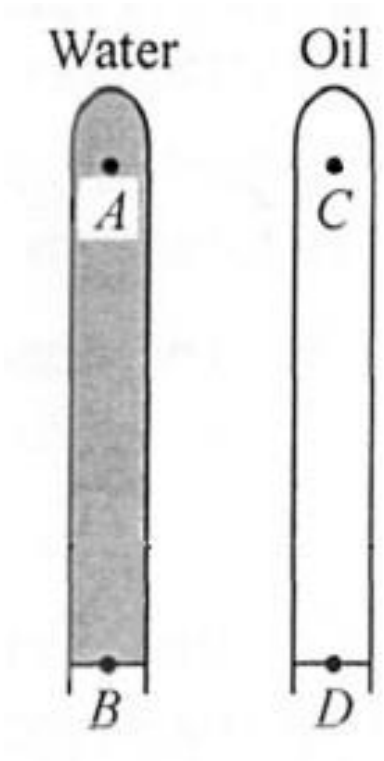
Covers dynamics, including fluids

Tasks are assigned on
- online pretests (given after lecture instruction)
- midterm exams
- final exams

Tutorials

- Developed by the Physics Education Group to address student difficulties found in research
- Original tutorials were designed for Calculus-based introductory classes
- Supplement traditional lecture instruction
- Tutorials on pressure and buoyancy have been shown to improve performance on certain questions
- Continuously reassessed and revised based on current research

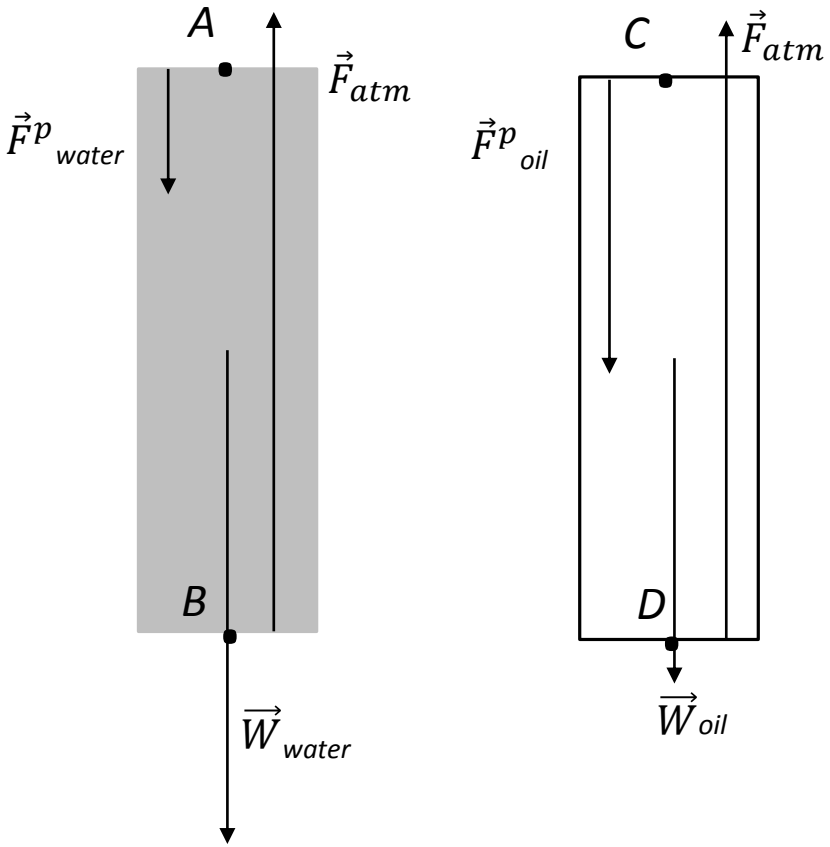
Motivation: Test Tube Question



$\rho_{water} > \rho_{oil}$

1. Is the pressure at point *B greater than, less than,* or *equal to* atmospheric pressure?
   - 60% correct ($P_B = P_{atm}$)
2. Is the pressure at point *A greater than, less than,* or *equal to* the pressure at point *B?*
   - 70% correct ($P_A < P_B$)
3. Is the pressure at point *A greater than, less than,* or *equal to* the pressure at point *C?*
   - **20% correct ($P_A < P_C$)**

Motivation: Test Tube Question



Is the pressure at point *A greater than, less than,* or *equal to* the pressure at point *B*

- 70% correct ($P_A<P_B$)

Is the pressure at point *A greater than, less than,* or *equal to* the pressure at point *C?*

- **20% correct ($P_A<P_C$)**

$$F_{net}=ma=0$$

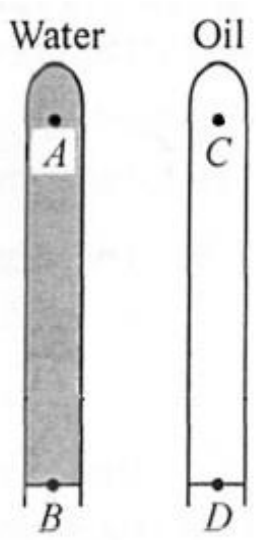
$F_{atm}=W_{water}+F^{p}{}_{water}$ $F_{atm}=W_{oil}+F^{p}{}_{oil}$

Research Question:

- To what extent can students reason about pressure using forces?
- This requires…
  - -Identifying forces and applying Newton's laws
  - -Treating a section of a liquid as an object

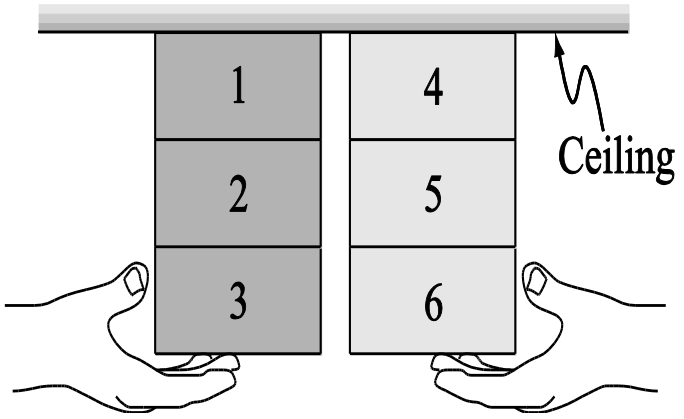
We designed two tasks to address the different aspects of this reasoning

First Task: Newton's Laws for Equilibrium



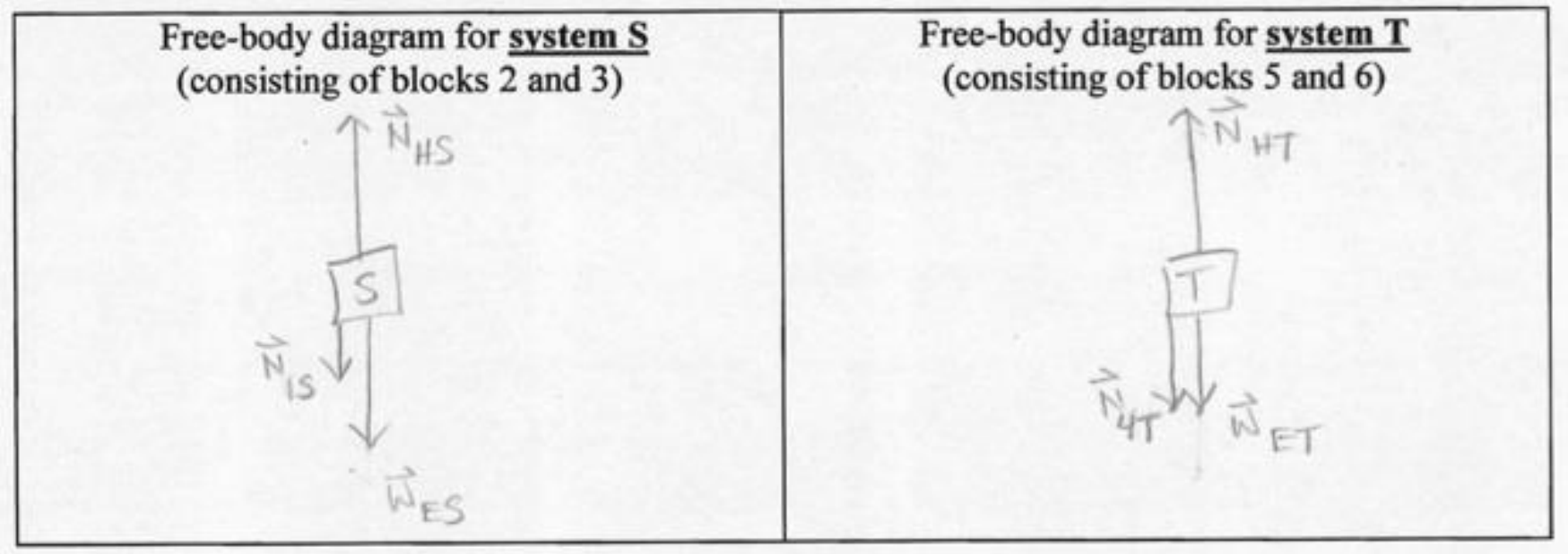
1. Compare P_B to P_{atm}.
2. Compare P_A to P_B.
3. Compare P_A to P_C.

1. Draw free body diagrams for System S (blocks 2 and 3) and System T (blocks 5 and 6)
2. Compare F_{1S} (by block 1 on System S) to F_{HS} (by hand on System S).
3. Compare F_{1S} (by block 1 on System S) to F_{4T} (by block 4 on System T).



$m_1=m_2=m_3>m_4=m_5=m_6$

Results for Newton's Laws Task



F_{1S} vs. F_{HS} : 90%

- 70% for analogous pressure question

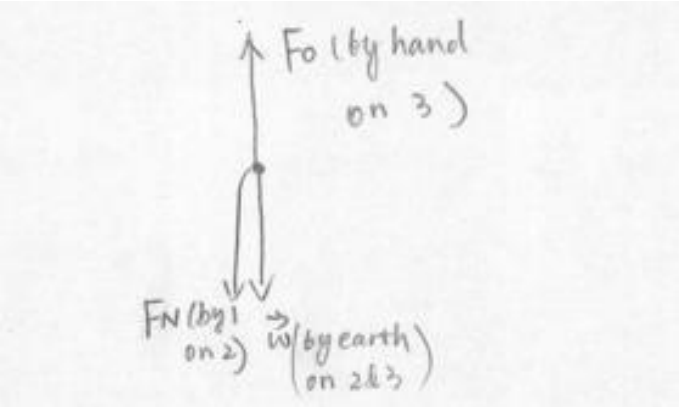
F_{1S} vs. F_{4T} : 45%

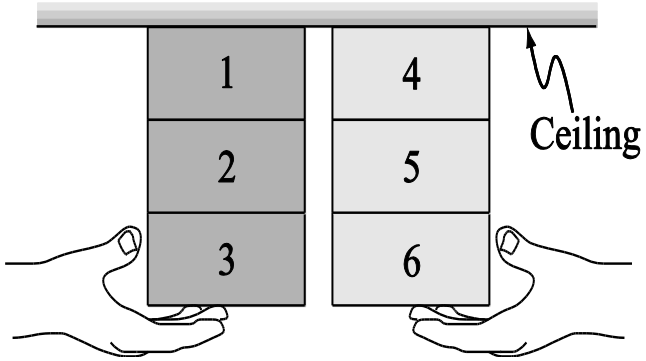
- 20% for analogous pressure question

Results for Newton's Laws Task

Difficulties in Reasoning:

- Differences in Free Body Diagrams





- Misunderstanding relationship between Normal Force and Weight

  $F_{1S}=W_1=m_1g$

  and $F_{4T}=m_4g$

  so $F_{1S}>F_{4T}$

- Incorrectly Applying Newton's Second Law

  $F=ma$

  $m_1>m_4$

  so $F_{1S}>F_{4T}$

Summary of Newton's Laws Task

- More students demonstrate correct reasoning about forces than about pressure.

- However, some students have difficulty reasoning about forces at the level they need to when discussing pressure.

A problem similar to this task *could* be very beneficial for developing a greater understanding of forces and connecting that understanding to pressure.

Research Question:

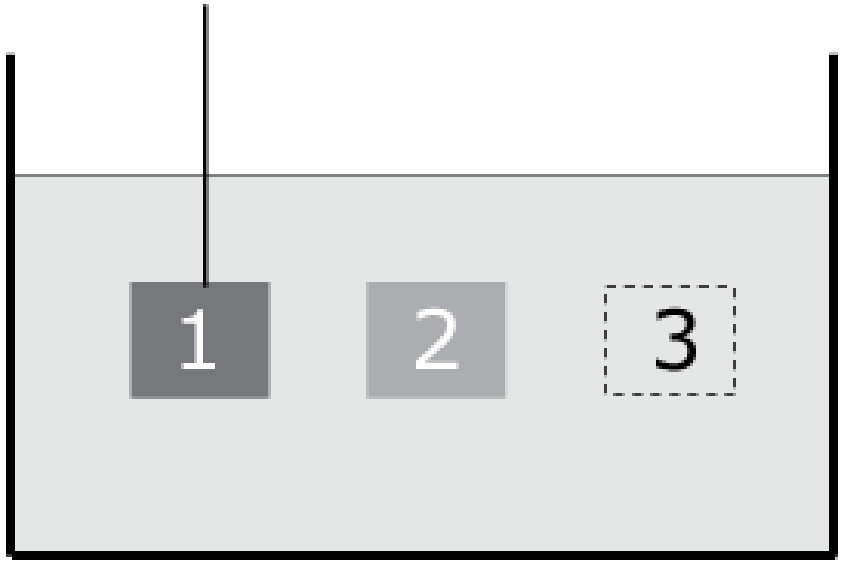
- To what extent can students reason about pressure using forces?
- This requires…

  -Identifying forces and applying Newton's laws

  -Treating a section of a liquid as an object

We designed two tasks to address the different aspects of this reasoning

Second Task:
Ranking Forces on a Liquid



Rank the buoyant forces on each cube. Explain.

Compare V1 to V2.

Compare $F_{1,top}$ to the $F_{1,bottom}$. Explain.

Compare $F_{3,top}$ to the $F_{3,bottom}$. Explain.

Compare $F_{1,total}$ to the $F_{3,total}$. Explain.

Results Coming Soon!

Acknowledgments

Physics Education Group

REU Staff

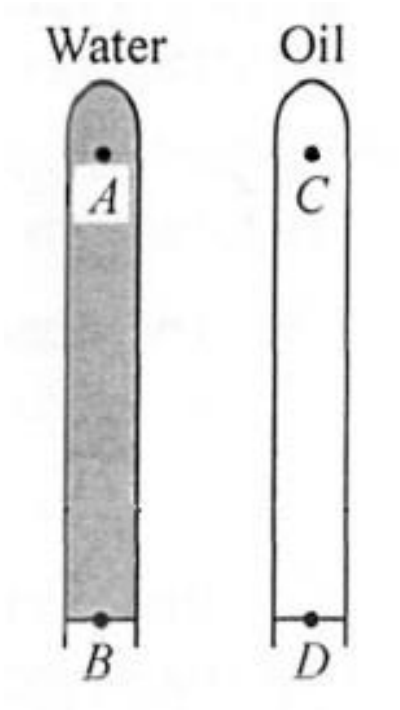
NSF

Dr. DJ Wagner and Grove City College Physics Education Research students

Questions?

Using the Pressure Equation

$P=P_o+\rho gh$



1. Is P_B, the pressure at point *B, greater than, less than,* or *equal to* P_{atm}, atmospheric pressure?

2. Is P_A, the pressure at point *A greater than, less than,* or *equal to* P_B, the pressure at point *B?*

3. Let $\Delta P_{BA} = |P_A - P_B|$ and let $\Delta P_{DC} = |P_C - P_D|$. Rank ΔP_{BA} and ΔP_{DC}.