Fluids in Motion

Eugenia Etkina
Videos of experiments by G. Planinsic
Experimental support G. Planinsic

Equipment

Three pieces of printing paper

Two empty soda cans (buy the healthiest and drink before the workshop)

Straws with the end that bends

A syringe

Straight straws (2 at least)

A container with water (a plastic water bottle will do)

Our bottles with holes that we used for the previous workshop

A hairdryer

Please rename yourself:

First name

Level that you teach

Country

Eugenia University USA

Links to the documents with activities

OALG Chapter 14 Final.docx

ALG Chapter 14 Final.Revised.docx

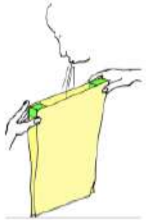
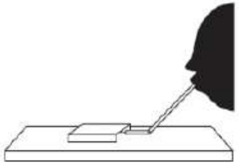
Need to know

https://www.youtube.com/watch?v=7qpEKm-M_x0

17-40 seconds

Team 1 OALG 14.1.1 [OALG Chapter 14 Final.docx]

Develop an explanation for the observations in these three experiments. Think about how the pressure of a fluid against a surface changes as the speed of the fluid moving across that surface increases.

Sketch and identify a system.	**Sketch a force diagram for the system. Include the force that the fluid exerts on the system on both sides.**
	*Immediately after you start blowing. Choose the left paper as the system and only consider horizontal forces.* 
	Immediately after you start blowing. Choose one can as the system. 
	*Immediately after you start blowing vigorously. The top surface of the card is the system. Only consider vertical forces.*

Team 2 OALG 14.1.1 OALG Chapter 14 Final.docx

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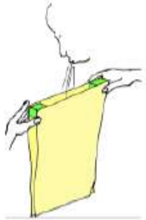	*Immediately after you start blowing. Choose the left paper as the system and only consider horizontal forces.* 
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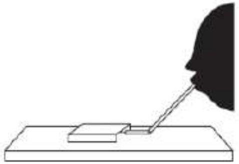	*Immediately after you start blowing vigorously. The top surface of the card is the system. Only consider vertical forces.* 

Team 3 OALG 14.1.1 [OALG Chapter 14 Final.docx]

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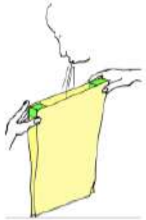
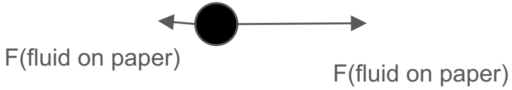
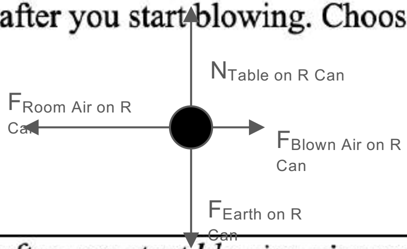
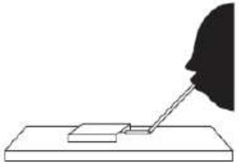
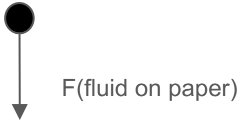
	*Immediately after you start blowing. Choose the left paper as the system and only consider horizontal forces.* 
	Immediately after you start blowing. Choose one can as the system. 
	*Immediately after you start blowing vigorously. The top surface of the card is the system. Only consider vertical forces.* 

Team 4 OALG 14.1.1 [OALG Chapter 14 Final.docx]

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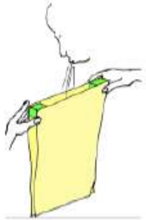	*Immediately after you start blowing. Choose the left paper as the system and only consider horizontal forces.* Fairinside on paper Fairoutside on paper
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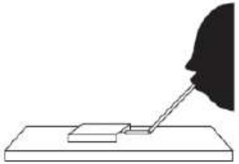
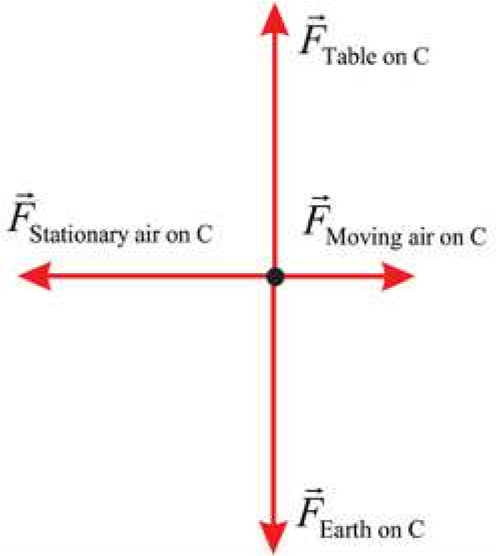
	*Immediately after you start blowing vigorously. The top surface of the card is the system. Only consider vertical forces.* Fairinside on paper Fairoutside on paper

Experiment 1

2



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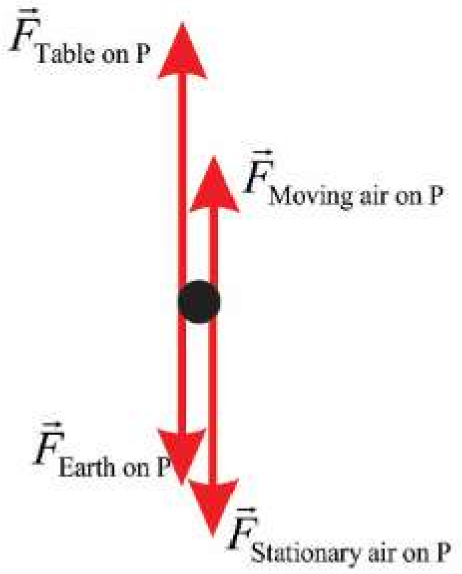
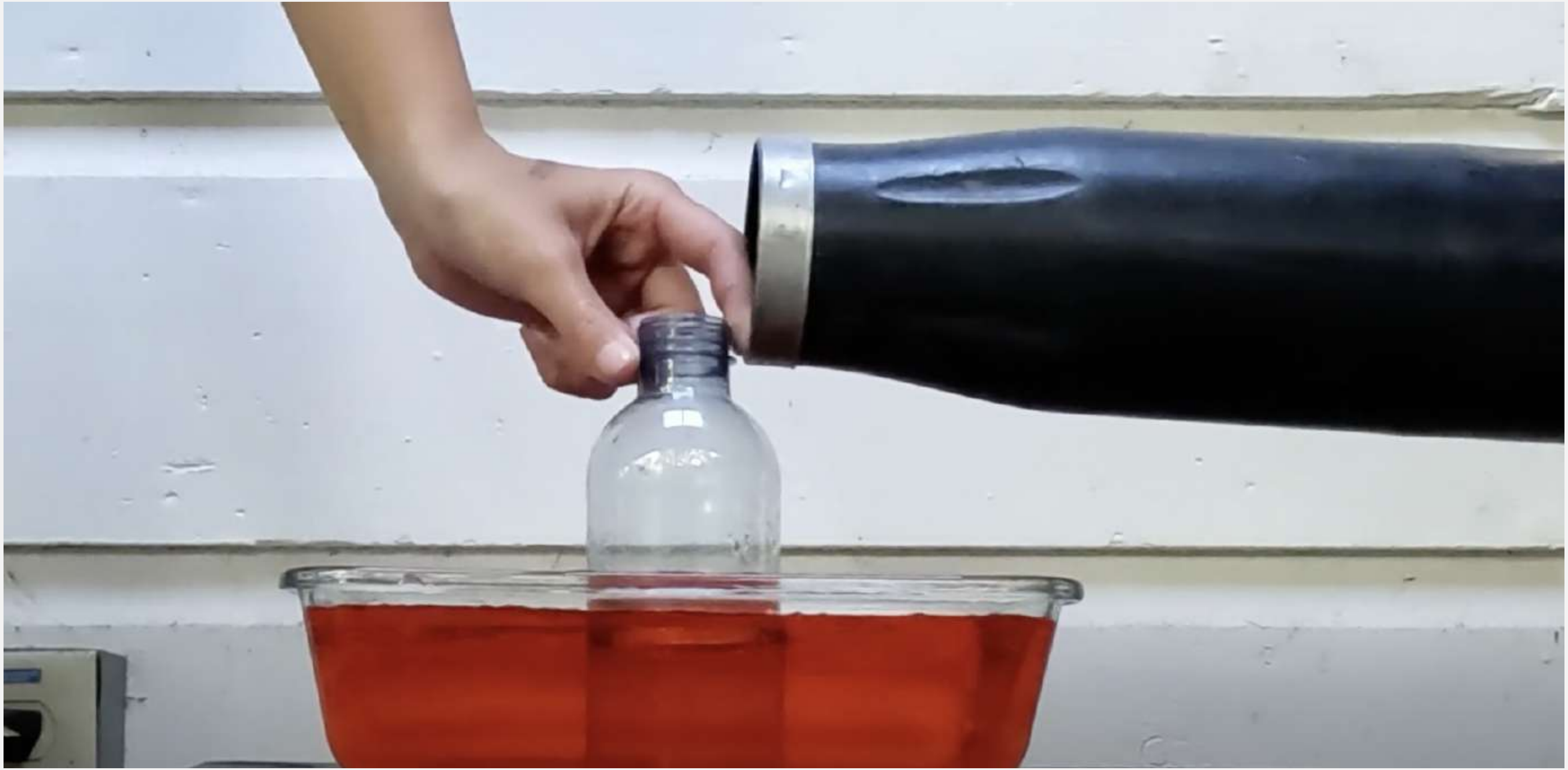


All together TESTING EXPERIMENT- use the new idea to predict the outcome



https://www.youtube.com/watch?v=YTnMg2ZfeuQ

All together 14.2.1

OALG 14.2.1 Observe and explain

Equipment: syringe, water.

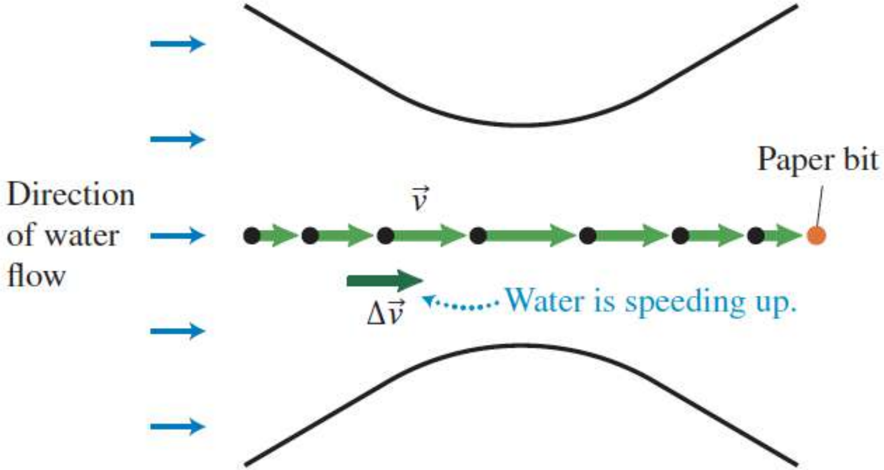
a. Observe how a syringe works and record your observations. Focus your attention on the speed with which the piston is moving and the speed with which the water is ejecting from the syringe.

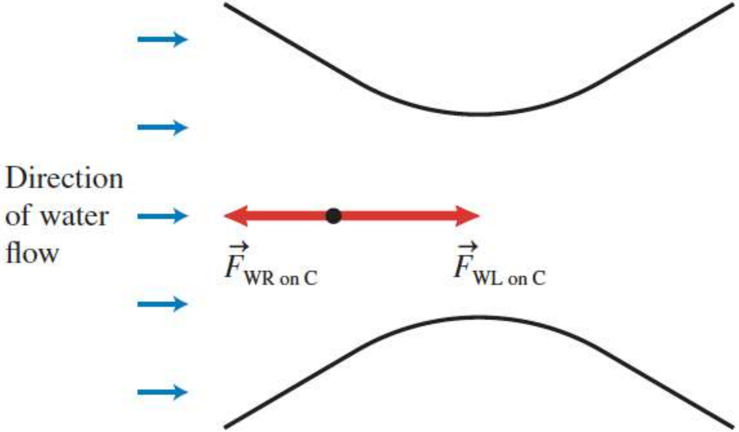
https://www.youtube.com/watch?v=H9b8QokPwFo

b. Explain the difference in these speeds.

Let’s look at this process in a different context

c. Observe the experiment at https://youtu.be/FJQYS9n9lDg.
Describe what is happening to the small piece of paper. How is it similar to the syringe experiment? Draw motion and force diagrams to explain what causes the acceleration of the piece of paper. What does it say about the pressure of the fluid in the wide and narrow parts?


Direction of water flow
$\vec{v}$
Paper bit
$\Delta\vec{v}$
Water is speeding up.


Direction of water flow
$\vec{F}_{\text{WR on C}}$
$\vec{F}_{\text{WL on C}}$

Team 1 ALG 14.3.1 Use the next slide to paste the screenshot of your whiteboard

OALG 14.2.3 Derive

The goal of this activity is to derive the relation between the speed of the fluid through a tube and the cross-sectional area of the tube and the flow rate. The flow rate $Q = \Delta V / \Delta t$ of a fluid through a tube is defined as the ratio of the volume ΔV of fluid passing a cross section in the tube and the time interval Δt needed for the fluid to pass that same cross section.

a. Sketch a tube filled with a liquid as seen from the side and indicate a cross section in the tube.

b. Suppose that all of the fluid a distance Δx from that cross section passes the cross section in time interval Δt. How does the flow rate depend on the average speed of the fluid through the tube v and the tube's cross sectional area A?

c. Under what conditions is the flow rate the same in a subsequent part of the tube where the cross-sectional area is different?

d. How does the speed compare between a narrower part of the tube and a wider part? Explain.

Team 1 ALG 14.3.1 Use this slide to do the derivation

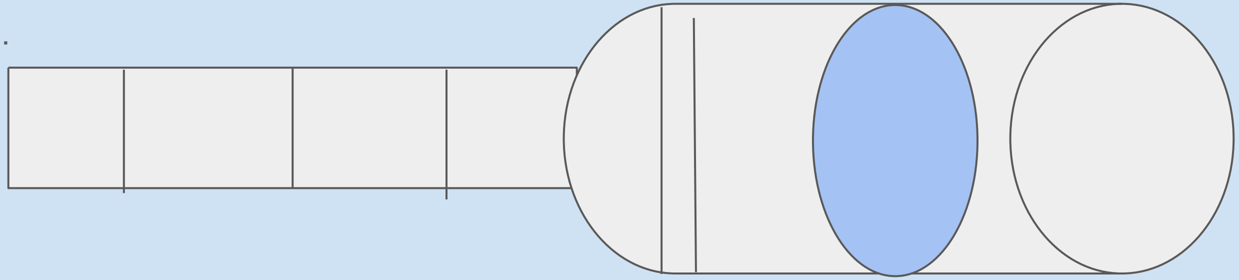
$Q_1 = \Delta V_1/\Delta t = \Delta x * A/\Delta t = A_1 * v_1$

$Q_2 = \Delta V/\Delta t = \Delta x * A/\Delta t = A_2 * v_2$

For incompressible fluids…

If $Q_1 = Q_2$

Then $A_1 * v_1 = A_2 * v_2$



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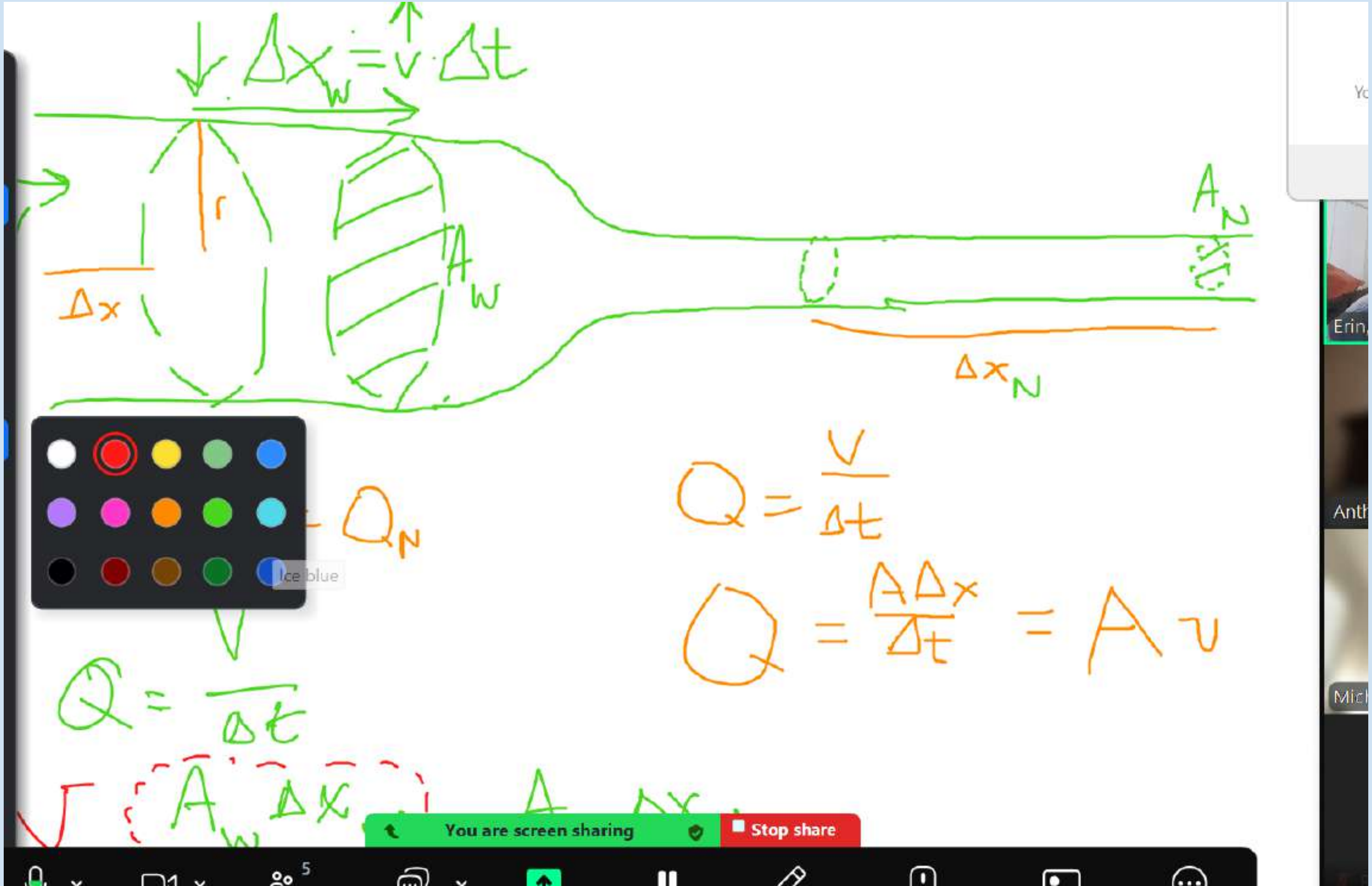

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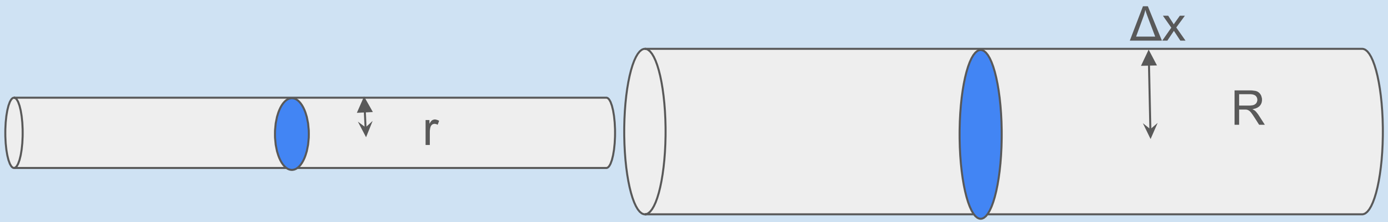

The volume of liquid that passes through a point would be the distance it travels (Δx) multiplied by its cross sectional area (A).

This results in the formula $V=A*\Delta x$, which can be substituted into our flow rate equation $Q = \Delta V / \Delta t$, where we get $Q = (\Delta x * A) / \Delta t$.

$Q = (\Delta x * A) / \Delta t$ can be rewritten as $Q = A * (\Delta x / \Delta t)$, where now we can substitute $\Delta x / \Delta t$ for the speed of the fluid through the section (v). This results in a final equation of $Q = A * v$

So for our example, $A = \pi r^2$, so the equation becomes $Q = \pi r^2 * v$. This means that at the point where the tube has radius r has a speed that is greater than the point where the radius is R since the flow rate isn't changing ($Q_r = Q_R$)

Team 4 ALG 14.3.1 Use the next slide to paste the screenshot of your whiteboard

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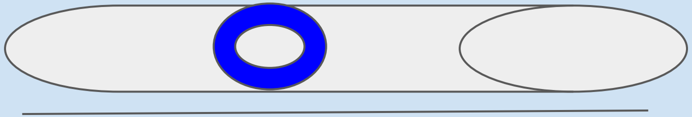
Team 4 ALG 14.3.1 Use this slide to do the derivation

Assuming Fluid is INCOMPRESSIBLE!



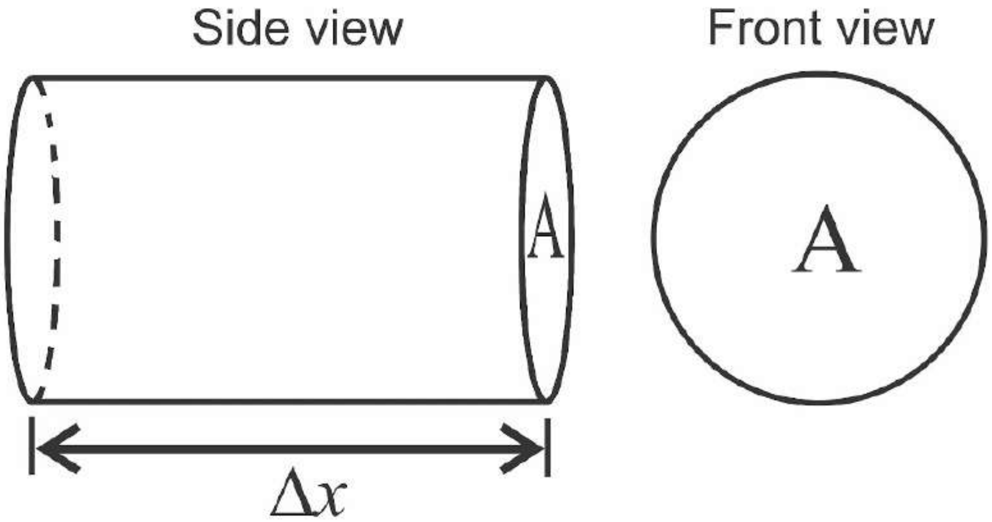
Q=DeltaV/Delta t= Deltax X A/ Delta t=vA

This is all assuming flow rate is CONSTANT.

C. If the velocity increases by the same factor the area decrease by [or vice versa]

D. Narrower is faster because the area and speed are inversely proportional (for constant flow rate).
It also makes sense since the only way the same volume of water can move through a smaller area is if it flows more quickly so the same amount of particles(?) come though.

a. Sketch a tube filled with a liquid as seen from the side and indicate a cross section in the tube.

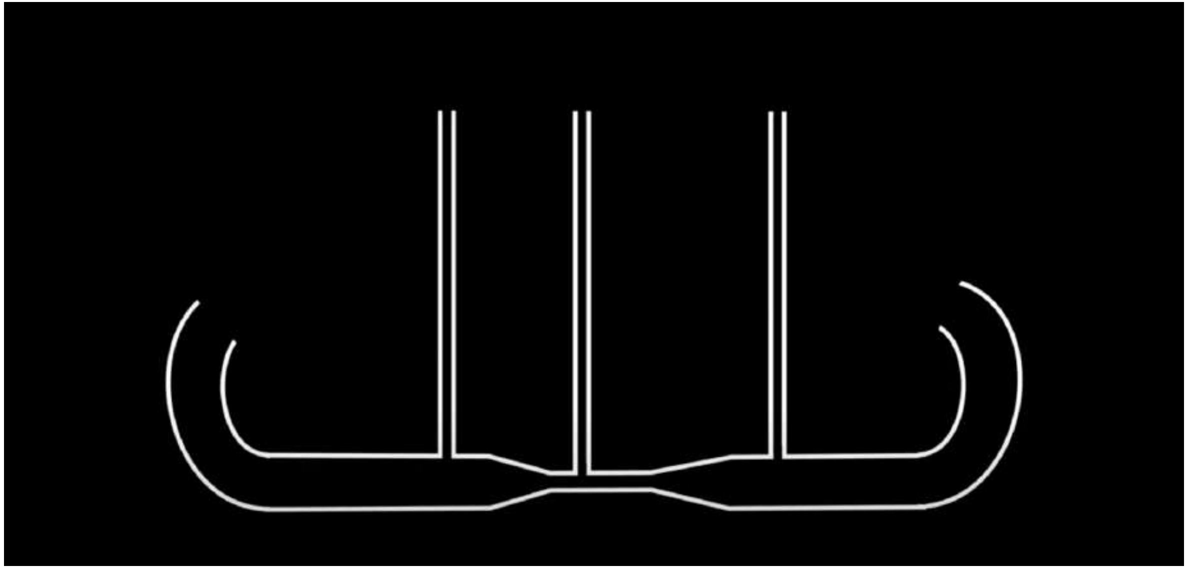


b. Suppose that all of the fluid a distance Δx from that cross section passes the cross section in time interval Δt. How does the flow rate depend on the average speed of the fluid through the tube v and the tube's cross sectional area A?

$$Q = \frac{\Delta V}{\Delta t} = \frac{\Delta x A}{\Delta t} = \frac{\Delta x}{\Delta t} A = vA$$

Testing experiment - Venturi tubes

Giovanni Battista Venturi, an Italian physicist and engineer. Venturi developed the device in the 18th century while studying fluid dynamics.



https://youtu.be/_mZDm1KdNjQ

Team 1 ALG 14.2.3

In the video you see a variation of an apparatus called a Venturi tube. Water flows through the horizontal tube and its levels in vertical tubes (where water is not moving) are as you see in the video at https://www.youtube.com/watch?v=_mZDm1KdNjQ Work with your group members to discuss answers to the following questions:

a. Describe in detail what you observe.

Middle tube was lowest. Entry side tube was highest. This was true going both directions.

b. Explain why it is happening.

It is happening because the velocity in the middle is higher than in the larger area. That creates a pressure difference that **(SUCKS)** lowers the height of the middle tube.

c. What is the difference between the description and the explanation?

What happened (direct observation) versus how did it happened (the hypothesis)

Team 2 ALG 14.2.3

In the video you see a variation of an apparatus called a Venturi tube. Water flows through the horizontal tube and its levels in vertical tubes (where water is not moving) are as you see in the video at https://www.youtube.com/watch?v=_mZDm1KdNjQ Work with your group members to discuss answers to the following questions:

a. Describe in detail what you observe. **When the water is not moving, the water level is low.** After the water is flowing, **all levels increase**, but the middle tube increases less.

b. Explain why it is happening. Water level increase doesn't make sense. The water moves faster through the smaller middle portion. Which reduces the pressure.

c. What is the difference between the description and the explanation?

Team 3 ALG 14.2.3

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a. Describe in detail what you observe. *The middle tube is the lowest; the trailing tube is the second lowest with the initial tube the highest*

b. Explain why it is happening. *Since the middle tube has the smallest radius, the material is moving the fastest, so the force of the fluid is less so it pushes up against the air less*

c. What is the difference between the description and the explanation? *The description is what we observe, but the explanation is attempting to describe why we observe what we observe*

Team 4 ALG 14.2.3

In the video you see a variation of an apparatus called a Venturi tube. Water flows through the horizontal tube and its levels in vertical tubes (where water is not moving) are as you see in the video at https://www.youtube.com/watch?v=_mZDm1KdNjQ Work with your group members to discuss answers to the following questions:

a. Describe in detail what you observe.

The water above the middle tube was lower than the water above the fatter tube.

b. Explain why it is happening.

The speed in the middle is faster, pressure is lower

c. What is the difference between the description and the explanation?

Explanation of the finding in 14.2.3 and what is missing?

What can we conclude about the relationship between the change of the speed of the fluid and the change in the pressure inside?

But why?

Team 1 14.4.1 [OALG Chapter 14 Final.docx]

Start with Energy bar: Ki + Ugi +W = Kf + Ugf

$\Delta W_{\text{water on left}} = F^*\Delta x$

List moments where you had difficulty:

Ask them to do energy bar chart first assuming the liquid is incompressible no other conversion of energy

Because they give you all the part of the energy chart, it is easier for students to follow it.

They may have not used ΔW in a similar exercise.

Team 2 14.4.1 OALG Chapter 14 Final.docx

List moments where you had difficulty:
- Why delta W, rather than just W?
- Volume isn’t in the equation

Team 3 14.4.1 OALG Chapter 14 Final.docx

List moments where you had difficulty

- Relating forces to pressure and area
- Relating mass to density and volume
- Units (J vs J/m^3)

$W=F*\Delta x*\cos\Theta$

$W=P*A*\Delta x*\cos\Theta$ ($P = F/A$)

$W=\rho*V*\cos\Theta$ ($V=A*\Delta x$)

$W=\rho*V$ ($\Theta = 0°$)

Team 4 14.4.1 OALG Chapter 14 Final.docx

List moments where you had difficulty

e. Took a moment but we soon realized it was W=deltaE [all divided by Volume change]

f. Assuming the fluid is incompressible. [Does it have to do with constant density or flow rate, or both?]

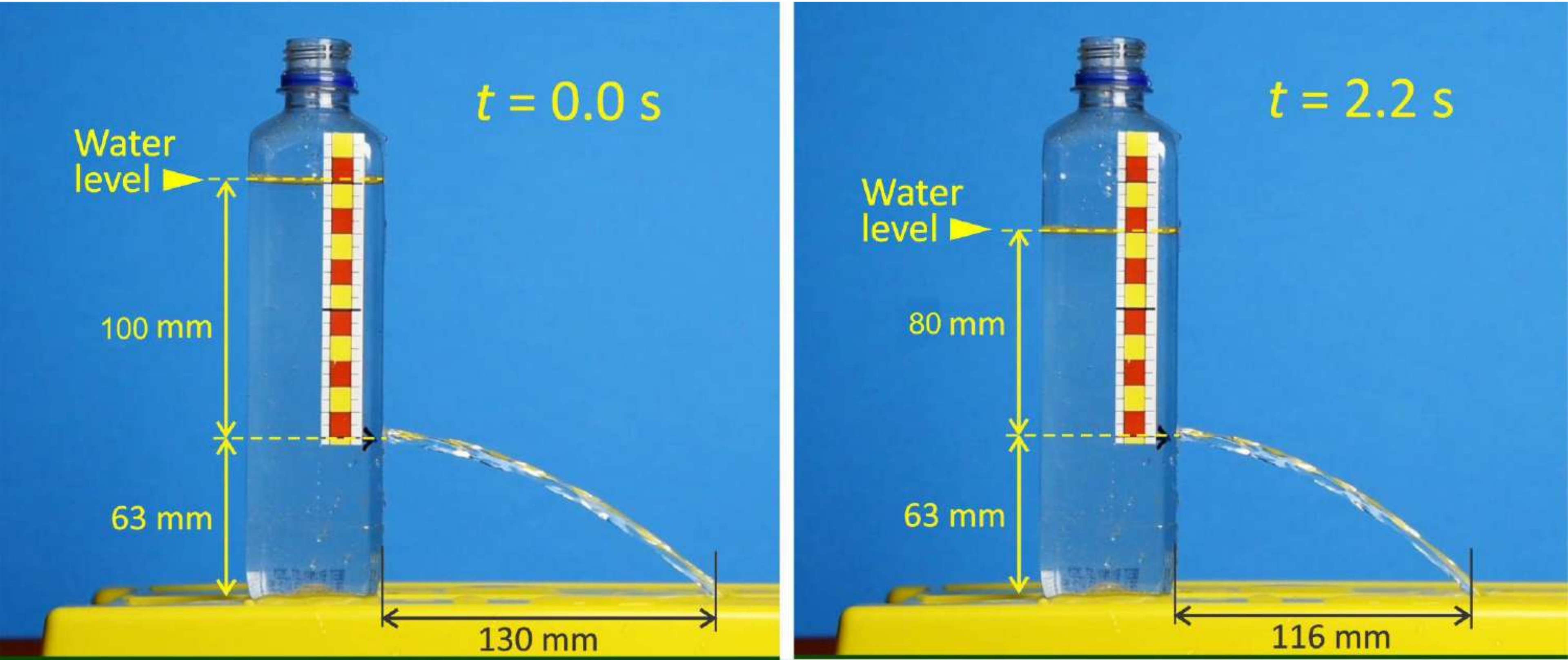
g. I do NOT get an analogy for the Pressure terms to energy terms.

What does it mean?

$$\left(1/2\right)\rho v_1^{\,2} + \rho g y_1 + P_1 = \left(1/2\right)\rho v_2^{\,2} + \rho g y_2 + P_2$$

Explain how we can use this setup to test Bernoulli equation that we just derived

https://youtu.be/qML9JUzkZmQ



Team 1 Make predictions about the outcome of the experiment

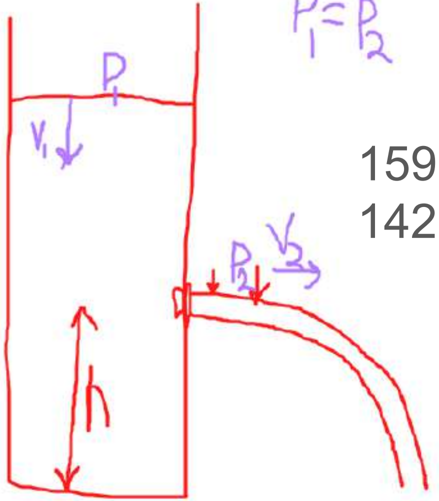
$$(1/2)\rho v_1^{\ 2} + \rho g y_1 + P_1 = (1/2)\rho v_2^{\ 2} + \rho g y_2 + P_2$$

½ (1000kg/m^3)(Vm/s)^2 + (1000kg/m^3)(9.8m/s^2)(0.1m) = ½ (1000kg/m^3)(vm/s)^2 + (1000kg/m^3)(9.8m/s^2)(0.08m)

$y_f = y_f + v_i t + (½)(-g)t^2$

$x_f = x_f + v_i t$

$P_1 = P_2$



159 mm for exp 1
142 mm for exp 2

$\frac{1}{2}\rho v_1^2 + \rho g y_1 + P_1 =$

0 (Assume v_1 is small)

$\frac{1}{2}\rho v_2^2 + \rho g y_2 + P_2$

$y_2 = 0$

$\rho g y_1 = \frac{1}{2}\rho v_2^2$

$v_2 = \sqrt{2 g y_1}$

x

$x = x_0 + v_{0x} t + \frac{1}{2} a_x t^2$

0 (coord sys.)

0

y

$t = \sqrt{\frac{2h}{g}}$

$t = x / v_2$

$x = \sqrt{2 \cancel{g} y_1 \frac{2h}{\cancel{g}}}$

$\boxed{= 2\sqrt{y_1 h}}$

Team 3 Make predictions about the outcome of the experiment

$$\left(1/2\right)\rho v_1^{\,2} + \rho g y_1 + P_1 = \left(1/2\right)\rho v_2^{\,2} + \rho g y_2 + P_2$$

Δy=12 cm

$P_1 = P_2 = P_{atm}$

$U_{g1} > U_{g2}$

$t = (2h/g)^{1/2}$ where h=.063m

Team 4 Make predictions about the outcome of the experiment

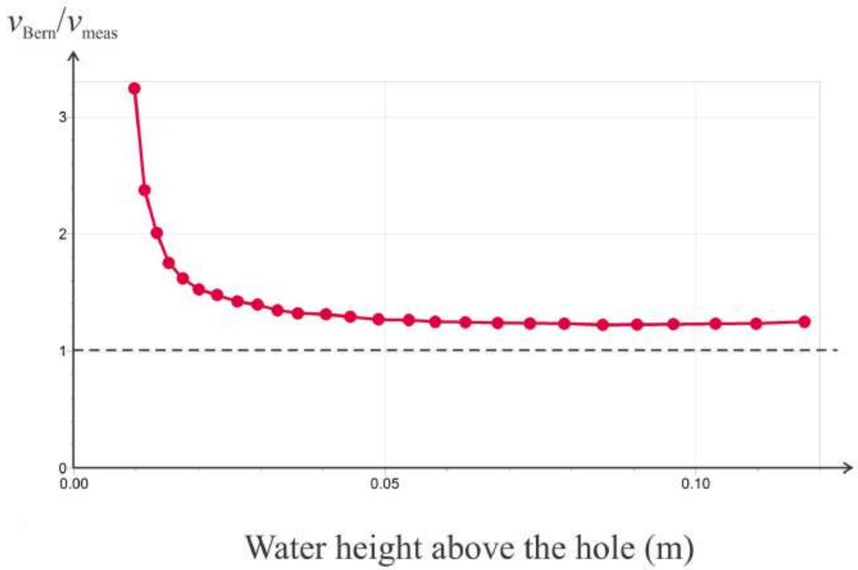
$$(1/2)\rho v_1^{\,2} + \rho g y_1 + P_1 = (1/2)\rho v_2^{\,2} + \rho g y_2 + P_2$$

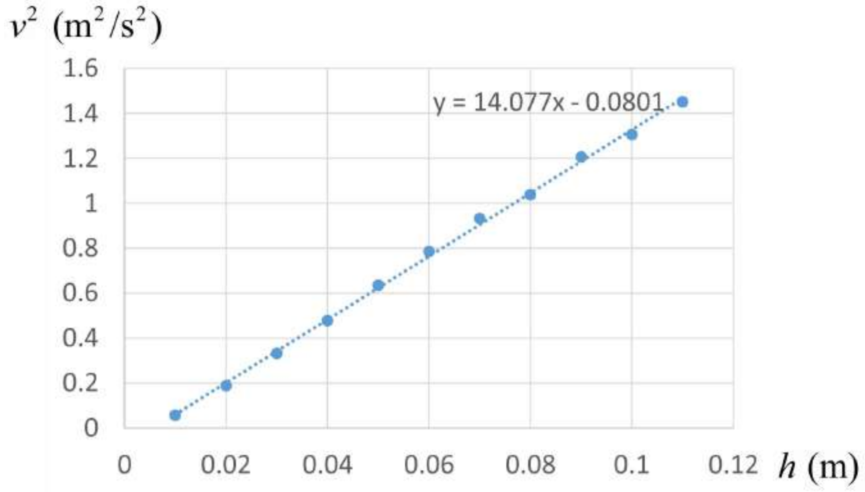
y1=0.1 m
y2=0.08 m
distance1=v0_1xt=sqrt(2gy1)sqrt(2x(0.063 m/g)
distance2=v0_2xt=sqrt(2gy2)sqrt(2x(0.063 m/g)

Assume no friction as the liquid leaves the hole in the container. If there is friction, the water will not squirt as far.

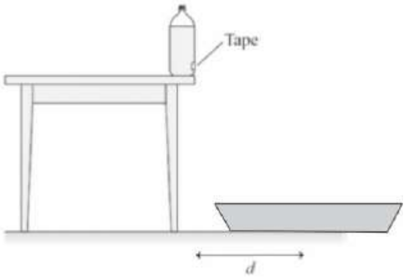
$\rho g(y_1 - y_2) + P_{atm} = \frac{1}{2}\rho v^2 + P_{atm}$; $v = \sqrt{2g(y_1 - y_2)}$; *The time for water to fall through the height of H:* $H = \frac{1}{2} g\Delta t^2$; $\Delta t = \sqrt{\frac{2H}{g}}$. *Therefore* $d = v\Delta t = \sqrt{2g(y_1 - y_2)} \times \sqrt{\frac{2H}{g}} = 2\sqrt{(y_1 - y_2)H}$

https://youtu.be/qML9JUzkZmQ





ALG 14.4.2 (in class)



OALG 14.4.2 Test your idea

Equipment: a 2-L plastic bottle with a 4-mm-diameter hole on the side near the bottom (initially covered with tape), a wide container to collect water, a ruler or another distance measuring instrument.

Fill a bottle with water and place it at the edge of a table with the hole facing away from the table and toward the floor, as shown in the figure below. Use Bernoulli's equation to predict quantitatively the largest distance from the table's edge at which the water will reach the floor if you remove the tape and thus open the hole. (Make sure the top of the bottle is open.) Answer the questions below to make your prediction and to evaluate your result.

a. On the sketch, label physical quantities that you will measure and physical quantities that you will calculate. Measure the needed quantities and record them.

b. Outline a mathematical procedure to make your prediction. Then, complete the procedure to predict where the water will reach the floor: Use Bernoulli's equation to find the speed of the water leaving the hole. Then, use your knowledge of kinematics to calculate how far the water jet will travel horizontally. If you are having difficulties, consult Example 14.2 on page 424 in the textbook.

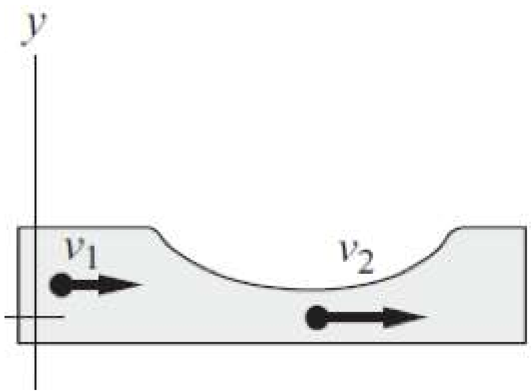
c. List the assumptions you made and describe how they will affect your result.

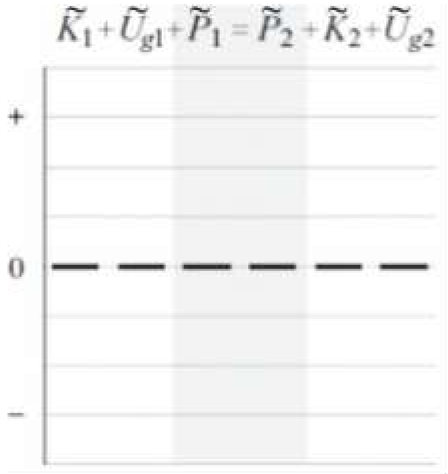
d. Perform the experiment. Record your results and make a judgment about whether Bernoulli's equation applies to the water flowing out of the bottle.

OALG 14.4.3 great activity, please do after the workshop

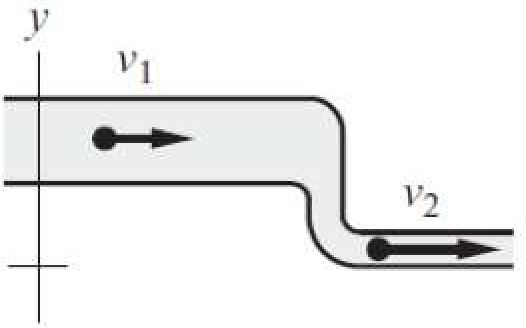
All together 14.5.1 OALG Chapter 14 Final.docx

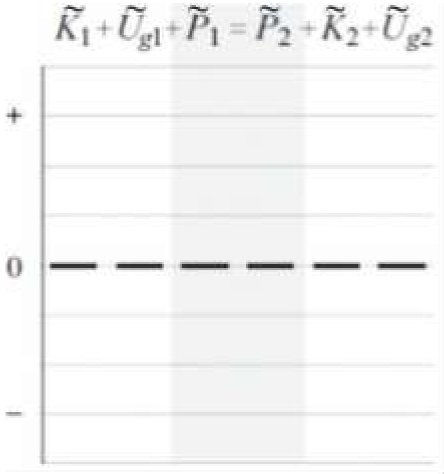
All together 14.5.2 [OALG Chapter 14 Final.docx]





Bernoulli equation





Apply Bernoulli equation

If time permits [OALG Chapter 14 Final.docx]

14.5.3; 14.5.4 - all together

Return to the need to know

Why do roofs fly off during tornadoes?

I like the example of the scaffolding derivation; helps them stay more engaged.

What did you learn in the workshop?

Great ideas of a logical order of how to introduce topics/concepts.

1.Simple experiments have so much of scientific discussion.

Great ideas/tips on how to run a productive discussion in a classroom while keeping to the ISLE philosophy (especially as it relates to fluids and experiments I haven't seen)

Reminder of 2 answers to the question how: 1)mechanism or 2)causal explanation

That P1 and P2 in Bernoulli's are from fluid OUTSIDE of system exerting pressure on it.

The process to arrive to Bernoulli equation

Energy density vs energy

I had time to think about how to solve and teach the problems as I have not taught bernoulli before.

The power of students using only one whiteboard instead of working independently

What did you learn in the workshop?

I’ve seen a better way to introduce the concept of the Bernoulli eqn to my students that builds over a series of explorations relating pressure, velocity changes

Honestly, as someone who hasn’t touched fluids since sophomore yr of undergrad a LOT about how to build/scaffold the knowledge students need around these ideas. Making the connections between what we’ve already learned in mechanics and this “weird” topic of fluids makes teaching fluids a lot less daunting.

Why it’s important to confirm your prediction with a real world outcome and why it’s important that this method is different from the method you got the prediction from

How important it is to start with the connection between DeltaP and DeltaV before discussing bernoulli eqn.

After using Bernoulli bar chart I started seeing Bernoulli everywhere