Physics 7B

DLM 10 Overview

Model/Approach: Newtonian Model

Act-5.1.5 Ball on a string in a horizontal circle **(~50 min)**

Learning Goals:

- Practice deciding which model to use
- More practice using force diagrams to help analyze physical situations
- Practice reasoning with models

More practice making use of the knowledge of acceleration in circular motion

Model/Approach: Energy Density Model

Act-6.1.1 DLM 09 FNTs **(~40 min)**

Learning Goals:

- Get an introduction to working with the energy density model
- Understand the differences between the new and old energy models
- Become familiar with the fluid energy-density systems

Act-6.1.2 Wrap-up of DLM 09 FNTs 1 and 2 **(~ 40 min)**

Learning Goals:

- Get a firmer grasp on the meaning and behavior of the various fluid parameters in dissipative and non-dissipative flow.
- Get a firmer grasp on how pumps affect other fluid parameters.
- Identifying and clearing up areas of confusion and uncertainty

Begin AC-6.1.3 Measuring Pressures with Fluid Columns **(~ 20 min)**

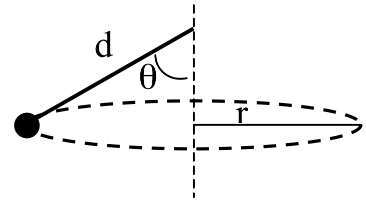
Learning Goals:

- Understand the use of fluid columns to measure pressure.
- Understand that the fluid in a column is not part of a fluid system that is moving (fluid circuit).

Announcements

- **Reading Assignment** - Read Summary and Review pages 125-130.

Ball on String in Horizontal Circle



Phenomenon: Ball swinging in a horizontal circle at constant speed supported by a string. **Experiment shows that if the ball moves faster then θ is larger and the tension in the string is larger**.

What model/approach would you use?

Suppose you are interested in how the tension in the string depends on the angle, θ, that the string makes with the vertical direction. Which approach would you help you make progress with this question - energy conservation, momentum or angular momentum conservation, or Newton's 2nd law?

1) Discuss in your group what specifically you need details about and which models/approaches can give you that information. Start by thinking about the specific motion and what is required to produce this motion. (Note that rotational velocity is assumed constant. What does this imply?)

Use the model.

2) Carry out the analysis using whichever approach/model you have decided on.

   a. Put a properly labeled force diagram (for the ball) on the board.

   b. Use the force diagram to develop **two** mathematical relationships (one for the vertical direction and one for the horizontal direction). You will need to figure out (or remember) the direction of the acceleration of an object traveling in a circle at constant speed. The magnitude of this acceleration is $a_{centripetal} = v^2_{tangential} / r$ (Notice this is the *tangential* speed of the ball).

   c. Does the force of the string on the ball equal the force of the Earth on the ball? If not, what does?

Whole class discussion

Illustrate using vectors what happens to the tension in the string ($F_{by\ string\ on\ ball}$) when the tangential speed of the ball increases. Think about how the two relationships in (2) can both be satisfied.

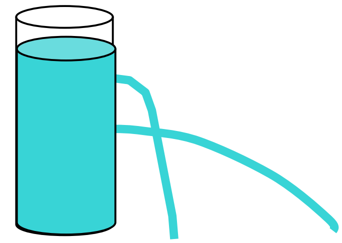
   d. Develop a short explanation of why the angle of the string (from the vertical direction) changes when the tangential velocity is increased significantly. Check this out with the real ball and string.

   e. What is the highest the ball can rise? Why?

Whole class discussion

Wrap-up of DLM 09 FNTs 1 and 2

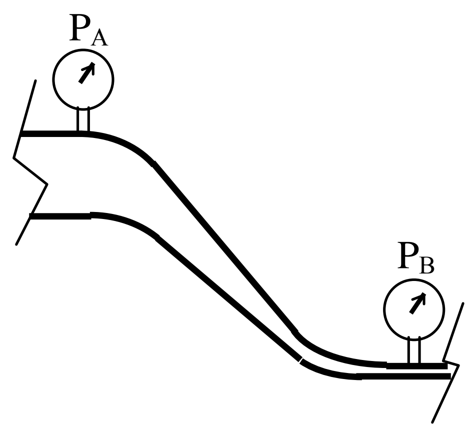
A) Phenomenon: Fluid squirting out of a hole.



1) Come to a consensus in your group and explain in your own words what causes the water to change how it squirts out of the hole in the phenomena of parts a and b. What are the indicators of these changes and what energy density systems are changing?

B) Phenomenon: Fluid flowing through a pipe of changing height and size.

Consider the fluid flow situation shown in the diagram. A fluid flows through the section of pipe shown with **minimal dissipation** (very little friction) in the direction of A to B. (The pipe continues in both directions, but only this section is shown in the diagram.) At position A the pipe has cross-sectional area A_A and is at height y_A. At position B it has area A_B and is at height y_B.



Analyze this situation using the energy density model and put it on the board.

1) What parameters/indicators determine the magnitude of the various energy-density systems in going from A to B?
2) Decide which energy-density systems you absolutely know increase or decrease in going from A to B and show these with vertical arrows on your diagram. How do you know this?
3) (a) How does conservation of energy constrain the changes in the various energy-density systems?

   (b) What are the implications of this for the change in pressure?

Note:
When a section of a pipe or tube is shown in this manner, it is assumed that it is part of a larger fluid circuit, which probably has a pump to keep the fluid flowing continuously. The fluid is assumed to totally fill the tube without voids.

Checking For Understanding
Make sure **each** member of your group is prepared to use your analysis of this section of the fluid circuit to answer the questions concerning the relative sizes of the pressures at point A and B.

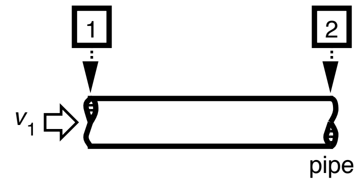
Physics 7B **Activity 6.1.2** **DLM 10**

Determining if Fluid Transport Quantities Change.

In Your Small Group

With other group members, discuss and develop **explanations** for why each of the statements below is either true or false

A) **Scenario 1**: Water enters a horizontal section of pipe (with the same cross-sectional area throughout) from the left with a speed v_1, and exits to the right. Using the energy density model, explain whether the three equations below are **true or false** if the flow is without dissipation (no friction) and whether they are true or false if dissipation is present. Put a table on the board like the one below with your answers and explanations.

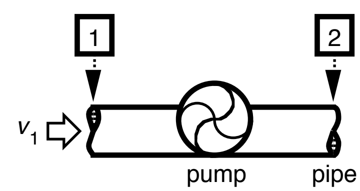


I. $I_1 = I_2$ II. III.

I. $I_1 = I_2$		II. $v_1 = v_2$		III.	
no dissipation	w/ dissipation	no dissipation	w/ dissipation	no dissipation	w/ dissipation
True or False? Explanation.					

Scenario 2: Now assume you have two pipes that are identical, except that one has become rough and very corroded inside (and thus has a very high resistance), while the other has a low resistance. Assume the **pressure difference is the same** for both pipes (perhaps point 1 is at a specified pressure and point 2 is open to the atmosphere). Which, if any, of the answers to the above questions are different for high or low dissipation? What is the difference between having small resistance and large resistance? Is the flow rate different for this corroded pipe compared to the non-corroded pipe? If yes, then how is it different? (Hint: to calculated the amount of thermal energy lost, we use the equation ΔE_{th}/vol = -IR)

B) Water enters a horizontal section pipe (with the same cross-sectional area throughout) from the left with a velocity v_1, and exits to the right, after passing through a pump that "pumps" this fluid. Using the energy density model, explain which of the following statement(s) (I)-(III) are true for the cases of both frictionless flow and flow with dissipation. For the case with dissipation, do any of your answers depend on the amount of resistance along the pipe?



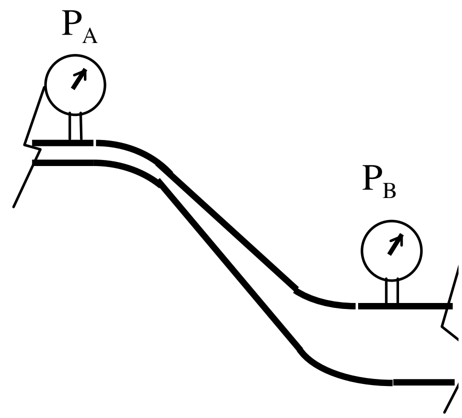
I. $I_1 < I_2$ II. $v_1 < v_2$ III. $P_1 < P_2$

. Make another chart like the one above on the board. Write a “T” or “F” by each statement and write your explanation.

Make sure everyone in your group is sure about whether the truth of the relation depends on whether there is dissipation or not. All explanations should, of course, be expressed in the context of the energy density model. Be sure you use the energy density model in your explanation with energy-density-system diagrams!

Determining Pressure Changes

A) Fluid flowing through a pipe of changing height and size

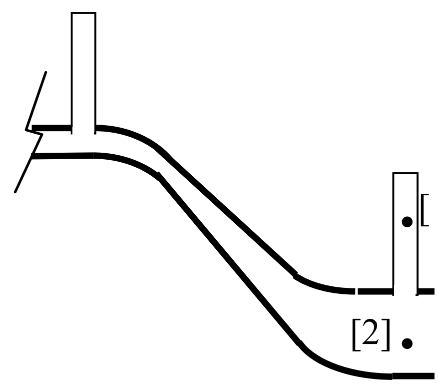


Consider the fluid flow situation shown to the right. Using the fluid transport model, answer the four questions listed below.

Question 1: Assuming minimal dissipation, is the pressure at point B less than, equal to, or greater than the pressure at point A?
Question 2: Does the pressure difference from A to B depend on which way the fluid is flowing?
Question 3: If this tube did not have minimal dissipation, how would this change your analysis? What if the fluid flowed from B to A, and there was dissipation?
Question 4: Does the pressure difference from A to B depend on the flow rate?

B) Measuring Pressure with Fluid Columns

Now suppose that you did not have pressure gauges to attach at points A and B. Rather, you will now use a vertical column of the same fluid to determine the pressures at these two points.



1) Is the fluid that is contained in the vertical columns a part of the fluid system that is *moving* along the tube? Or is it the case that the fluid in each column is a separate fluid system, distinct from each other and from the fluid that is flowing?

   Another way to phrase this question is this: Can you apply our energy density *interaction* model between the points [1] and [2]? If not, is there any connection between the fluid systems? Are they totally independent of each other, or is there a parameter that is the same where the fluids in the systems touch each other? Explain.

2) Explain exactly how a vertical tube can be used to measure the pressure where it is attached. You need to choose two points for each system and show the energy density changes with an appropriate energy-density-system diagram on the board.

   Next, express this relationship in an algebraic equation. You should get an algebraic expression of the form $P_2 = \ldots$ that gives the pressure in the big tube at position [2] in terms of the fluid properties in the vertical tube at that location. Does the height of the fluid in each tube (measured from the bottom of the tube) tell us the change in pressure (gauge pressure) or the absolute pressure? Explain.

3) Draw in reasonable water heights for each tube. In which tube will the water level be higher? Why?

4) If the fluid in the pipe were not flowing, could you treat the fluid in the columns as part of the same system as the fluid in the tube? That is, could you use our model between the points [1] and [2]? Explain.

Be prepared to share your responses with another small group and/or the whole class.

Physics 7B **Exit Handout** **DLM 10**

FNTs: Use the energy density model with energy-density-system representation to logically respond to these FNT prompts.

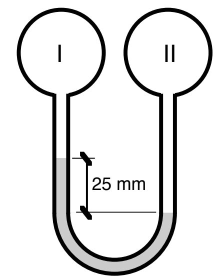
1. An important "vital sign" for monitoring human health is blood pressure. In particular, doctors want to know what the pressure of a patient's blood is as it passes through the heart. Use the energy density model with energy-density-system representation to logically respond to these FNT prompts.

(a) Why is blood pressure normally measured with a cuff around the upper arm with the person sitting upright?

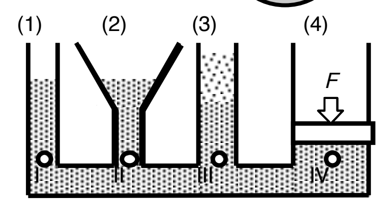
(b) Suppose you want to measure the blood pressure of a person and for whatever reason (perhaps due to injury), you are not able to use an upper arm of the person to measure the blood pressure, and you have to use a leg instead. In what position would you place the person before making the measurement? Why?

(c) Given that you want to find the pressure at heart level, and if you knew what the normal blood pressure at that level should be, show how you could calculate the percent error you would get if you measured a patient's blood pressure on the patient's leg while the patient was sitting up?

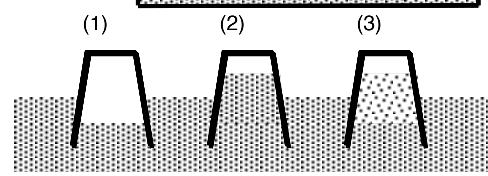
2. To reach an absolute pressure of 3 Atm, you must dive down (in water) to depth of approximately 20 m. Why might someone think that the answer was 30 m?



3. The apparatus at right shows a pressure difference between gases in containers I and II that cause 25 mm of oil to be displaced from being level. Explain how you would convert this "25 mm·oil" measurement (density of 0.85 g/cc) to a relative pressure difference in pascals. Carry out the conversion.

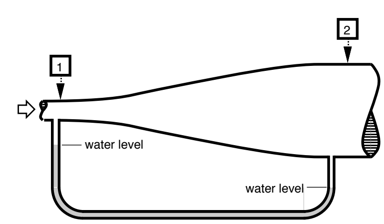


4. The device shown at right was constructed in a physics lab. When this system reaches equilibrium, the water levels in each tube are shown below. Tubes 1 and 2 are both open to the air. Tube 3 is open to the air but has some less dense oil on top of the water in the tube. Tube 4 has a piston in it with a force *F* applied (perhaps a weight rests on the piston). At which point (I, II, III, or IV) will the hydrostatic pressure be the greatest, or will all of the pressures be the same? Explain.



5. Three cups inverted into water are shown below. Cup 1 has a water level inside that is below the water level exposed to the atmosphere. Cup 2 has a water level inside that is above the water level exposed to the atmosphere. Cup 3 has a layer of oil (which is less dense than water) atop the water level inside of it. Cup 2 and cup 3 have the same *volume* of air trapped in them. All three cups have air trapped inside of them. Apply the energy density model to each cup so you can rank the pressures (P_1, P_2, P_3) of the air pockets trapped inside them, from least to greatest pressure.

6. There are many interesting applications of our energy density model to the flow of blood in the human circulatory system. One interesting phenomenon is an *aneurysm*, a sudden abnormal enlargement of a section of an artery due to a weakening of the arterial wall. If the blood flow rate remains constant through the artery, how does the pressure in the enlarged section (the aneurysm) compare to the pressure in the rest of the artery? Neglect any affects of resistance to flow in your explanation.



7. Air flows from left to right through a horizontal pipe that has different diameters in two different sections, as shown below. The narrow section has a radius of 5.0 cm, and the wider section has a radius of 20.0 cm. At point 1 the air is flowing with a velocity of 10 m/s, and has an absolute pressure of 150,000 Pa. A narrow u-shaped tube has been attached to the air tube, and this u-tube is filled with water. Note that no air actually flows into or out of the u-shaped tube, but instead flows right across its openings. The pressures at points 1 and 2 are different, so the water in the u-shaped tube is not level. Assume that the transitions between the sections have a negligible effect on the frictionless flow of air, and that the density of air is constant throughout the pipe. Apply the energy density model to this situation and find the speed of the air and its pressure at point 2 and the difference in heights of the water in the u-shaped tube.