

Model/Approach: Steady-State Energy Model**AC-6.1.6 The Fluid Transport Equation (fully extended Bernoulli Equation) (~ 50 min)****Learning Goals:**

- Develop understanding of the concept of head and head loss
- Develop understanding of the constructs of head loss through circuit elements and increases in head due to a pump
- Gain experience applying the fully extended Bernoulli equation (transport equation)
- Deepen understanding of the constructs of current and resistance
- Make concrete the connection between the constructs resistance and current with physical pipes and water flows

Act-6.1.7 Wrap-up of DLM 11 FNTs 1 & 2 & Circuit Apparatus Review (~ 50 min)**Learning Goals:**

- Clear up any remaining questions about the use of the steady-state energy model with fluid systems.
- Practice metacognitive skills. (Becoming more explicitly aware of your thinking process)
- Becoming explicitly aware of those thought processes that keep you from applying the model that you know to new situations.

AC6.2.1 Analogies Between Electrical and Fluid Circuits (~ 20 min)**Learning Goals:**

- Gain experience with electric circuits
- Use fluid analogies to think about electric circuits.

AC6.2.2 Making Sense of Simple Circuits (~ 15 min)**Learning Goals:**

- Practice applying the electric transport equation to simple electric circuits.
- Deepen understanding of the meaning of complete circuits.
- Develop understanding of how V, I, and R “work” when there is more than one simple loop.
- Develop understanding of relative currents in battery and bulb circuits in terms of the basic ideas of conservation of charge and energy conservation expressed in terms of the transport equation ($\Delta V = \mathcal{E} - IR$).

Announcements

- The cycle for **DL 13** begins next Thursday because of **President’s Day**.

The Fluid Transport Equation (Fully Extended Bernoulli Eq.)

Your Job

Your job in this activity in your small group is to make sense of and develop a working understanding of the concepts mentioned in the learning goals on the Overview Sheet. Rather than lead you through step-by-step guided questions, which will not likely fit the way a majority of students are actually thinking right now, you are simply given a measurement task. You will make two different quantitative measurements of the resistance, R , of the copper tube in the flow apparatus, **but the more important goal is to develop a useful understanding of the concepts and constructs involved.** By all means refer to your copy of the Course Notes as necessary, especially the meaning of the fluid transport equation (fully extended Bernoulli equation):

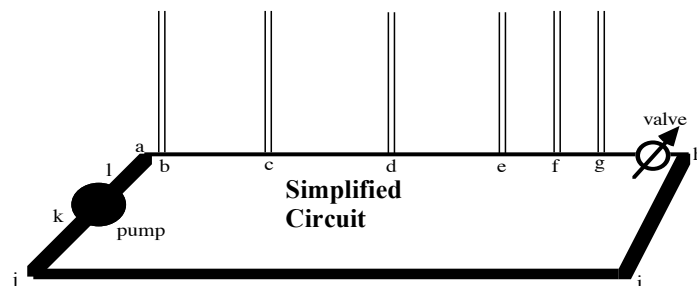
$$\Delta(\text{total head}) = E_{\text{pump}}/\text{vol} - IR \quad \text{or} \quad \Delta P + \rho g \Delta y + \frac{1}{2} \rho \Delta(v^2) = E_{\text{pump}}/\text{vol} - IR$$

where $\Delta(\text{total head}) \equiv \Delta(\text{pressure head}) + \Delta(\text{gravity head}) + \Delta(\text{velocity head}) \equiv \Delta P + \rho g \Delta y + \frac{1}{2} \rho \Delta(v^2)$

Feel free to do your scratch work at the board. **WE ENCOURAGE YOU TO WORK AT THE BOARD!** Then, when you believe you've got it, you might want to summarize your steps in a neat way to share with the whole class.

Simplifying the Model:

- 1) Which terms in the total head change as you move along the copper pipe from point "a" to point "h"? Why don't the other terms change? Write out the fluid transport equation that applies to the section of copper pipe between point "b" and point "e."



The Measurements:

Note: All refer to the real water circuit apparatus. The values will be determined from experimental measurements of ΔP and I on the actual apparatus.

- 2) Determine the resistance of the section of copper pipe between point "b" and point "e" when (a) the flow rate is at its maximum value and (b) when it is about 1/3 of its maximum value (or other value as directed by your instructor). You will need to figure out how to do this. First, determine how measurements of ΔP and I can give you the value of R , and then figure out how to make the measurements.
- 3) Determine the *resistance per unit length* (from your measurements) of the copper pipe in both cases.
- 4) Why do you think the *resistance per unit length* of the pipe increases as the flow increases? Check the Course Notes.

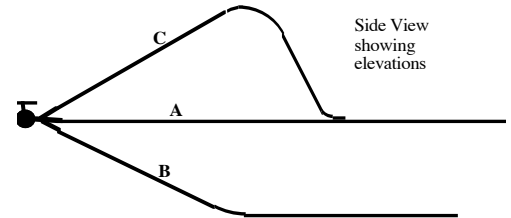
Be prepared to share your responses with the whole class.

Wrap-up of DLM 11 FNTs 1 and 2

FNT 1 (30 min.)

... How do the flow rates through the three hoses compare? Justify your answer using the physics we have studied this quarter.

Compare with other members of your small group *the specific approach you took to respond to the prompt in this FNT*.



- 1) Outline on the board the specific steps you need to take to successfully respond to this FNT.

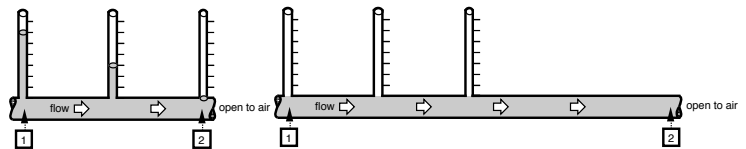
- 2) Discuss in your group what made part of the process you outlined in (1) difficult and what the reasons for the difficulty were. Try to be as specific as you can. List these difficulties and what made these parts difficult on the board.

- 3) Discuss in your group what you need to remember to do to “get past” the difficulties you listed in part (2). List these on the board.

Whole Class Discussion

FNT 2 (20 min.)

... Now suppose that the length of this pipe is doubled. The pressure at point (1) is the same as before. Point (2) is still open to the atmosphere. Water is again allowed to flow from point (1) to point (2).



- (a) We find the flow rate in the longer pipe is smaller than the flow rate in the shorter pipe. Explain why this happens. By what factor would the flow of water through this pipe decrease? Explain your answer and show your reasoning.
- (b) Fill in the water levels in each of the vertical tubes in the pipe whose length has been doubled, in the diagram above. Be clear and accurate in drawing each water level.

Compare with other members of your small group *the specific approach you took to respond to the prompt in this FNT*.

- 1) Outline on the board the specific steps you need to take to successfully respond to this FNT.

- 2) Discuss in your group what made part of the process you outlined in (1) difficult and what the reasons for the difficulty were. Try to be as specific as you can. List these difficulties and what made these parts difficult on the board.

- 3) Discuss in your group what you need to remember to do to “get past” the difficulties you listed in part (2). List these on the board.

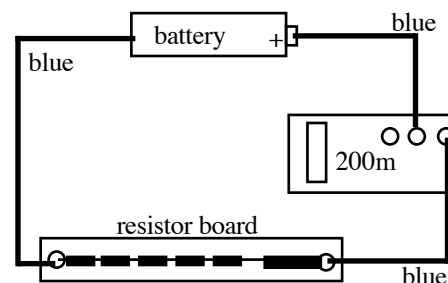
Whole Class Discussion

Analogies Between Electrical and Fluid Circuits

Your Job

On your table you have an electric circuit very similar to the one shown in the schematic diagram to the right.

Your first job is to explore the electric circuit using the voltmeter function of the multimeter (the thing with the red and black wires coming out). **Then you are to list and describe as many analogies as you can come up with between the water circuit and this electric circuit.**



Things you might want to know and/or be concerned about.

- The maximum voltage from the D-cell battery is 1 1/2 volts and will NOT harm you. No need to worry about getting shocked.
- There are two multimeters. You will use one to measure current (hooked up in the circuit as shown) and the other to measure voltage drops across various points in the circuit.
- It IS possible to burn out the fuse in the multimeter, so make sure it is first set to 20 on the DCV position when you use it as a voltmeter. Make sure the multimeter used to measure current is set to 200m (200 mA) on the DCA scale when used to measure current as shown in the diagram. Set the meters BEFORE completing the circuit by attaching the “last” blue wire to the battery.
- Electric charge has to flow through the multimeter for it to measure the current. The multimeter must be set on 200m on the DCA range to measure current.

Dos

- Measure voltage **differences** across as many places as you can think of. Do this by touching the metal tips of the red and black voltmeter leads to any points on the circuit, including the little hole on the end of the plug of the blue wires.
- Disconnect the blue leads from the battery when you are not using the circuit. Also, turn off the multimeters when you are finished using them.

Useful Information

- Electric charge flows out of the “+” end (terminal) of the battery (or power supply) and returns at the “-” end (terminal).
- The voltmeter measures a voltage difference between the two points in the circuit where the two wires (red and black) are attached. (Very little current flows through the voltmeter, because it has a very high resistance).
- The notation “common” or “COM” on the multimeter means the “low side” of voltage or where current “comes out” when the sign of the reading is *positive*.

Now, play with the circuit and find the analogies.

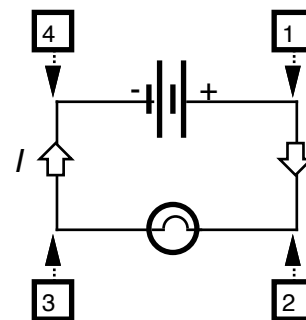
- Think of as many analogies as you can between the water circuit and electric circuit. Focus on both things and methods of measuring things. Put your response on the board.
- Try moving the multimeter that is set for current to another part of the circuit and compare readings.
- Try hooking a second battery in your circuit. What happens to the values of the current and resistors? Try bypassing several resistors. What happens to the current?

Making Sense of Simple Circuits

A) Use the Transport Model

Consider the electrical circuit at right, with an ideal battery with emf \mathcal{E} and a light bulb of fixed resistance R , connected by wires of negligible resistance. Use the appropriate form of the transport equation to answer (explain and justify) the following questions. Keep your answers in terms of the two variables, \mathcal{E} and R (no numbers).

- What are the currents at points [1], [2], [3], and [4]?
- Determine the voltages V_1 , V_2 , V_3 , V_4 with respect to the voltage at point [4]
- Now determine the voltages with respect to the voltage at point [1].



B) Batteries and Bulbs

You will do some simple experiments with holiday light bulbs and AA batteries, both here in DL and at home as FNTs. You will take three bulbs on pigtail leads and two AA batteries home with you. You need to get started on these activities in DL, but will finish them at home.

A Question to Consider

Discuss in your group and come to a consensus: Does the brightness of a light bulb indicate the power “dissipated” in it? If two light bulbs are identical (and thus have the same resistance), does their relative brightness indicate the relative currents in each bulb?

Your First Task

Your first task is to strip the plastic insulation from the ends of the pigtail leads on the bulbs. You should expose about 1/2 inch of copper wire. Use the wire-strippers at your table to do this.

NOTE: An easy way to hold either one or two batteries is to place them in the crease of an open book (your Class Notes work well.) You can then simply momentarily hold the ends of the wires up against the ends of the battery(s). You can twist wires together to make a connection between bulbs when you have more than one bulb.



What you will do for each situation:

Shown on the Exit Handout are a lot of configurations of one or two batteries and one, two, or three light bulbs. For each configuration, you will draw either a physical picture or a schematic or the situation, wire up the batteries, observe the brightness of each bulb, and make sense of the relative brightness. See the FNT sheet for more details.

Have these FNTs all written up and ready to turn in when you come to the next DL

1) Finish part A of 6.2.2.

You must have two AA or AAA batteries and three holiday light bulbs with attached pigtail leads in order to do this assignment. The plastic insulation needs to be stripped back about 3/4 inch on the end of each wire.

- 2) For each of the situations 1-11 shown below, follow the instructions below. All batteries have the same voltage, \mathcal{E} , and all bulbs have the same resistance, R .
- (1) Draw either a physical picture or circuit (schematic) diagram. If a circuit diagram is presented, make a simple physical picture of the batteries, bulbs and wires showing how they are arranged.; If the physical picture is presented, draw a circuit diagram..
 - (2) Actually wire up the batteries and bulbs as you have drawn them.
 - (3) Indicate the observed brightness of each bulb on your diagram in (1). Decide if the bulbs are “very bright” (VB), “bright” (B), “standard” (S), “dim” (D), “very dim” (VD), or not lit (NL). Use the symbols VB, B, S, D, VD to indicate how bright or dim the bulb is. S means “standard brightness,” which we will call the brightness of the bulb in #2. Make absolutely certain that any bulb you rank NL is truly not lit, rather than being extremely dim.
 - (4) Make sense of and develop a written explanation of the relative brightness of the bulb(s) in terms of current(s). Use the basic concepts of charge conservation and energy conservation as expressed in the transport equation in your explanation. Don’t take shortcuts in your explanation. You will probably need to label some points on your diagram to refer to, as in “ $V_{a \text{ to } b}$ is ...”.

